ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΙΓΑΙΟΥ – ΣΧΟΛΗ ΠΕΡΙΒΑΛΛΟΝΤΟΣ – ΤΜΗΜΑ ΕΠΙΣΤΗΜΩΝ ΤΗΣ ΘΑΛΑΣΣΑΣ

MAPPING OF MARINE PROTECTED SPECIES IN THE AEGEAN SEA USING CITIZEN SCIENCE AND DATA FROM SCIENTIFIC LITERATURE.

Μαρία Ζώτου

ΠΤΥΧΙΑΚΗ ΕΡΓΑΣΙΑ

Επιβλέπων Καθηγητής: Στέλιος Κατσανεβάκης
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ΠΤΥΧΙΑΚΗ ΕΡΓΑΣΙΑ

Αποφοίτου του Τμήματος Επιστημών της Θάλασσας

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ΑΝΤΙΚΕΙΜΕΝΟ ΕΡΓΑΣΙΑΣ:

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Τριμελής Επιτροπή Επίβλεψης και Κρίσης της Εργασίας **Υπογραφές**

Πρόλογος

Οι αυξανόμενες ανθρωπογενείς πιέσεις που ασκούνται στο θαλάσσιο περιβάλλον θέτουν σε κίνδυνο τη ζωή στη θάλασσα. Προκειμένου να διατηρηθεί η βιοποικιλότητα, είναι αναγκαίο να ληφθούν μέτρα προστασίας και να οριστούν θαλάσσιες προστατευόμενες περιοχές. Ο θαλάσσιος χωροταξικός σχεδιασμός αποτελεί το εργαλείο το οποίο συνδυάζει οικολογικά και κοινωνικοπολιτικά στοιχεία, ούτως ώστε να εφαρμοστούν τακτικές προστασίας της βιοποικιλότητας, διαταράσσοντας όσο το δυνατόν λιγότερο τις ανθρώπινες δραστηριότητες. Για να είναι αποδοτικό ως εργαλείο, απαιτούνται χωρικά δεδομένα τόσο για τις ανθρώπινες δραστηριότητες, όσο και για τις οικολογικές παραμέτρους που μελετώνται.

Μια μέθοδος συλλογής δεδομένων είναι το Citizen Science, δηλαδή η συμμετοχή περιβαλλοντικά ενεργών πολιτών, οι οποίοι όμως δεν είναι καταρτισμένοι επιστήμονες. Η αγάπη για το περιβάλλον και ο πηγαίος ενθουσιασμός για την επιστήμη είναι τα κίνητρα των εθελοντών για να συμβάλλουν με τον δικό τους μοναδικό τρόπο στην επιστημονική έρευνα. Στην εργασία αυτή, εξετάζονται τα πλεονεκτήματα της μεθόδου τόσο ως προς την επιστημονική κοινότητα, όσο και ως προς τους πολίτες που συμμετέχουν, καθώς επίσης και η συμβολή της μεθόδου αυτής στην επιστημονική έρευνα.

Η παρούσα εργασία αποτελεί μια πρωταρχική προσπάθεια χαρτογράφησης προστατευόμενων ειδών στο Αιγαίο με τη χρήση δεδομένων από δημοσιευμένη (π.χ. επιστημονική βιβλιογραφία) και μη (π.χ. βάσεις δεδομένων και συνεντεύξεις με μη-καταρτισμένους πολίτες) πληροφορία. Δευτερεύον στόχος ήταν η σύγκριση της αποτελεσματικότητας κάθε μεθόδου ως προς την παροχή πληροφοριών για ερευνητικούς σκοπούς.

Ευχαριστίες

Θα ήθελα να ευχαριστήσω ιδιαιτέρως την Μαρία Σίνη, μεταδιδακτορική ερευνήτρια του Τμήματος Επιστημών της Θάλασσας, για την παροχή δεδομένων από επιστημονική βιβλιογραφία, βάσεις δεδομένων και συνεντεύξεις, καθώς και για τη δημιουργία του ερωτηματολογίου, στα πλαίσια του προγράμματος MARISCA.

Κατόπιν, θα ήθελα να ευχαριστήσω τον επιβλέποντα καθηγητή της παρούσας εργασίας, Στέλιο Κατσανεβάκη, αναπληρωτή καθηγητή του Τμήματος Επιστημών της Θάλασσας, για την εμπιστοσύνη που μου έδειξε και την πολύτιμη βοήθειά του.

Τέλος, θα ήθελα να ευχαριστήσω όλα τα καταδυτικά κέντρα, τους δύτες και τους πολίτες-επιστήμονες που ανταποκρίθηκαν στο ερωτηματολόγιο και συνέβαλλαν με τον τρόπο τους στη συλλογή πληροφοριών για την ολοκλήρωση της εργασίας.

Prologue

The increasing anthropogenic pressures in the marine environment are posing a threat to marine life. In order to conserve the biodiversity, it is necessary to enforce protection measures and create marine protected areas. Marine spatial planning is the tool which combines ecological and socioeconomic features, in order to apply protection measures with the less possible disturbance of human activities. The effectiveness of this method relies on the amount of spatial information needed, not only towards human activities, but environmental parameters involved as well.

One of the techniques available for data gathering is Citizen Science, which describes the participation of environmental active citizens, who are not scientists. The love for nature and the genuine passion for science are the motivations of volunteers to contribute with their unique way to the scientific research. In this study, we examine the benefits of this technique towards the scientific community and the participating citizens as well, and its contribution to scientific research.

The present study is a preliminary mapping of marine protected species in the Aegean Sea, using data from published (scientific literature review) and non- published (online databases, citizen science) sources. A secondary goal of this study was the comparison of the effectiveness of each information source.

Acknowledgements

I would like to thank Maria Sini, postodoc researcher of the Department of Marine Sciences, for providing data obtained through scientific literature, online databases, and interviews with citizen scientists, as well as for the production of the questionnaire, during the MARISCA project.

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Finally, I would like to thank all the diving centers, individual SCUBA divers and citizens that responded to the questionnaire and contributed with their own way to the completion of this study.

ΠΕΡΙΛΗΨΗ

Το Αιγαίο Πέλαγος είναι το βορειοανατολικό τμήμα της Μεσογείου Θάλασσας, η οποία θεωρείται περιοχή αυξημένης βιοποικιλότητας. Το Αιγαίο αντιμετωπίζει ποικίλες ανθρωπογενείς πιέσεις και είναι εκτεθειμένο τόσο στην κλιματική αλλαγή, όσο και στην εισβολή αλλόχθονων ειδών. Παράλληλα, η περιοχή χαρακτηρίζεται από υψηλά επίπεδα αφθονίας ειδών και κατοικείται και από προστατευόμενα είδη. Προκειμένου να προστατευτεί η θαλάσσια βιοποικιλότητα, είναι απαραίτητο να ληφθούν μέτρα προστασίας και το εργαλείο με το οποίο συνδυάζονται οι διάφορες οικολογικές, κοινωνικές και οικονομικές παράμετροι είναι ο θαλάσσιος χωροταξικός σχεδιασμός. Για να προβούμε στο θαλάσσιο χωροταξικό σχεδιασμό, προαπαιτείται η γνώση κατανομής της βιοποικιλότητας στην προς μελέτη περιοχή, καθώς και οι ανθρώπινες δραστηριότητες που λαμβάνουν χώρα σε αυτή. Η παρούσα εργασία εκπονήθηκε στα πλαίσια του προγράμματος MARISCA, το οποίο στόχευε στην πρόταση ενός δικτύου θαλάσσιων προστατευόμενων περιοχών, συνδυάζοντας οικολογικά δεδομένα από ποικίλες πηγές, όπως: εκτενής βιβλιογραφική ανασκόπηση, διαδικτυακές βάσεις δεδομένων, συλλογή νέων στοιχείων με δειγματοληψίες πεδίου, και συνεντεύξεις με δύτες, φυσιοδίφες ή μη-επαγγελματίες επιστήμονες (citizen scientists). Σκοπός αυτής της εργασίας είναι η δημιουργία χαρτών κατανομής θαλάσσιων προστατευόμενων ειδών και η αξιολόγηση της συμβολής της επιστήμης των πολιτών (citizen science) στη χαρτογράφηση της βιοποικιλότητας. Ως citizen science ορίζεται η συλλογή πληροφοριών επιστημονικού ενδιαφέροντος με τη βοήθεια μη-καταρτισμένων εθελοντών, που κατ’ επέκταση μειώνει το χρόνο και τα έξοδα της έρευνας (ειδικά σε περιοχές μεγάλου γεωγραφικού εύρους), ενώ παράλληλα προάγει την περιβαλλοντική εκπαίδευση και επικοινωνία. Τα είδη που μελετήθηκαν προστατεύονται από εθνική και διεθνή νομοθεσία και ανήκουν σε πέντε ταξινομικές ομάδες (σπόγγοι, ανθόζωα, μαλάκια, εχινόδερμα, ακτινοπτερύγια). Οι χάρτες κατανομής απεικονίζουν την παρουσία των ειδών ανά πηγή πληροφορίας, ούτως ώστε να αποτυπωθεί και να ποσοτικοποιηθεί η συμβολή του citizen science στην συλλογή δεδομένων. Η έλλειψη γνώσης ως προς την κατανομή ορισμένων ειδών από μια πηγή δεδομένων, επιβεβαιώνει την ανάγκη συνδυασμού διαφορετικών τεχνικών συλλογής χωρικής πληροφορίας. Ως εκ τούτου, είναι απαραίτητη η ενίσχυση επιστημονικών εγχειρημάτων που αποβλέπουν στην κατανόηση της προς μελέτη περιοχής, χρησιμοποιώντας κάθε διαθέσιμο εργαλείο για συλλογή οικολογικών δεδομένων, προκειμένου να προταθούν πιο αποτελεσματικά μέτρα προστασίας. Η χρήση σύγχρονης τεχνολογίας μπορεί να ωφελήσει τη συλλογή δεδομένων ορίζοντας μια παγκόσμια βάση δεδομένων, με ελεύθερη πρόσβαση που θα περιλαμβάνει και παρατηρήσεις από πολίτες μη-εξειδικευμένους.

