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ORIGINAL PAPER

Citizen-science for monitoring marine invasions and stimulating public engagement: a case project from the eastern Mediterranean

Ioannis Giovos · Periklis Kleitou · Dimitris Poursanidis · Ioannis Batjakas · Giacomo Bernardi · Fabio Crocetta · Nikolaos Doumpas · Stefanos Kalogirou · Thodoros E. Kampouris · Ioannis Keramidas · Joachim Langeneck · Mary Maximiadi · Eleni Mitsou · Vasileios-Orestis Stoilas · Francesco Tiralongo · Georgios Romanidis-Kyriakidis · Nicholas-Jason Xentidis · Argyro Zenetos · Stelios Katsanevakis

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Abstract The distribution of marine life has been alarmingly reshaped lately and the number of non-indigenous species and their impacts are rapidly escalating globally. Timely and accurate information about the occurrence of non-indigenous species are of major importance for the mitigation of the issue. However, still large gaps in knowledge about marine bioinvasion exist. Mediterranean Sea is among the most impacted ecoregions globally. In this work we present a comprehensive overview of the project "Is is Alien to you? Share it!!!" which monitors non-indigenous species in Greece and Cyprus with the help of citizen scientists. The goal of this work is to present this project as a case study in order to demonstrate how citizen science can substantially contribute to the monitoring of biological invasions. We compared the projects database with the data-based of ELNAIS and EASIN, for discuss weaknesses and advantages and future steps for advancing the effort. In total 691 records of marine alien and cryptogenic species were collected in these 2 years from Greece and Cyprus, with the density of

I. Giovos (✉) · P. Kleitou · N. Doumpas · I. Keramidas · M. Maximiadi · E. Mitsou · V.-O. Stoilas · F. Tiralongo · G. Romanidis-Kyriakidis · N.-J. Xentidis · A. Zenetos
iSea, Environmental Organization for the Preservation of the Aquatic Ecosystems, Ochi Av, 11, 55438 Thessaloniki, Greece
e-mail: ioannis.giovos@isea.com.gr

P. Kleitou
Marine and Environmental Research (MER) Lab Ltd., 202 Amathountos Av., Marina Gardens, Block B, Offices # 13-14, Parekklisia, 4533 Limassol, Cyprus

P. Kleitou
School of Biological and Marine Sciences, Plymouth University, Plymouth PL4 8AA, UK

D. Poursanidis
Foundation for Research and Technology—Hellas (FORTH), Institute of Applied and Computational Mathematics, N. Plastira 100, Vassilika Vouton, 70013 Heraklion, Greece

I. Batjakas · T. E. Kampouris · S. Katsanevakis
Department of Marine Sciences, School of the Environment, University of the Aegean, 81100 Mytilene, Lesvos Island, Greece

G. Bernardi
Department of Ecology and Evolutionary Biology, University of California Santa Cruz, Santa Cruz, CA, USA

F. Crocetta
Department of Integrative Marine Ecology, Stazione Zoologica Anton Dohrn, Villa Comunale, 80121 Naples, Italy

S. Kalogirou
Hellenic Centre for Marine Research, Hydrobiological Station of Rhodes, 85100 Rhodes, Greece

J. Langeneck
Dipartimento di Biologia, Università di Pisa, Via Derna 1, 56126 Pisa, Italy

records reaching 20 observations per km^2 in some locations. The project has contributed significantly in the assessment of descriptor D2 "Exotic Species" of the Marine Strategy Framework Directive, with 3 new species for Greece. Future steps should focus on training citizens to report less reported taxa and raising the awareness of all relevant stakeholders.

Keywords Participatory science · Alien species · Invasive species · Marine bioinvasions · Greece · Cyprus

Introduction

During the past 150 years, the distribution of biota has been alarmingly reshaped as a result of intensification of human activities, technical advances and increased global marine trade (Katsanevakis et al. 2014a; van Kleunen et al. 2015; Early et al. 2016; Sardain et al. 2019). Non-Indigenous Species (NIS) are those taxons that have managed to cross biogeographic barriers, by direct or indirect human agency, and survive and reproduce in their new regions (Essl et al. 2018). Established NIS may become invasive, with adverse ecological and socioeconomic threats for the recipient areas (Pimentel et al. 2005; Blackburn et al. 2014; Katsanevakis et al. 2014b). As the number of NIS and their impacts are rapidly escalating globally (Seebens et al. 2017), scientists, conservation managers, policy makers, and the public are ever more interested in species monitoring and the promotion of targeted research to support policy for their prevention and mitigation (Tollington et al. 2015).

Accurate and comprehensive spatial and temporal information on NIS occurrence and distribution are integral for the management of biological invasions, developing and testing predictive models and ecological hypotheses (Ricciardi et al. 2000; Kalogirou et al. 2010, 2012a, b; Latombe et al. 2017). However, restricted resources limit the availability of such data collected through scientific monitoring, resulting in large gaps in knowledge of invasion patterns (Crall et al. 2010). Citizen scientists can supplement scarce resources and complement national or regional repositories of NIS data at minimal cost, if properly guided and provided with the capabilities to effectively collect and share information (Delaney et al. 2008; Crall et al. 2010). Citizen science participation in biodiversity data collection has increased rapidly during the last decade, albeit concerns exist regarding taxonomic accuracy and reliability (ElQadi et al. 2017). When properly designed, citizen science projects can provide scientifically robust and reliable data, as those derived from professionals (Danielsen et al. 2005; Theobald et al. 2015; Chase and Levine 2016; Chandler et al. 2017).