ΛΕΞΕΙΣ - ΚΛΕΙΔΙΑ:

citizen science, προστατευόμενα είδη, θαλάσσια βιοποικιλότητα, χάρτες κατανομής ειδών, Αιγαίο

ABSTRACT

The Aegean Sea is the northeast part of the Mediterranean Sea which is considered a biodiversity hotspot. The Aegean Sea is facing various anthropogenic pressures and is exposed to climate change and invasive species. Meanwhile, the area is characterized by high levels of species richness and is inhabited by protected species as well. In order to protect the marine biodiversity, conservation measures should be taken and the tool to achieve the combination of ecological, social and economic features is Marine Spatial Planning (MSP). In order to proceed with MSP it is important to collect information about the biodiversity distribution in the study area and the human uses of the sea. This study was carried in the framework of the MARISCA project, which aimed to the proposition of a network of Marine Protected Areas and combined ecological data from various sources such as: scientific literature, online databases, collection of new data through fieldwork, and citizen science. The goal of this paper was the creation of distribution maps of marine protected species in the Aegean and the assessment of the value of citizen science for biodiversity mapping. Citizen science is defined as the gathering of information of scientific interest by using the knowledge of non-expert volunteers, which as a result could decrease the money and time needed in field research (especially in large scale studies), at the same time the environmental education and communication can benefit the participants. The studied species are protected by national and international legislation and were categorized in five taxonomic groups (Porifera, Anthozoa, Mollusca, Echinodermata, Actinopterygii). The maps were illustrated with point data to mark the presence of the targeted species and showed the distribution of spatial data that occurred from scientific literature, citizen science and online databases. The lack of knowledge considering the distribution of several species from single source data, confirms the need to combine different spatial information gathering techniques. As a result, it is important to invest to scientific initiatives (aiming to the ecologic data gathering by using any tools available) in order to understand the study area and propose the most effective conservation measures. The use of modern technology can benefit the data collection by setting a global database with public access that includes observations from citizens as well.

KEY WORDS:

Citizen science, marine protected species, marine biodiversity, distribution maps, Aegean Sea

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INTRODUCTION

From the Mediterranean to the Aegean Sea: a biodiversity hotspot that needs protection

The Mediterranean Sea is a biodiversity hotspot due to its high level of endemism noticed in plant and animal species (Vié et al., 2009). Within the semi closed basin a variety of ecoregions is found, thus there are a lot of different habitats (Mouillot et al., 2011) to host more than 17.000 marine species (Coll et al., 2010) (4-18% of all known marine species) and approximately 25% of them are endemic. In the Mediterranean Sea, a decreasing gradient of species richness is noticed from north-west to south east, with the exception of the northern Aegean coasts, where there is an increasing trend of species richness (Coll et al., 2010). Most of the protected vertebrate species (i.e. fishes, mammals, sea turtles) occur in the southwest coasts of the Mediterranean as well as the North Aegean Sea (Coll et al., 2010).

Natural forces and anthropogenic pressures such as overfishing, marine pollution, coastal development, aquaculture, climate change, habitat degradation and the introduction of alien species consist the biggest threats to the Mediterranean biodiversity (Coll et al., 2010; Costello et al., 2010; Katsanevakis et al., 2014) leading the enclosed sea to the most threatened seas worldwide -in terms of biodiversity- (Costello et al., 2010).

The Aegean Sea is highly affected by human activities such as tourism, overfishing, agriculture, waste disposal, aquaculture and shipping, posing a threat to endemic species which are already facing the menace of climate change and the invasion of alien species (Halpern et al., 2008; Coll et al., 2011; Micheli et al., 2013).

Despite the centuries of natural resources exploitation in the Aegean, there is noticed a lack of knowledge regarding the species distribution (Juanes, 2001; Voultsiadou et al., 2013).

In order to prevent the species extinction, the Convention on Biological Diversity (CBD) set the Aichi Target 11 which suggests that by 2020, 10% of the sea should be protected (Thomas et al., 2014). In addition, protected species are safeguarded by national and/or international legislation. However, if the law is not enforced, the species are still exposed to threats (Katsanevakis et al., 2011). Ecological information and spatial details should be considered before any application of protective measures. Marine Spatial Planning is an essential tool for the environmental protection, since it helps set the boundaries between human use of the sea and Marine Protected Areas (Douvere, 2008; Issaris et al., 2012).

Designing a protected area requires information about the distribution of protected species, the habitat type and the pattern of threats in the surrounding environment, highlighting the necessity of creating maps with all the details needed (Margules and Pressey, 2000). If the coverage area of the protected species is unknown, it is not possible to have effective protection measures. It is mandatory to collect, visualize and analyze all the natural and socioeconomic features in order to set the base for an effective conservation plan (Issaris et al., 2012).

Considering the surface of the Mediterranean Sea, and even in this case, the Aegean Sea, the lack of information on ecological features is prohibitive to proceed to marine spatial planning (Giakoumi et al., 2011).

In an attempt to understand the spatial and biological details of the study area, the scientific community needs all the possible available information. Scientific literature is a valid source of information. The problem in searching scientific literature occurs when the current study area or the targeted species do not concur with the information found published. In this case study, the targeted species were twenty and not all of them had available scientific literature data. In addition, the study area was large, and the published information sometimes covered only parts of it. As a result, in order to fill the gap of knowledge, Citizen Science is an additional tool to help scientists gather the information needed (Johnson et al., 2014).

This study aims to locate protected species throughout the Aegean Sea by collecting citizen science data and compare the results with data occurred from an extended scientific literature review gathered in the framework of the MARISCA project. Detailed distribution maps of the protected species of the taxonomic groups of Porifera, Anthozoa, Mollusca, Echinodermata and Actinopterygii were produced.

What is Citizen Science?

The history of Citizen Science goes back in the 1900, when the National Audubon Society started the annual Christmas bird count which still provides data by thousands of participants every year (Cohn, 2008; Silvertown, 2009). However, the term "citizen science" first appeared in 1960 (Cohn, 2008).

The term Citizen Science (CS) describes a scientific initiative in which volunteers participate in one or more steps of the research (Cooper et al., 2007).

CS volunteers can be amateur naturalists or science enthusiasts without scientific background, students or professional scientists volunteering usually as field assistants (Cohn, 2008; Groom et al., 2016).

Typically, in CS the volunteer's duty is to collect data and any further analysis concerns the scientists supervising the project (Cohn, 2008). Nevertheless, in some cases, volunteers participate in the analysis or help co-design projects with scientists (Johnson et al., 2014). The difference between community-based monitoring and citizen science occurs from the level of involvement of citizens in the monitoring of a natural resource (Chandler et al., 2017). For the purpose of this work, we refer to CS only for gathering information from citizen scientists.

The biggest advantage of recruiting volunteers is the number of data collectors. More people can cover easier wide geographic ranges; thus CS is a great tool to gather spatial information (Cooper et al., 2007; Bonney et al., 2009).

Over the past decades, more and more scientific initiatives use CS as data collection tool (Foster- Smith & Evans, 2003) for projects concerning biological conservation, climate change, ecology restoration, alien species and monitoring (Silvertown, 2009). There are numerous on-going CS projects around the globe, apart from the Audubon Christmas Bird Count, such as: Plankton Portal (https://www.planktonportal.org/), Microplastics Project (https://www.adventurescientists.org/microplastics.html) and JellyWatch (http://jellywatch.org/).

Citizen science is a very flexible tool in scientific studies since volunteers gather information according to the researchers' question. The goals and objectives of the research determine the information needed from citizens (Cooper et al., 2007), if the tasks given to volunteers are realistic and achievable, as long as the goals and methods of the research are clear, then citizen science can provide reliable and sufficient information (Foster-Smith & Evans, 2003; Barnard et al., 2017). The quality of data provided by citizen science can be ensured by training the participants to recognize species, using new tools and techniques or any further knowledge is considered vital to the specific study (Cohn, 2008). So far, citizen science projects were completed successfully regarding large scale biodiversity monitoring, developing guidelines for habitat preservation, restoration activities, presence/ absence of target species, population structures, population trends, distribution range changes and can also benefit the research of long term patterns, early warning system for biodiversity changes and help guide-lining preserved habitats (Foster-Smith & Evans, 2003; Cooper et al., 2007; Delaney et al., 2007; Cohn, 2008; Barnard et al., 2017; Chandler et al., 2017). CS projects are not only beneficial towards scientific research, but environmental education is also promoted and as a result, citizens can participate in environmental advocacy (Cooper et al., 2007; Bonney et al., 2009; Johnson et al., 2014).

Why scientists use CS? / Benefits for scientific research

Given the demands of a scientific project, sometimes it is impossible to cover the financial needs, especially if it concerns a large geographic area that needs more manpower to collect sufficient data (Foster-Smith & Evans, 2003). In an effort to gather more information in a large-scale project, scientists turn to CS (Silvertown, 2009). The aforementioned annual Christmas bird count is the best example of collecting ecological data by volunteers over decades, creating a data pool over a wide area with the less possible expenses (Cohn, 2008; Silvertown, 2009). Volunteer field assistants have helped reduce not only the research cost, but also the time needed to gather data, since more people are working for it (Foster-Smith & Evans, 2003; Delaney et al., 2007; Cohn, 2008). CS is recognized as an effective tool in large scale environmental projects because of the sample sizes and the area of coverage, but also for the ability to run for longer time periods counter to traditional research methods (Cohn, 2008; Johnson et al., 2014). Beside the rising recognition of CS in environmental projects, the decline from the standard model of research often lead CS data to grey-literature (Silvertown, 2009). The value of volunteers in science is not only economical, but educational as well, since the hands-on experience benefits the participants too (Delaney et al., 2007).

Why participate in CS? / Benefits for citizens

Citizens that volunteer to science projects are usually characterized by their concern about the nature and their awareness about environmental issues (Cohn, 2008). The reasons to participate in such projects may vary: career motives, building self-esteem, social factors, psychological reasons (positive feelings while in nature), learning new skills, admiring the wildlife and contributing in the protection of the nature are some primary motivations (Johnson et al., 2014; Groom et al., 2016). By participating in CS projects, volunteers have the opportunity to broad their horizons and appreciate the nature (Foster-Smith & Evans, 2003; Cohn, 2008). Being a type of informal education, CS projects promote the environmental education and build the interest of the public towards science, thus this hands-on science experience can benefit the level of science literature (Cooper et al., 2007; Silvertown, 2009; Barnard et al., 2017). The knowledge and understanding of environmental issues raise the public awareness and inspire feelings of responsibility towards the community and eventually it works as a motivation to take action through public engagement (Foster-Smith & Evans, 2003; Cooper et al., 2007; Cohn, 2008; Johnson et al., 2014; Chandler et al., 2017).

Values of citizen science: economical, educational, social

During the last 20 years, the use of CS as a tool for research has increased, not only because of the undeniable economic value, but also due to the connection between ecology and society, promoting environmental justice and public engagement. Public education may not be the focal point of citizen science projects, although it is achieved since it is an informal educational method and rises the public awareness (Johnson et al., 2014). Biological conservation is a complex issue since it involves a variety of stakeholders and interests, thus environmentally educated citizens can help the environmental monitoring or become advocates and make an ecological and social impact (Cooper et al., 2007).

Technology and citizen science

The effectiveness of CS in large scale projects regarding data gathering can benefit from new technologies and create better methods to help the scientific field work. Collecting ecological information can be obtained sometimes without the strict supervision of scientists but can be accomplished by adopting new technologies to promote the communication and interaction between participants without the need to be in the same location (Newman et al., 2012). With the internet and the development of mobile computing, collecting ecological information can be a lot easier. Individuals can upload their observations in a database and then scientists can continue the research (Silvertown, 2009). The use of new technologies can broad the participation and promote CS projects (Newman et al., 2012; Johnson et al., 2014).

METHODS

Study Area

The Aegean Sea is located in the northeastern Mediterranean Sea, connecting the continents of Europe, Asia and Africa and is enclosed by the Turkish coastline in the east, by Greek mainland in the northwest and by Crete island in the south (Figure 1). The Aegean Sea is a very complex ecoregion due to its habitat diversity and its geological morphology which includes more than 1,400 islands and islets, wide plateaus, deep waters, coastal lagoons, marine caves, seagrass meadows and coralligenous formations (Voultsiadou et al., 2013; Sini et al., 2017). The habitat diversity combined with the oceanographic characteristics results to the species richness of the area (Voultsiadou et al., 2013).

Within the study area, there are 7 National Parks (only one of them marine: the “National Marine Park of Alonissos Northern Sporades”) and 186 Natura 2000 sites (without necessarily implied management measures) (Sini et al., 2017), meaning that we still have a long way to achieve the Aichi Target 11 of the CBD.

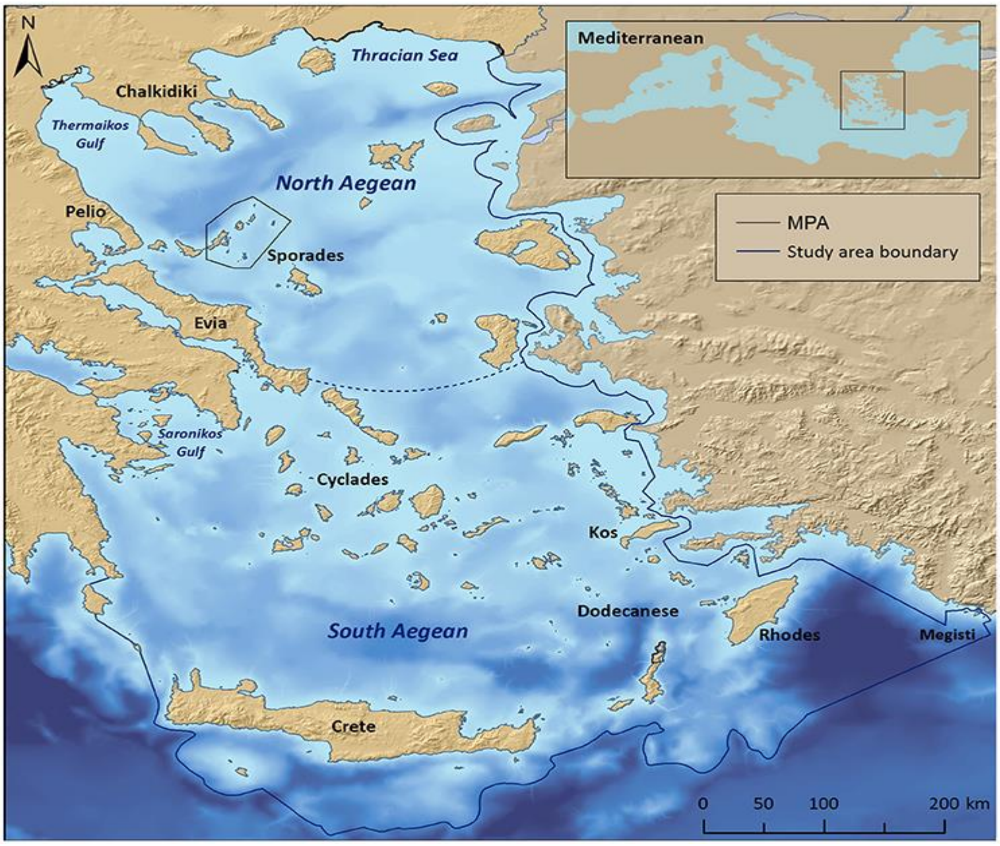


Figure 1: Map of the Aegean Sea, illustrating the study area, the boundary between south and north Aegean, MPA's and the main island complexes [Source: Sini et al., 2017]

Study Species

The Mediterranean is a biodiversity hotspot, thus in order to set the limits of the research, certain species were selected by their enacted protection status by national and international legislation and Conventions. The species selection was based on: Annex II of the "Protocol for Specially Protected Areas and Biological Diversity in the Mediterranean" of the Barcelona Convention, Annex IV of the EU Habitats Directive (92/43/EEC), Annex II of the Bern Convention on the conservation of European wildlife and natural habitats and Appendix II of the Greek Presidential Decree 67/81 on the protection of native flora and wild fauna (Sini et al.,2017).

The targeted species were in the taxonomic groups of: Porifera, Anthozoa, Mollusca, Echinodermata and Actinopterygii (Table 1).

Table 1: The targeted species of the study and the legislation protecting them.

Taxonomic Group	Species	Annex II of Barcelona Convention	Annex II of Bern Convention	Annex IV of EU Habitats Directive	Appendix II of the Greek Presidential Decree
Porifera	*Aplysina* spp	X	X		
	Axinella polypoides	X	X		
	Axinella cannabina	X			
Anthozoa	*Antipatharia* spp	X			
	Callogorgia verticillata	X			
	Cladocora caespitosa	X			
	Savalia savaglia	X	X		
Mollusca	*Charonia variegeta*	X	X		
	Erosaria spurca	X	X		X
	Lithophaga lithophaga	X		X	
	Luria lurida	X	X		X
	Mitra zonata	X	X		
	Pholas dactylus	X			
	Pinna nobilis	X	X	X	X
	Tonna galea	X	X		X
	Zonaria pyrum	X	X		X
Echinodermata	*Ophidiaster ophidianus*	X	X		
	Centrostephanus longispinus	X	X	X	
Actinopterygii	*Hippocampus guttulatus*	X	X		
	Hippocampus hippocampus	X	X		

Case Study

This study was carried out in the framework of the MARISCA project (2015-2016; www.marisca.eu) whose objective was to propose a network of Marine Protected Areas and protection zones in the Aegean Sea, using Marine Spatial Planning to achieve marine biodiversity conservation by combining al the natural, social, economic and spatial features. The information used to run the project were collected from scientific literature, datasets from previous projects, online databases, interviews and questionnaires, remote sensing of satellite images and new field data gathered for the purposes of the research.

The creation of accurate distribution maps demands the use of all the possible existing information. Data acquired through the scientific literature by Sini et al. (2017), were combined with data collected through a questionnaire which was created for citizen scientists. The questionnaire included a photograph of the target species, along with their scientific and common names in order to gather data about their presence, depth, range and abundance in different localities. The information provided was validated through photographs taken by the contributing citizen scientists when available. In addition, a number of “false” species were presented within the questionnaire, in order to evaluate the experience of citizen scientists in identifying different species and to eliminate unreliable observations.

The questionnaires were forwarded to snorkelers, free divers, professional or recreational SCUBA divers, diving centers, and university students. They were initially sent by email to a list of diving centers around the Aegean Sea, and they were also promoted through social media to various groups and fun pages of diving centers, underwater photography and SCUBA diving in general. In addition, interviews using the questionnaire were also taken -in person and over the phone- in order to collect information when available.

Additional information regarding the distribution of target species was obtained through an extensive review of available scientific and grey literature, and online databases in the framework of the MARISCA project (see Sini et al. 2017). This information was combined and compared with data acquired from the citizen science questionnaires during the present study.

All data collected were processed to create distribution maps of the targeted species in the Aegean and compare the effectiveness of each method. The tool used to create the maps was ArcMap: ArcGIS 10.5, using the WGS 84 projection coordinate reference system and illustrating each species data entry by a point on the coastline shapefile of Greece.

RESULTS

A summary of the results on the distribution of the target species and the analysis of the data collection methods are provided below. The main outcomes of this research include distribution maps of each species and charts showing the contribution of the different techniques used to gather information.

Porifera

The geographic distribution of the three species is illustrated by 353 point data on the map (Figure 2), most of them (58%) correspond to locations where *Aplysina* spp. was observed, followed by locations where *A. cannabina* (34%) and *A. polypoides* (8%) were found. *Aplysina* spp. seems to be distributed throughout the Aegean, while observations of *A. cannabina* decline from north to south. The data available for *A. polypoides* indicate the presence of the species in few areas of presence and are not enough to track a distribution pattern.

Out of the information used to create these maps, 54% of them were gathered from the questionnaires and interviews in the framework of Marisca project (Citizen Science), 39% from scientific literature and only 7% from online databases (Figure 3).