With proper verification protocols and tools, accurate data can be collected in a cost-effective manner (Gardiner et al. 2012) providing substantial complementary information on species' distribution, population abundance, and species traits (Chandler et al. 2017; Soroye et al. 2018). Technological developments and emerging communication tools such as the world wide web, smartphones, social networks, geographic information systems (GIS), and the development of an infrastructure for creating simple online data-entry systems, enable the collection and sharing of large volumes of species occurrence data through web applications (Dickinson et al. 2012; Newman et al. 2012).

More than 820 multicellular NIS have been introduced to the Mediterranean Sea (Zenetos et al. 2017a), with increasing abundance in many Mediterranean countries (Galil et al. 2018). Citizen science has recently been flourishing in the Mediterranean Sea. Several projects, initiatives and campaigns contributed to the early detection and monitoring of marine NIS species, with social media and smartphone technology playing a critical role, as they enhance participation and ease community building, while at the same time boost data collection (Newman et al. 2012, Dickinson et al. 2012, Azzurro et al. 2013a, b; Kleitou et al. 2015; Bariche and Azzurro 2016; Cardoso et al. 2017, Crocetta et al. 2017; Deidun and Sciberras 2017; Langeneck et al. 2017; Zenetos

F. Tiralongo
Department of Biological, Geological and Environmental Sciences, University of Catania, Catania, Italy

F. Tiralongo
Ente Fauna Marina Mediterranea, Avola, Italy

N.-J. Xentidis · A. Zenetos
Institute of Marine Biological Resources and Inland Waters, Hellenic Centre for Marine Research, 19013 Anavyssos, Greece

et al. 2017b; Giovos et al. 2018b; Kampouris et al. 2018c; Tiralongo et al. 2018a, b). Present efforts include social media initiatives like Facebook groups/pages and web pages managed by scientists, web-based platforms, campaigns and/or projects (see Table 1).

The project "Is it Alien to you? Share it!!!" was launched in May 2016, by the Environmental NGO iSea, with the main aim to collect information on the occurrence, distribution, and expansion of marine NIS species in Greece and Cyprus. However, cryptogenic species, i.e. taxa of uncertain biogeographic status (Carlton 1996; Essl et al. 2018), have also been included. In 2017, the project obtained a research permit from the Greek Ministry of Environment and Energy for the collection of species biological material. Apart from research, the project invests on communication and dissemination for educating the participants and the general public about NIS. To date, the project has gathered a vast amount of data, including several first and rare records, as well as fulfilled an important role in improving our knowledge of species distribution data, and further elucidating the current state of the country's marine bio-invasions.

The main objective of this study was to demonstrate how citizen science can substantially contribute to filling gaps in our knowledge on the distribution and dynamics of marine bio-invasions by complementing professional surveys and databases. To this end we used the "Is it Alien to you? Share it!!!" project as a case study. By highlighting new information, such as first records of NIS and range expansion of established species, collected by this citizen science project and by comparing collected data with existing valid long-established databases, we aim to underline the added value of marine citizen science efforts but also assess their limitations.

Materials and methods

Data collection

On December 2016, an online data repository was established, in the framework of the citizen science project "Is it Alien to you? Share it!!!". In this project citizen scientists could easily upload NIS observations and photographic material along with information on specimen size (length and/or weight), depth at which the specimen was recorded, number of specimens, location (coordinates), date, and observer profile (free or SCUBA divers, shore or boat recreational fishers, spear-fishers, scientists). A Google Form and a Group on Facebook was established to facilitate these reports. Data collection followed three stages:

- *Stage 1: Data Gathering* NIS observations were collected through social media, primarily the project's Facebook Group (FG), the Project's Observation Form (POF), and via Personal Communications (PC) from various sea users that directly reported to project members (Fig. 1). Once an observation was recorded, a "confidence score" was attributed to it, defined at a three-level scale (1 to 3: low to high quality) based on the assessment of two criteria: (1) if the observation was accompanied by photographic evidence and (2) if the observer had a demonstrated identification experience. All observations accompanied by photographic evidence that enabled identification were scored as 3. Observations that were provided by observers with demonstrated identification experience but without photographic evidence were scored 2. All other observations by less experienced observers that were not accompanied with photos or had photos of low quality that did not enable identification were scored as 1.
- *Stage 2: Identification and Validation* Collected observations with confidence score 3 were sent to taxonomic experts for identification and validation. When the identification was ambiguous, the confidence score was lowered to 1 or 2.
- *Stage 3: Database Updating* The project manager received valid records and updated the database on a monthly basis, after a final check. If questions arose the project manager contacted project members or relevant experts for each observation.