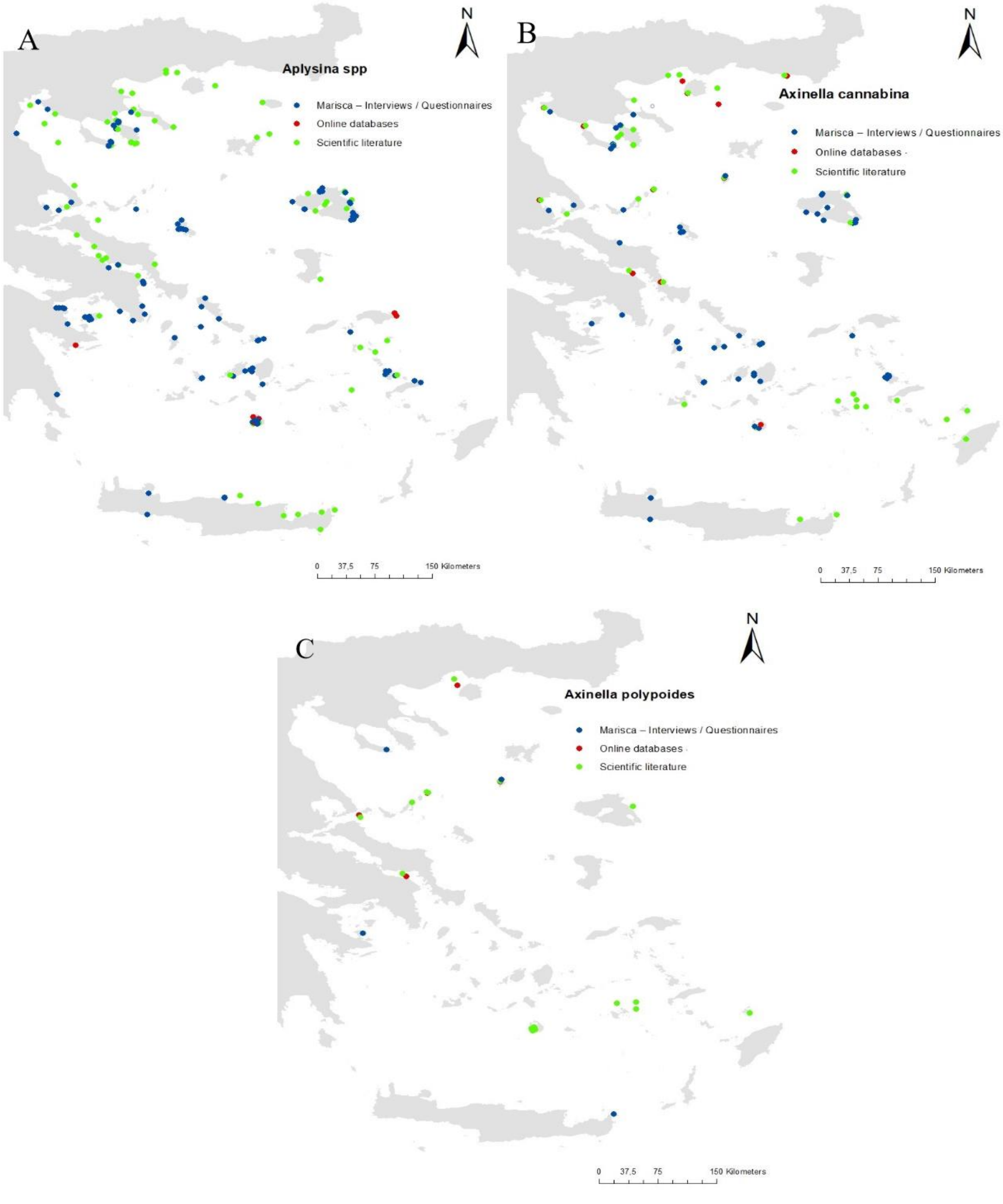


Figure 2: Distribution maps of Porifera (A)*Aplysina* spp., (B)*A. cannabina*, (C)*A. polypoides*.

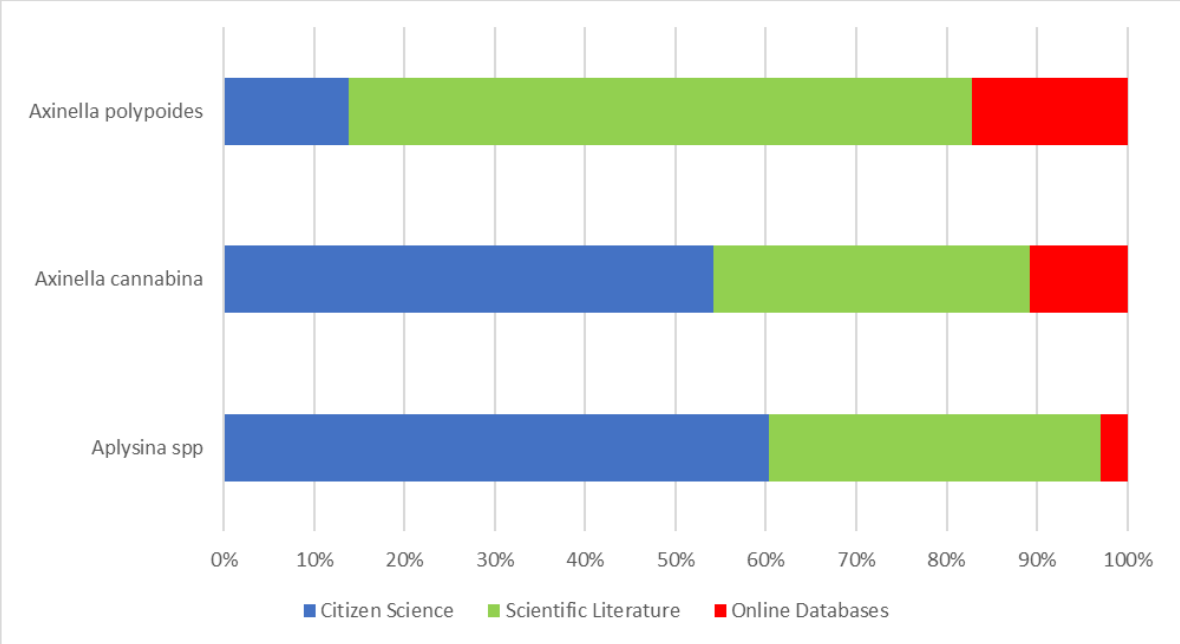


Figure 3: Chart diagrams of the contribution of each data collection method used on the taxon of Porifera; blue color is for information gathered from Citizen Science, red color is for information gathered from Online databases, green color is for information gathered from scientific literature

Anthozoa

The distribution of this taxonomic group is represented by a total of 85 point data (Figure 4). The vast majority of them correspond to *C. caespitosa* (87%), while the distribution of the remaining three species is described by less than 10% of the point data. The data points of *C. caespitosa* are depicted almost in a line from northwest to southeast of the Aegean with a decreasing trend. The number of points available for the other species is not enough to notice a possible distribution trend, however the only point data of *C. verticillata* and *S. savaglia* are located in the northern Aegean.

In this taxon, the origins of the data came mostly from questionnaires (CS) (64%), while online databases and science literature contributed equally (18%) in the information gathering (Figure 5).

Figure 4: Distribution maps of Anthozoa (A): *Antipatharia* spp., (B): *C. verticillata*, (C): *C. caespitosa*, (D): *S. savaglia*.

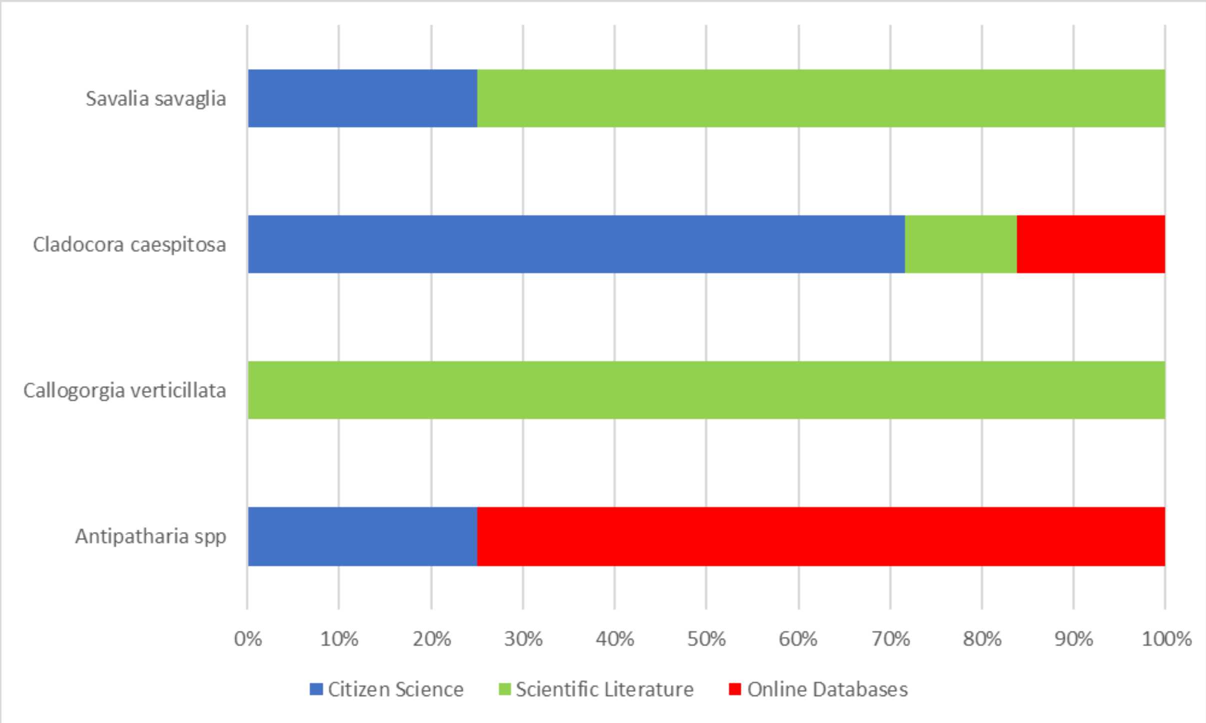


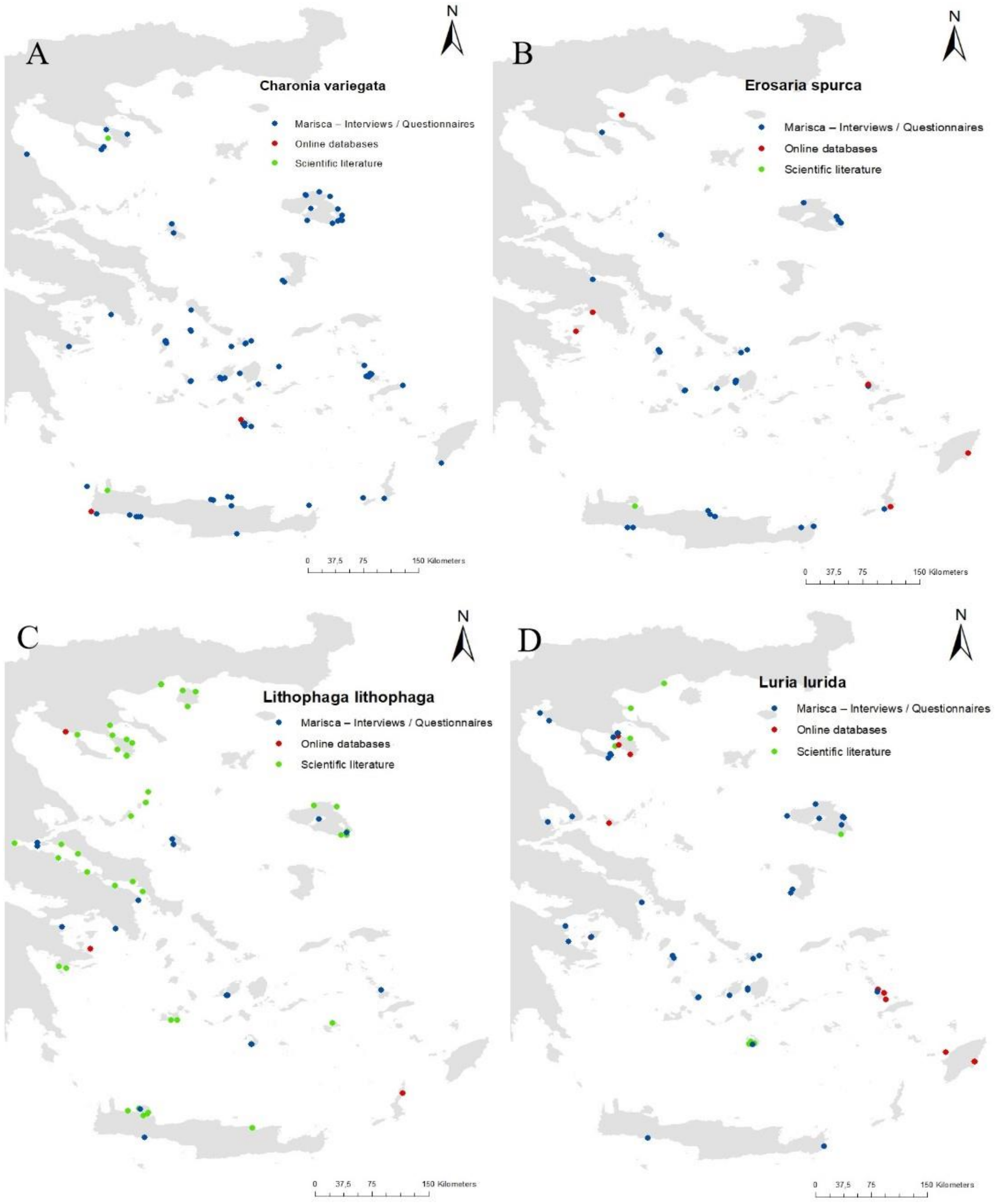
Figure 5: Chart diagrams of the contribution of each data collection method used on the taxon of Anthozoa; blue color is for information gathered from Citizen Science, red color is for information gathered from Online databases, green color is for information gathered from scientific literature

Mollusca

The Mollusca dataset includes 646 point data (Figure 6), 44% of which correspond to *P. nobilis* (282 points). *T. galea* represents 14% of the total data followed by *C.variegata* (13%) and *L. lurida* (10%), the other molluscan species represent less than 10% each of the total observations.

P. nobilis and *C. variegata* are widely spread throughout the Aegean, covering most of the islands and parts of the mainland's coastline. *E. spurca*, *T. galea and Z. pyrum* present a tendency to increase from north to south, while *L. lurida* shows the exact opposite, as it decreases from north to south. Observations of *L.lithophaga* are mostly located in the west coasts of Aegean (Evoikos Gulf and Chalkidiki), with less data point in the east (mainly in Lesvos island).

Most of the information used to create the maps originated from CS data (questionnaires) (67%) and scientific literature (23%) (Figure 7), since *L. lithophaga* and *P. nobilis* are studied more than the other molluscs of the list. The least represented species had no references in scientific literature and the only source of information was the questionnaires (for *P. dactylus*) and the online databases (for *M. zonata*).


A
N
Charonia variegata
Marisca – Interviews / Questionnaires
Online databases
Scientific literature
0 37,5 75 150 Kilometers
B
N
Erosaria spurca
Marisca – Interviews / Questionnaires
Online databases
Scientific literature
0 37,5 75 150 Kilometers
C
N
Lithophaga lithophaga
Marisca – Interviews / Questionnaires
Online databases
Scientific literature
0 37,5 75 150 Kilometers
D
N
Luria lurida
Marisca – Interviews / Questionnaires
Online databases
Scientific literature
0 37,5 75 150 Kilometers

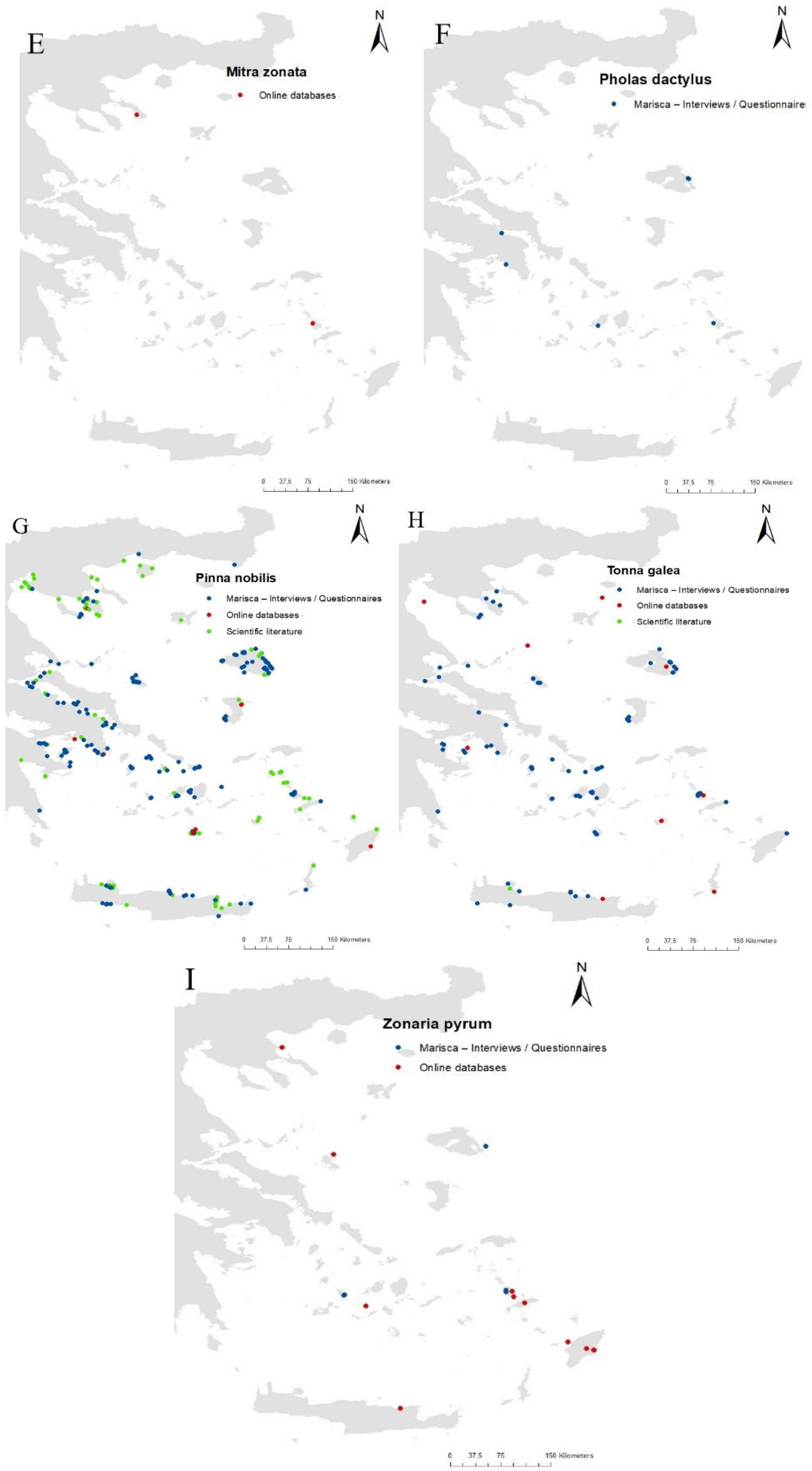


Figure 6: Distribution of Mollusca (A): C. variegata, (B): E. spurca, (C): L. lithophaga, (D): L.lurida, (E): M. zonata, (F): P. dactylus, (G): P. nobilis, (H): T. galea, (I): Z. pyrum.