Visual or genetic identification

All photographic material provided to the project by citizen scientists was reviewed by taxonomic experts and identified to species level, when possible. In specific cases of rare observations or first records, project members tried to retrieve the specimen to accurately record the meristic and morphometric data and perform genetic barcoding to definitively identify the species and its origin. All retrieved specimens

Table 1 Initiatives for monitoring marine alien species in the Mediterranean

Project name	Type of project	Spatial coverage	Managed by	Link
Oddfish	Facebook group/page	Mediterranean	Scientist(s)	https://www.facebook.com/groups/1714585748824288/
Is it Alien to you? Share it!!!	Project	Greece and Cyprus	NGO	https://www.facebook.com/groups/104915386661854/
Mediterranean Marine Life	Facebook group/page	Mediterranean	Scientist(s)	https://www.facebook.com/groups/396314800533875/
البحر اللبناني—Sea Lebanon	Facebook group/page	Lebanon	Scientist(s)	https://www.facebook.com/groups/109615625861815/
Marine Life and Biodiversity in Lebanon	Facebook group/page	Lebanon	Scientist(s)	https://www.facebook.com/groups/351425191625456/
Monitoring the lionfish expansion in the Mediterranean Sea	LIFE Project	Mediterranean	Consortium of Entities	https://www.facebook.com/groups/1999454630305867/
Invasive Species in Albanian Coast	Facebook group/page	Albania	NGO	https://www.facebook.com/groups/1377118565724588/
AlienFish	Project	Italy	NGO	https://www.facebook.com/alienfish/?ref=br_rs
Marine Biology in Libya	Facebook group/page	Libya	NGO	https://www.facebook.com/MarineBiologyinlibya/
Aliens in the Sea	Project	Italy	University	https://www.facebook.com/Progetto-Aliens-in-the-sea-699458823457040/
Spot the Alien Fish	Facebook group/page	Malta	University	https://www.facebook.com/aliensmalta/
MAMIAS	Web Based Platform	Mediterranean	RAC/SPA	http://www.mamias.org/
ESENIAS	Network	East and South Europe	Scientist(s)	http://www.esenias.org/
Ellenic Network on Aquatic Invasive Species (ELNAIS)	Network	Greece	Research Institute	https://elnais.hcmr.gr/
Seawatchers	Web Based Platform	Mediterranean	Scientist(s)	http://www.observadoresdelmar.es/projecte-9.php
MedMIS	Web Based Platform	Mediterranean	IUCN	http://www.iucn-medmis.org/?c=Map/show
EASIN	Network	Europe	Joint Research Center	https://easin.jrc.ec.europa.eu/easin
Hellenic Conches	Facebook group/page	Greece	Naturalist(s)	https://www.facebook.com/groups/helleniconches/
Alien Species in Greece and Cyprus	Facebook group/page	Greece and Cyprus	Scientist(s)	https://www.facebook.com/groups/270257066665784/?ref=group_browse
Citizen Science MONitoring (CSMON) Life	LIFE Project	Italy	Consortium of Entities	http://www.csmon-life.eu/
LIFE ASAP	LIFE Project	Italy	Consortium of Entities	http://www.lifeasap.eu/en/
Invasive Alien Species Tracker (IASTracker)	Web Based Platform	Spain	Scientist(s)	http://iastracker.ic5team.org/
AquaNIS	Web Based Platform	Europe	Scientist(s)	http://www.corpi.ku.lt/databases/index.php/aquanis

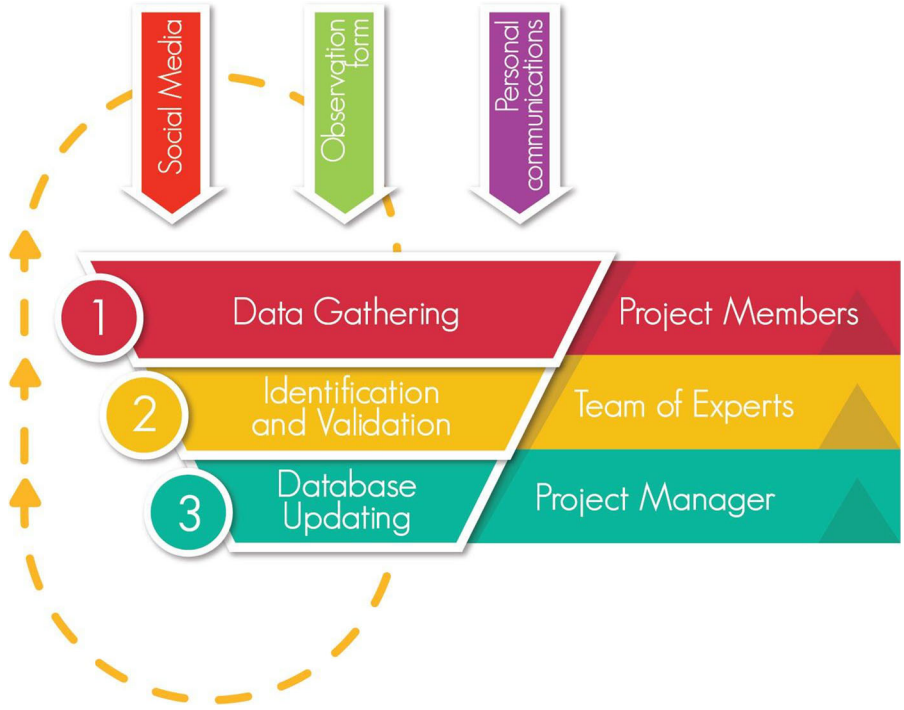

Fig. 1 The procedures for updating the database has 3 steps; Data Gathering (Stage 1), Identification and Validation (Stage 2) and Database Updating (Stage 3) The team roles are further indicated in all three different stages

were collected on the same day or maximum one day after record. When metric reference objects appeared in the photographic material, project members used Digimizer Image Analysis Software (DIMS 2018) for morphometric analysis.