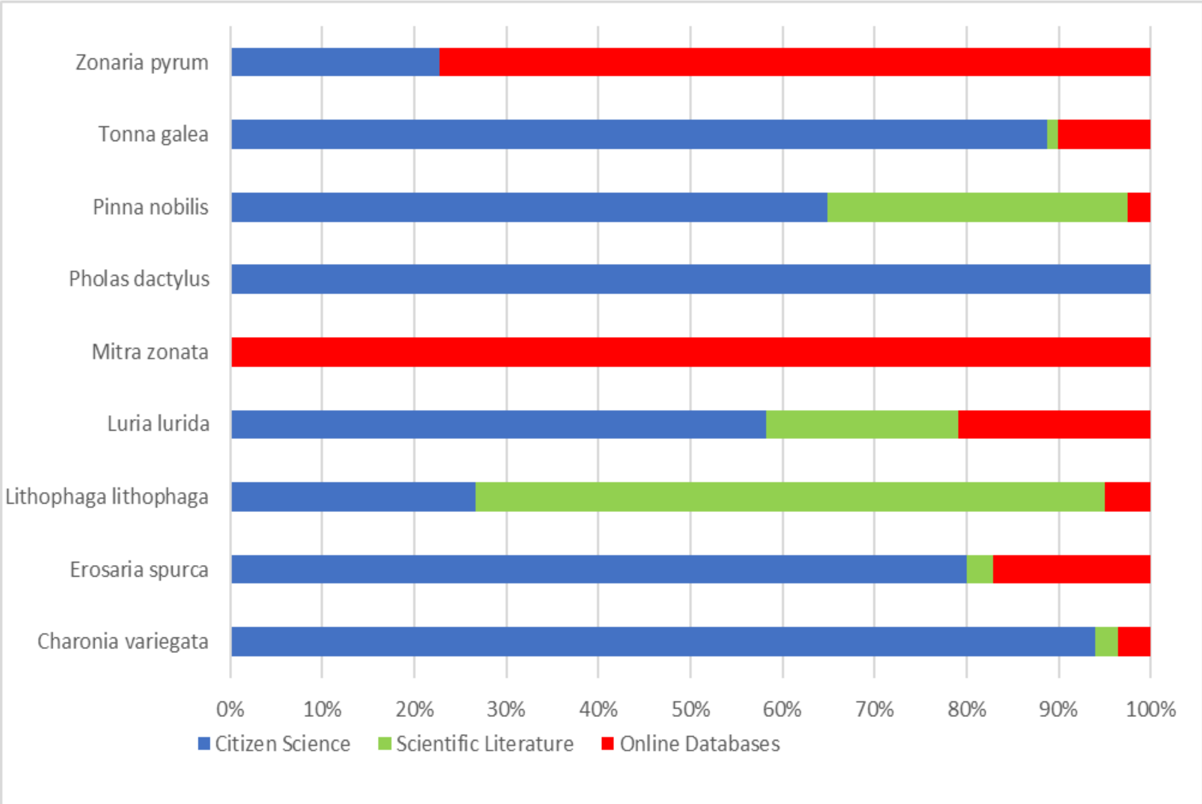


Figure 7: Chart diagrams of the contribution of each data collection method used on the taxon of Mollusca; blue color is for information gathered from Citizen Science, red color is for information gathered from Online databases, green color is for information gathered from scientific literature.

Echinodermata

The geographic distribution of the two protected Echinodermata species is depicted by 125 point data (Figure 8). *C. longispinus* is represented by 47 points and *O. ophidianus* by 78 points (62% of total taxon observations). Both species seem to follow a decreasing trend from south to north, with the point data of *O. ophidianus* more heterogenous distributed between north and south.

The majority (87%) of the information was collected through the use of CS questionnaires and only 13% occurred from scientific literature (Figure 9). Echinodermata is the only taxon without any information provided by online databases.

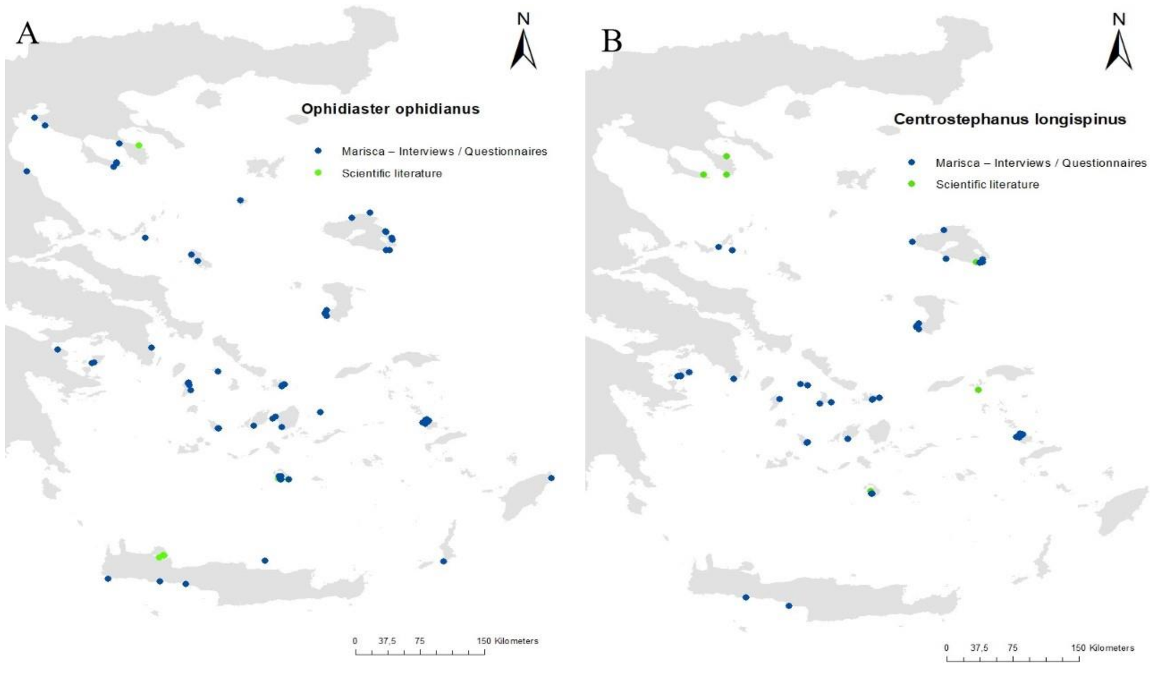


Figure 8: Distribution maps of Echinodermata (A): *C. longispinus*, (B): *O. ophidianus.*

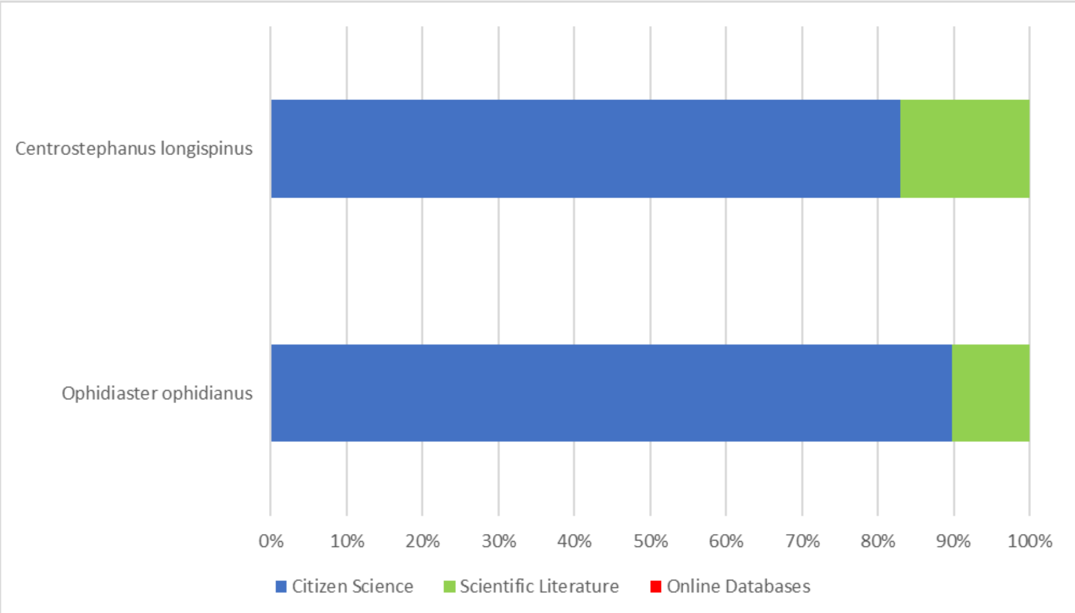


Figure 9: Chart diagrams of the contribution of each data collection method used on the taxon of Echinodermata; blue color is for information gathered from Citizen Science, green color is for information gathered from scientific literature.

Actinopterygii

The distribution of this taxon is marked by 44 point data on the map of the Aegean (Figure 10). The main two species considered were *H. guttulatus* and *H. hippocampus*, but due to the difficulty of correctly identifying the species, a third category was added, *Hippocampus* spp..

43% of the recorded observations corresponded to *H. guttulatus*, 34% to *H. hippocampus* and 23% to *Hippocampus* spp.

Examining the distribution of *Hippocampus* as a genus, it seems to be more abundant in the central Aegean Sea (Evoikos Gulf, Pelio Peninsula, Cyclades) and there is a decreasing trend from the west to east.

The questionnaires contributed most of the information provided (84%), followed by scientific literature (9%) and online databases (7%) (Figure 11). The observations enlisted in online databases were only three and referred only to *H. guttulatus*,

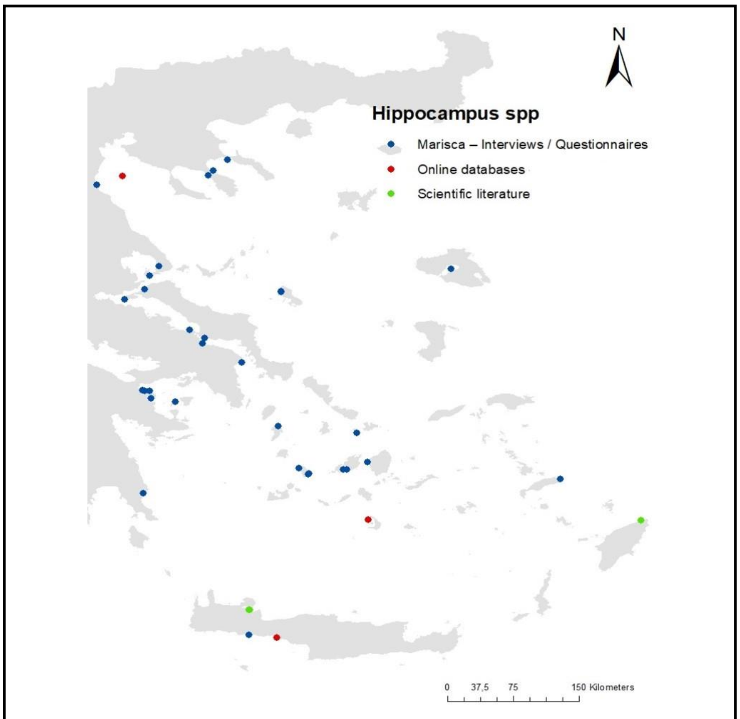


Figure 10: Distribution maps of Actinopterygii: *Hippocampus* spp.