For genetic identification, DNA was extracted from the available specimen(s). Mitochondrial barcode gene CO1 (Cytochrome oxidase 1) was then PCR-amplified and sequenced following published protocols (Bariche et al. 2015). Briefly, for fish the amplification of COI uses fish specific primers VF2T1 and VR1dT1 (Ward et al. 2005). PCR amplified fragments were sequenced in both directions using the same primers, and then compared with available sequences in GenBank. Potential relationships among sequences were further examined by phylogenetic inference using Neighbour-Joining (NJ) and Maximum-Likelihood (ML) approaches generated in R (R Core Team 2013) using the *ape* package (Paradis et al. 2004) and the software package Garli (Zwickl 2006), respectively.

Statistical analyses

Only records of high quality (i.e. confidence score 3) were used in the analyses. The inventory of NIS and cryptogenic species in Greek waters by the "Is it Alien to you? Share it!!!" project (hereafter: iSea data) were compared with the respective inventories reported by EASIN (Katsanevakis et al. 2015; Tsiamis et al. 2016; Deriu et al. 2017) and ELNAIS (Zenetos et al. 2018). The latter is the more recent review of NIS and cryptogenic species in the Greek Seas and may be considered as the most comprehensive inventory currently available for the area. The distributions of species richness by Phylum, as reported by these three sources, were compared by Chi square tests (using STATGRAPHICS Centurion XVI; 95% confidence level for significance).

Regarding the demographics and the insights of the Facebook group of the project we used the Facebook Group insights tool of Facebook downloading all the information since the launch of the group.

Results

Analysis of records

The vast majority of the observations were reported from Greece (≈80.0%), followed by Cyprus (≈

19.0%). In both countries, there was a good spread of records in all territorial waters, with the density of records reaching 20 observations per km^2 in some locations (Fig. 2). Chordata was the most commonly recorded phylum (Fig. 3a) for all observer profiles, constituting 85.2% of the records provided by spear-fishers, 81.2% provided by shore or boat fishers, 71.6% by divers, and 59.1% by scientists. Mollusca was the second most commonly observed phylum for all observer profiles—except for scuba divers—with substantially lower contribution (15.1% for scientists, 11.5% for scuba divers, 11.3% for spear-fishers, and 9.9% for shore/boat recreational fishers). The majority of the Echinodermata (88.2%) were recorded by scuba divers, while none were recorded by fishers. Arthropoda were recorded mostly from shore/boat recreational fishers (54.7%), followed by scientists (35.7%). Underwater observers, such as scuba divers and spear-fishers, recorded only 7.4% of the Arthropoda records. Most commonly, observations originated from shore-based fishing, followed by underwater photography by SCUBA diving, spearfishing, underwater photography by free diving, boat-based recreational fishing, nets (professional fishing), and others (bottom trawling, recreational longlining, hand-collection, beach-stranded) (Fig. 3b).

Reported taxa/species

In total, 1003 observations were collected resulting in 691 records of marine alien and cryptogenic species (68.8%). Among those, 537 (77.7% of the total records of NIS) were photo-identified and validated by the taxonomic experts, thus had a confidence score of 3, while 116 (11.5%) were attributed to a confidence score of 1, and 38 (3.7%) to a confidence value of 2. In total (among the 537 quality-3 records), 58 different species were recorded, with *Lagocephalus sceleratus* (Gmelin, 1789) (Tetraodontiformes: Tetraodontidae; being the most reported species (N=74, 13.7%), followed by *Pterois miles* (Bennett, 1828) (Scorpaeniformes: Scorpaenidae) (N=57, 10.7%) and *Stephanolepis diaspros* Fraser-Brunner, 1940 (Tetraodontiformes: Monacanthidae) (N=37, 6.8%). In agreement with previous results, the vast majority of quality-3 records belonged to the phylum Chordata, followed by Mollusca, Arthropoda, Echinodermata, Cnidaria, and others (Fig. 3a).

Nine different Arthopoda species were recorded, six of which are Brachyuran crabs and the remaining three are prawn species belonging to the Suborder Dendrobranchiata. Overall, 40% of the records are observations of *Callinectes sapidus* Rathbun, 1896 (Decapoda: Portunidae) (N=25) and 28.3% of *Percnon gibbesi* (H. Milne Edwards, 1853) (Decapoda: Percnidae) (N=18). Overall, 57 validated observations of molluscan taxa were recorded, accounting for 10.6% of the total number of quality-3 records. The majority of records come from the Greek coastline (N=48: ≈84.2%), with the remaining 9 (15.7%) coming from Cyprus. Among them, the alien cephalopod *Sepioteuthis lessoniana* d'Orbigny, 1826 (Myopsida: Loliginidae) had almost half of the records (N=28: 49.1%), followed by the cryptogenic taxon *Aplysia dactylomela* Rang, 1828 (Aplysiida: Aplysiidae) that accounted 19 records (33.3%). The 5 remaining species had a low number of records; in particular, *Coryphellina rubrolineata* O'Donoghue, 1929 (Nudibranchia: Flabellinidae) accounted for three records (5.2%), *Conomurex persicus* (Swainson, 1821) (Littorinimorpha: Strombidae) and *Melibe viridis* (Kelaart, 1858) (Nudibranchia: Tethydidae) for two records (3.5% each), and *Chama pacifica* Broderip, 1835 (Venerida: Chamidae) and *Dendostrea* cf. *folium* (Linnaeus, 1758) (Ostreida: Ostreidae) for single records (1.7% each).

Validated observations of Echinodermata represented a minor part (N=16: ≈3%) of all quality-3 records, and included only two species, both considered rather common in the eastern Mediterranean. The majority of records (N=11: 68.7%) refers to *Synaptula reciprocans* (Forsskål, 1775) (Apodida: Synaptidae), and the rest (N=5: 31.2%) to *Diadema setosum* (Leske, 1778) (Diadematoida: Diadematidae. Cnidaria represented only 0.9% of all validated observations, and with the exception of a single specimen belonging to the genus *Chrysaora*, all records referred to the invasive *Rhopilema nomadica* Galil, 1990 (Rhizostomeae: Rhizostomatidae) (N=4). The *Chrysaora* specimen did not correspond to the native *Chrysaora hysoscella* (Linnaeus, 1767) (Semaeostomeae: Pelagiidae) and was subsequently identified as *Chrysaora* cf. *achlyos* Martin, Gershwin, Burnett, Cargo & Bloom, 1997 (Semaeostomeae: Pelagiidae), constituting the first record of this