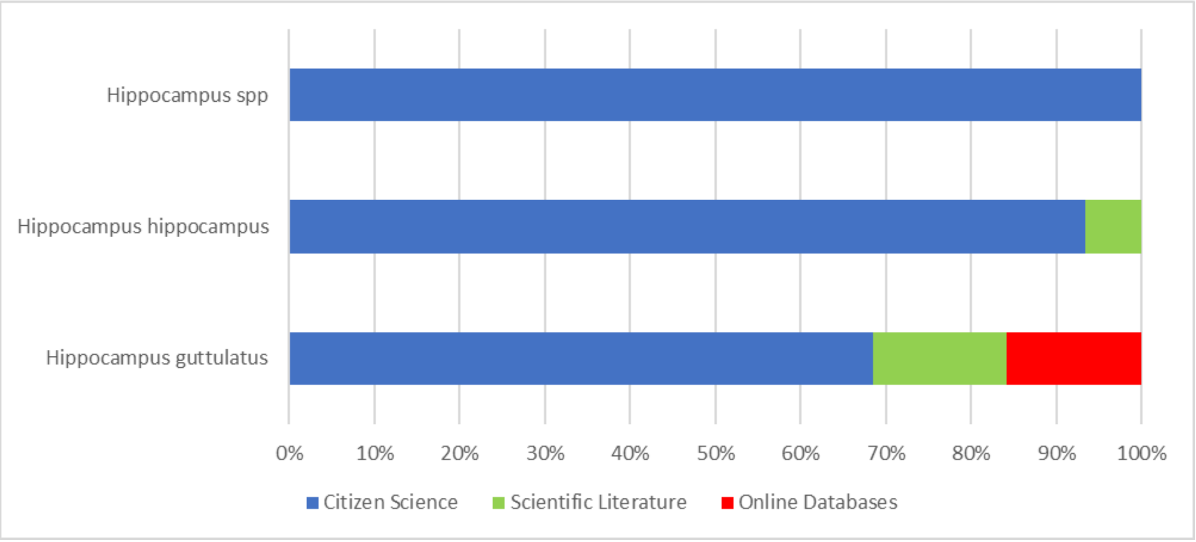


Figure 11: Chart diagrams of the contribution of each data collection method used on the taxon of Actinopterygii; blue color is for information gathered from Citizen Science, red color is for information gathered from Online databases, green color is for information gathered from scientific literature.

The majority of the observations (74%) used to create the distribution maps occurred from non-scientific methods: questionnaires (66%) and online databases (8%). The comparison between the 3 sources (Citizen Science, Online databases, Scientific literature) used to collect information is illustrated above.

DISCUSSION

Since the ultimate goal is the creation of a network of MPA's, the amount of information needed is tremendous. Scientific method is the most accurate (in terms of data quality and the use of systematic methodologies) but at the same time it is very costly (in terms of time and resources), thus data collection by non-scientific methods is considered a solution. However, in this case the contribution of non-scientific methods was impressive.

Out of the maps created, a considerable lack of knowledge occurs regarding the distribution of several understudied species (*Antipatharia* spp., *M. zonata, P.dactylus, Z. pyrum*). It is worth mentioning that in Greece, some of the targeted species (*L. lithophaga*, *P.nobilis*, *C. variegata*, *T. galea*), despite their protection status, are considered commercial species, since their consumption is considered a delicacy (Katsanevakis et al., 2011). As a result, these species are more studied than others, that don't have an added commercial value. The locations where no information occurred are not characterized necessarily by the absence of the species, but possibly by the lack of information about the area. The most studied areas are near the coastline (where the access is easier), but offshore areas are still unknown. It is important to continue with further, more dedicated research to understand and map the ecological features of the Aegean Sea.

The charts depict the contribution of each method in the data gathering. It is important to combine different techniques in order to achieve more realistic results, considering that for some species the total observations were originated only from one source (*C. verticillata*, *M. zonata*, *P. dactulus*), while in some cases there was no scientific data available (*Antipatharia* spp., *M. zonata*, *P. dactylus*). For *Z. pyrum* (77%) and *Antipatharia* spp. (75%) the information gathered from online databases was more than 3 quarters of the total information. The most studied species of the list, with the majority of their observations published by scientists were *L. lithophaga* (68%), *A. polypoides* (69%) and *S. savaglia* (75%). The contribution of citizen science was stupendous, but for several species the percentage of data provided by questionnaires was higher than 80% (*C.longispinus*: 83%, *Hippocampus* spp.: 84%, *O. ophidianus*: 89%, *T. galea:* 89%, *C. variegata*: 94%). Concluding, it is obvious that citizens have a lot of information about their local area and the species that inhabit it, but these data are scattered and not available for scientific purposes. However, it is very important to get access to this information in order to fill the gap of knowledge regarding the distribution of protected species.

This study was an attempt to collect spatial information about marine protected species by creating a bridge between the scientific community and local professionals. Despite their response and the willingness to exchange information, there were a few difficulties. First of all, the problem of species recognition. The photographs of the species included in the questionnaire were helpful, but not enough to eliminate the misidentification problem. In cases when citizens submitted their own photographs of the targeted species, it was easier to validate the quality of their records. In addition, records of questionnaires completed to impress were considered untrustworthy and were not taken into account. Getting the spatial information was tricky as well. In some cases, the spatial information was a descriptive location of the adjacent coast and not geo-referenced spatial information, while in other cases the coordinates given referred to the location of the diving spot and not the exact spot where the targeted species were found.

Additionally, it is important to understand that the results of the citizen science refer to occasional visual observations and not to systematic methodologies, thus the results have an added coefficient of randomness. Communication with local professionals showed that they have valuable information for many endemic species (apart from those included in the questionnaires) that is not in display, and as a result it cannot benefit the scientific research somehow with the existing available tools. This is the reason why the creation of public accessible data repositories is necessary, so valuable information from citizens can be translated to available data for scientists. Nevertheless, citizen science is a very helpful tool to collect data and help the monitoring of MPA's (Delaney et al., 2007).

In this case, volunteers that questionnaires were addressed to were mostly professionals that work every day by the sea and have a close relationship with the marine environment, and as a matter of fact the sea is like their backyard; they know the ecological features of the area and they have a record through years of observing their environment, noticing every change of the local biodiversity and details that scientists cannot know in such large geographic scale. This can help the early detection of invasive species or population declines, that scientists may not notice until too late (Barnard et al., 2017). This kind of volunteer-based research can play a significant role in studies and can also benefit the development of environmental management strategies in a local scale (Foster- Smith & Evans, 2003).

Within the framework of the research, citizens that responded to the questionnaires often gave more information than asked about interesting facts and rare observations, irrelevant to the present study; this proves that citizens are interested in having more interaction with science and are willing to help as much as possible. Several individuals were also willing to extend the period of data gathering to a whole summer season in order to enlist more observations.

The reactions of the diving centers that responded can be grouped in two categories: the first includes suspicious citizens, who were afraid to share information either because of the competition between professionals (especially in small islands), or due to lack of knowledge regarding MPA's and protective measures (fear of strict no-take zones); the second category enlisted the passionate divers with very positive attitude towards marine conservation who were willing to connect and exchange knowledge with the researchers and help from their point the preservation of the marine ecosystem. In both groups, the dialogue and the discussion about marine protection and other environmental issues was a first attempt to promote the environmental education and communication.

CONCLUSION

Summing up, CS is a tool that can benefit the scientific research, especially in large geographic scale projects, and can benefit the data collection by increasing the number of observants and decrease the resources costs. Volunteer-based data gathering is efficient when the aim of the study is simple, thus it is easy to track the presence or absence of targeted species and record them.

When local professionals, relevant to the study topic (e.g. professional divers, fishermen), are involved in the scientific procedure, it is easier to research and understand the natural forces and anthropogenic pressures of the study area, and access observations of locals through the years. The risk in such studies is the data quality and reliability of the source, but there are available techniques (e.g. training of the volunteers, cross-validation of data gathered) to avoid misleading information.

The addition of CS in the scientific research could produce more effective results towards marine ecosystem protection.Unfortunately, there is not any available open access database aiming the support of marine conservation planning in the Mediterranean (Katsanevakis et al., 2015). Although global species datasets specialized in cataloging would be a great tool for monitoring that can help countries achieve the Aichi Target 11 of the Convention on Biological Diversity (Sini et al., 2017). However, over the last years, the significant contribution of volunteer's data gathering was recognized, thus several online databases (https://www.gbif.org/) share records of citizen scientists that are enlisted in other global platforms (https://www.inaturalist.org/). Additionally, in the Mediterranean there are on-going citizen science initiatives, such as: CIGESMED (http://www.cigesmed.eu/) for records of coralligenous assemblages by divers, PERSEUS (http://www.perseus-net.eu) for jellyfish spotting and marine litter watch.

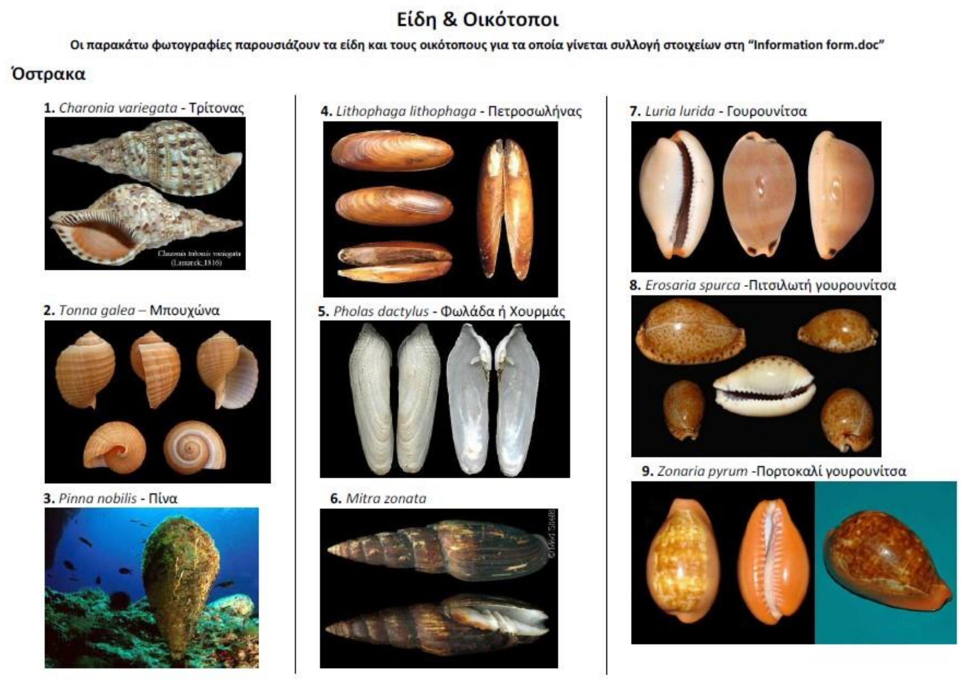
The use of global technologies and available technical tools (Internet, Mobile computing, geographic information systems) could support the gathering and sharing information between the scientific researchers and citizens, by setting a database connected with online mapping tools (Delaney et al., 2007).