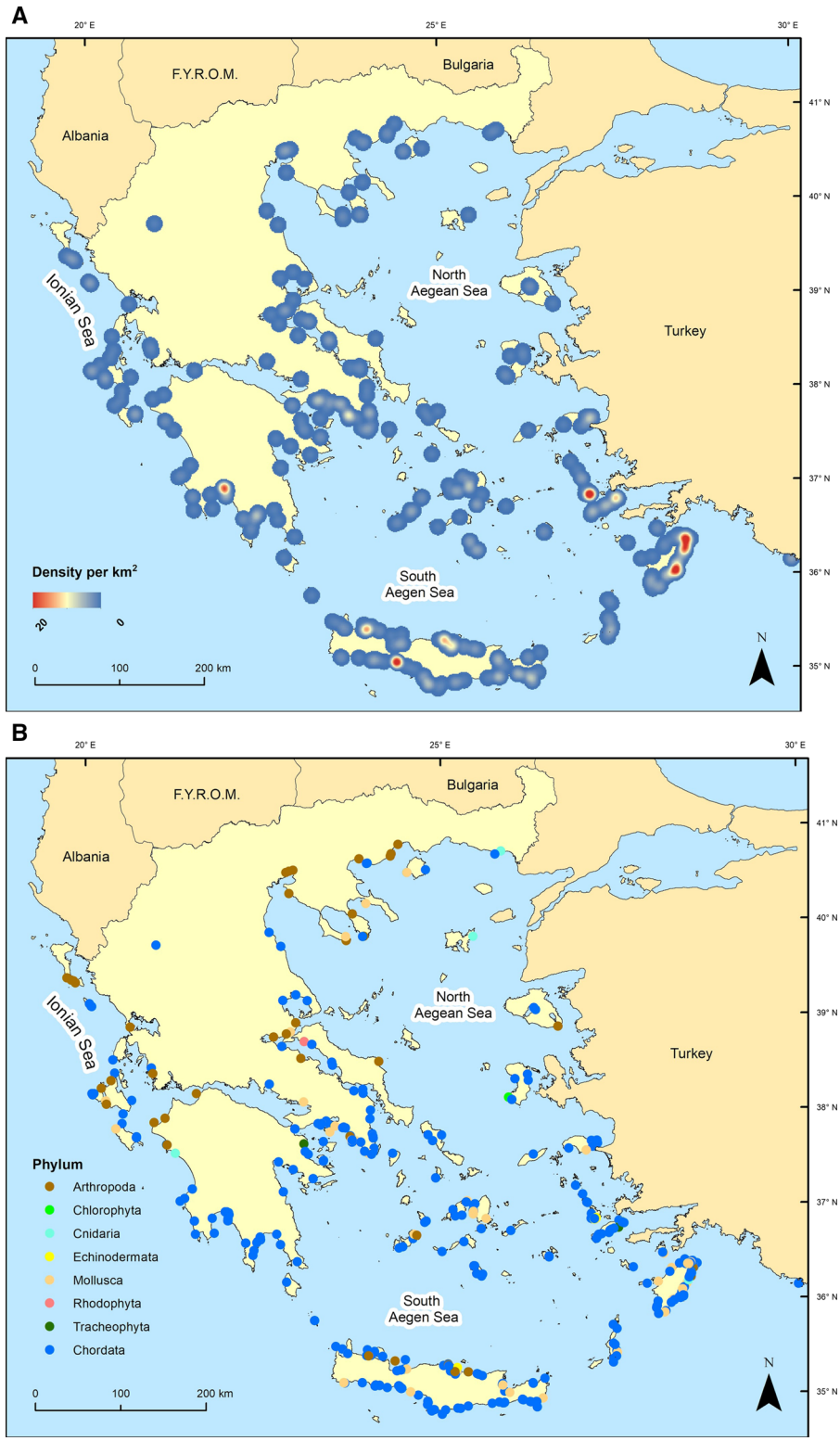

Fig. 2 **a** Density of records in the iSea database, **b** distribution of records by Phylum

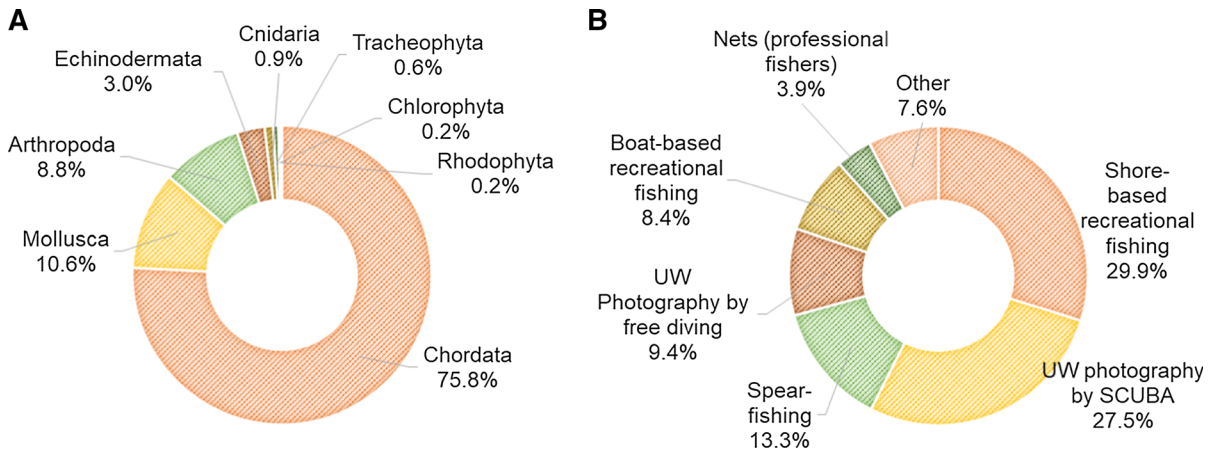

Fig. 3 Classification of validated records of alien and cryptogenic species included in the database of the "Is it Alien to you? Share it!!!" project by Phylum (**a**) and by type of observation (**b**). (UW is underwater)

species from the Mediterranean Sea (see Langeneck et al. 2019).

First records Citizen science observations allowed the identification of a number of species for the first time in Greece or in the Mediterranean Sea: (a) *Abudefduf sexfasciatus* (Lacepède, 1801) (Perciformes: Pomacentridae) and *Acanthurus sohal* (Forsskål, 1775) (Perciformes: Acanthuridae) are the first records in Greek waters and the Mediterranean Sea (Giovos et al. 2018a); *Chrysaora* cf. *achlyos* (Langeneck et al. 2019), (b) an individual of *Lagocephalus guentheri* Miranda Ribeiro, 1915 (Tetraodontiformes: Tetraodontidae) (see Kleitou et al. 2018); (b) a specimen of the genus *Schedophilus* was recorded and the specimen retrieved. Based on the photographic identification, the specimen does not correspond to the native *Schedophilus ovalis* (Cuvier, 1833) (Perciformes: Centrolophidae). Based on the genetic identification performed, it seems to belong to *Schedophilus velaini* (Sauvage, 1879) (Perciformes: Centrolophidae); however, further investigation is required (currently in progress) in order to confirm the species presence, due to inaccuracies in the Genetic Database regarding the native *S. ovalis*. (c) *Nemipterus randalli* Russell, 1986 (Perciformes: Nemipteridae), a Lessepsian species, recorded for the first time from Dodecanese islands based on a retrieved specimen, constituted the first record of the species from the Greek waters.

Geographic expansion The iSea's dataset revealed the geographic expansion of a number of species:

(a) **in the Greek Adriatic Sea:** *Lagocephalus sceleratus* (see Mitsou and Maximiadi in Yokes et al. 2018) (Fig. 4a);
(b) **in the Greek Ionian Sea:** *Pterois miles* and *Cassiopea andromeda* Forsskål, 1775 (Rhizostomeae: Cassiopeidae) (see Mitsou and Maximiadi in Yokes et al. 2018); *Torquigener flavimaculosus* Hardy & Randall, 1983 (Tetraodontiformes: Tetraodontidae) (Fig. 4b–d);
(c) **in the North Aegean Sea**: *Pempheris rhomboidea* Kossmann & Räuber, 1877 (Perciformes: Pempheridae) and *Upeneus moluccensis* (Bleeker, 1855) (Perciformes: Mullidae) (Fig. 4e, f);
(d) **in the South Aegean Sea:** *Rhopilema nomadica* Galil, 1990 (Doumpas and Giovos in Kousteni et al. 2019) (Fig. 4g);
(e) **in Crete:** Records of *Penaeus aztecus* (Ives, 1891) (Decapoda: Penaeidae), *Penaeus hathor* (Burkenroad, 1959) (Decapoda: Penaeidae), *Penaeus pulchricaudatus* (Stebbing, 1914) (Decapoda: Penaeidae) and *Sepioteuthis lessoniana* suggest the westward expansion of these species to Crete (see Kampouris et al. 2018a, b).

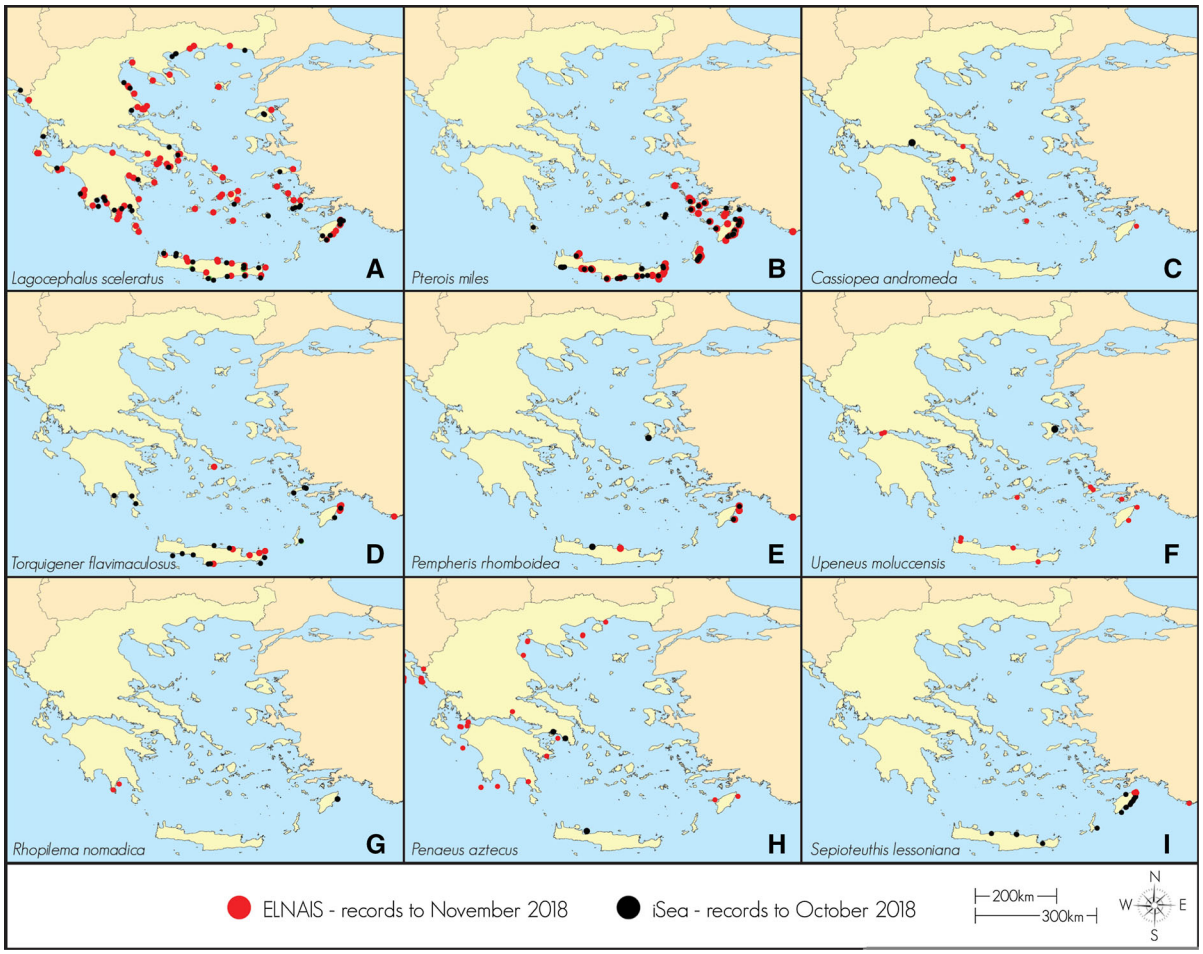

Fig. 4 Contribution of iSea to the Geographical expansion of selected species in new MSFD Greek areas. **a** *Lagocephalus sceleratus*; **b** *Torquigener flavimaculosus*; **c** *Pterois miles*; **d** *Cassiopea andromeda*; **e** *Pempheris rhomboidea*; **f** *Upeneus mollucensis*; **g** *Rhopilema nomadica*; **h** *Penaeus aztecus*; **i** *Sepioteuthis lessoniana*