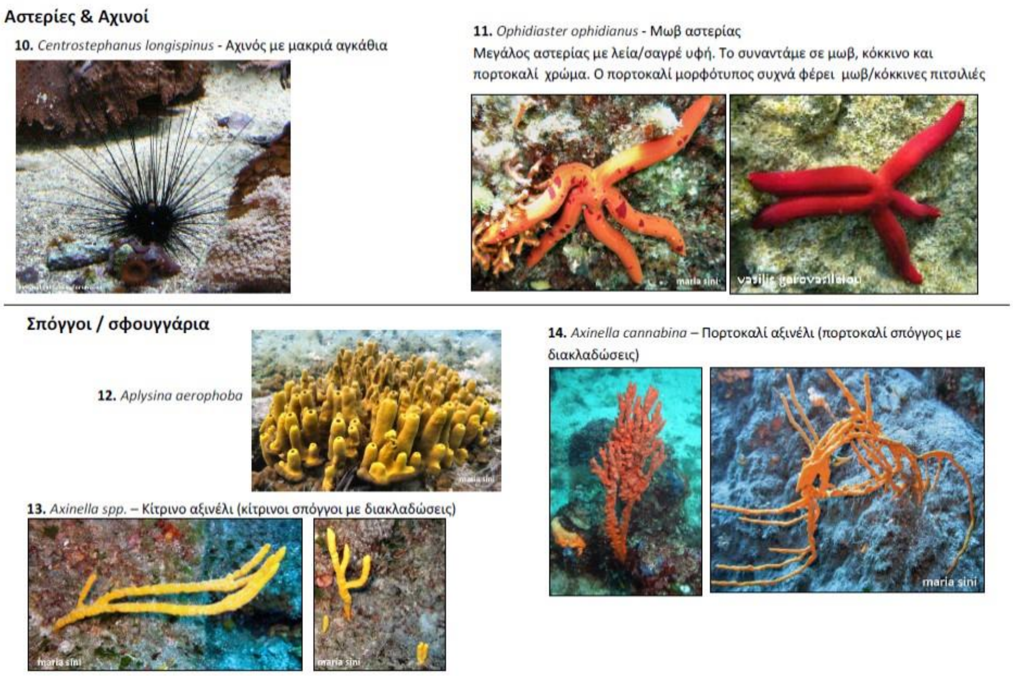
A global, publicly accessible database, with scientific and citizens' observations of protected species included, updated with the already existing information, checked with the data quality standards and protocols (Katsanevakis et al., 2015) may improve the measures and plans of MPA's and support the conservation efforts.

Concluding, it is important to understand that the conservation of marine biodiversity is an important goal of the Mediterranean Sea countries and in order to achieve it, all means available should be used to enforce protection measures.

APPENDIX

The questionnaire and its completion form.





Ιππόκαμποι

15. *Hippocampus hippocampus* – Κοντόρυγχος ιππόκαμπος

16. *Hippocampus guttulatus* – Μακρύρυγχος ιππόκαμπος

Κοράλλια και γοργονίες που βρίσκονται σε νερά ρηχότερα των 60 μέτρων

17. *Cladocora caespitosa* - Κλαδοκόρα

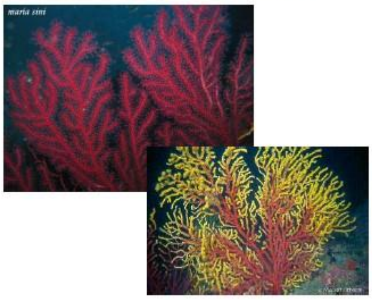
Από τα πιο συνηθισμένα κοράλλια των νερών του Αιγαίου και της Μεσογείου. Απαντάται σε ρηχά νερά (περίπου από 5 μέτρα βάθος), και κάποιες φορές μπορεί να σχηματίσει και υφάλους.

18. *Eunicella singularis* – Λευκή γοργονία

19. *Eunicella cavolini* - Κίτρινη γοργονία

20. *Paramuricea clavata* – Κόκκινη γοργονία

Άλλες πιθανές αποχρώσεις: μωβ, κίτρινο-μωβ



Κοράλλια και γοργονίες που βρίσκονται σε νερά βαθύτερα των 60 μέτρων

21. *Corallium rubrum* - Κόκκινο κοράλλι

Σε άλλες περιοχές της Μεσογείου το κόκκινο κοράλλι αναπτύσσεται και σε ρηχότερα νερά, αλλά στο Αιγαίο οι πληθυσμοί του πλέον είναι πλέον περιορισμένοι και συνήθως βρίσκονται σε βάθη μεγαλύτερα των 60 μέτρων.

22. *Savalia savaglia* - Ψευδομαυροκόραλλο

23. *Leptogorgia sarmentosa* – Πορτοκαλί γοργονία

24. *Antipathes spp.* - Μαύρο κοράλλι ή γιουσούρι

25. *Ellisella paraplexauroides*

Ένα πολύ σπάνιο είδος γοργονίας.

26. *Callogorgia verticillata*

27. *Dendrophyllia cornigera* – Δενδροκοράλλι κίτρινο

28. *Dendrophyllia ramea* – Δενδροκοράλλι πορτοκαλί

29. *Lophelia pertusa* – Λευκό κοράλλι

30. *Madrepora oculata* – Λευκό κοράλλι

Για τους τύπους οικότοπων στην επόμενη σελίδα….

Τύποι οικοτόπων

31. Κοραλλιγενείς ύφαλοι της Μεσογείου χωρίς παρουσία γοργονιών

32. Κοραλλιγενείς ύφαλοι της Μεσογείου με πληθυσμούς γοργονιών

33. Θαλάσσια σπήλαια - **Ημιβυθισμένα**

34. Θαλάσσια σπήλαια - **Πλήρως βυθισμένα**

Είδη & Οικότοποι
Ενδεικτική φόρμα συμπλήρωσης στοιχείων

Οδηγίες

Συμπληρώστε τα είδη / οικοτόπους που υπάρχουν στο αρχείο «Species & Habitats.pdf» και που έχετε παρατηρήσει στις περιοχές που έχετε επισκεφτεί. Συμπληρώστε τα στοιχεία σύμφωνα με τα παρακάτω παραδείγματα που θα βρείτε στην επόμενη σελίδα. Οι πληροφορίες που συλλέγουμε:

1. Στίγμα ή περιγραφή περιοχής
2. Είδος (αρ. Φωτογραφίας από Species & Habitats. pdf) / Αριθμός ατόμων κατά προσέγγιση (1-5 άτομα, 5-10 άτομα, >10 άτομα, >20 άτομα) / Βάθος (κατά προσέγγιση).
3. Οικότοπος (αρ. Φωτογραφίας από Species & Habitats) / Αριθμός σημείων οπού βρήκατε τον οικότοπο/ Βάθος (κατά προσέγγιση)
4. Συνοδευτικό φωτογραφικό υλικό: το φωτογραφικό υλικό που μας στέλνετε εσείς

Εναλλακτικά προωθήστε σχετικές πληροφορίες σε όποια μορφή προτιμάτε.

Προσωπικά στοιχεία

Συμπληρώστε προαιρετικά. Τα στοιχεία αυτά θα χρησιμοποιηθούν μόνο για να διευκολύνουν την επικοινωνία σχετικά με τη συμπλήρωση της συγκεκριμένης φόρμας.

Ονοματεπώνυμο:____

Επωνυμία καταδυτικού κέντρου / συλλόγου κ.λ.π.________________________________

Τηλέφωνο επικοινωνίας:____

e-mail:____

Στοιχεία επικοινωνίας

Για την επιστροφή της φόρμας ή για οποιαδήποτε άλλη πληροφορία / διευκρίνιση παρακαλώ χρησιμοποιήστε τα παρακάτω στοιχεία.

Όνομα: Μαρία Ζώτου & Μαρία Σίνη

Τηλέφωνο: 6977120426; 22510 54433

e-mail: mar12024@marine.aegean.gr; mariasini@marine.aegean.gr

Ευχαριστούμε πολύ για τη συμμετοχή σας και για το χρόνο που αφιερώσατε.

Παραδείγματα

Περιοχή 1- Βραχονησίδα στο στόμιο του κόλπου Γέρας, Λέσβο, (39° 0'33.66"N, 26°32'37.63"E)

Είδος 3 / 5-10 άτομα / 10μ

Είδος 10 / 1-5 άτομα / 20 μ
Οικότοπος 32/ 2 σημεία / 40 μ
Συνοδευτικό φωτογραφικό υλικό: φωτό. 1-3

Περιοχή 2 – Φανάρι, Κάστρο Μυτιλήνης, Λέσβο (39° 6'43.79"N, 26°34'1.55"E)
Οικότοπος 33 / 3 σπηλιές / 5,15,18 μ.
Είδος 12 / 1-5 άτομα / 15μ
Φωτό. 4

Περιοχή 3 – Βραχονησίδα ΒΑ Λέσβου (39°16'18.47"N, 26°24'44.68"E)
Οικότοπος 31 / μία μεγάλη περιοχή / 20-35μ.
Φωτό. 5

Συνεχίστε με τις δικές παρατηρήσεις….

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