Similarities and discrepancies with other databases: potential biases

In terms of species richness, the comparison of the iSea records with the EASIN inventory and the recent Zenetos et al. (2018) review of the NIS and cryptogenic species in Greek seas revealed significant differences (Fig. 5a). In total, 295 marine NIS and cryptogenic species were reported as present in the Greek seas by EASIN, 288 species by Zenetos et al. (2018) and 52 by iSea. The species richness reported by EASIN and Zenetos et al. (2018) was similar with no significant differences in terms of its distribution by Phylum (χ^2=2.66, p=0.99), while species richness reported by iSea was substantially lower, with a significantly different distribution by Phylum (χ^2= 80.7, $p < 0.0001$). Chordata was the Phylum for which species richness estimated by iSea data was the closest to the richness estimated by EASIN and Zenetos et al. (2018). For all other Phyla, the estimated richness by iSea data was substantially lower. For thirteen Phyla (i.e., Annelida, Foraminifera, Ochrophyta, Bryozoa, Myzozoa, Ctenophora, Sipuncula, Platyhelminthes, Nematoda, Haptophyta, Cercozoa, Porifera, Cyanobacteria) there were no records in the iSea's database.

The results were similar for the comparison of the reported species richness by Phylum in Cyprus by EASIN and the iSea dataset (Fig. 5b). In total, 163 marine NIS and cryptogenic species were reported as present in Cyprus by EASIN and 33 by iSea. Species richness reported by iSea was substantially lower

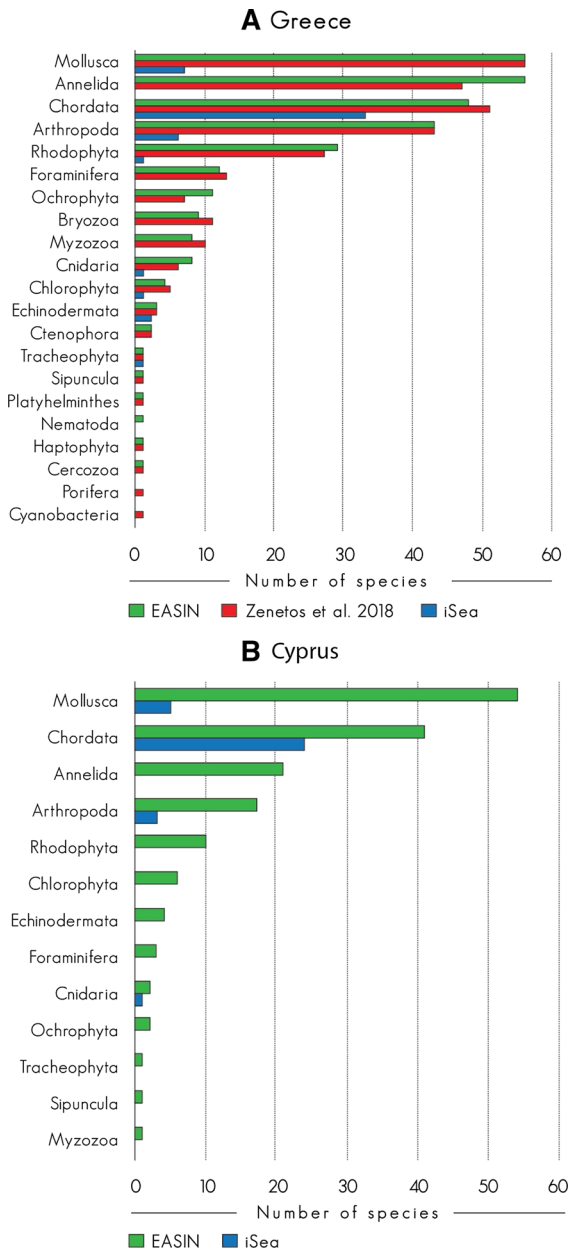

Fig. 5 **a** Reported species richness in Greece by Phylum, in EASIN, Zenetos et al. (2018) and the iSea database; **b** Reported species richness in Cyprus by Phylum, in EASIN and the iSea database

than that of EASIN, with a significantly different distribution by Phylum (χ^2=15.3, $p < 0.016$). Chordata was the Phylum for which species richness estimated by iSea data was the closest to the richness estimated by EASIN.

Citizens community and outreach

The project's Facebook group, which is the main source of records, currently numbers 5752 members with an average of 3878 active members that visit the group on a daily basis. Among all members, 88.5% are men and 11.4% women, while 79.8% age 25–54 years. As an average, four posts are uploaded every day; however not all referring to observations of NIS species. The vast majority of group members are located in Greece (85.6%), followed by Cyprus (7.9%), and in total the group includes members from 57 countries. Greek and Cypriot members are located in 100 town/cities (based on Facebook insight statistics, including only users with open access geolocation settings; N=4057), most being residents of Athens (28.2%), Thessaloniki (9.7%), Nicosia (3.6%), and Herakleion (3.5%). All regions of Greece are represented, while there are several members from neighbouring countries, i.e. Albania, Bulgaria, Italy, and Turkey. The Facebook group of the project is linked to a large number of other Facebook groups of relevant topics, like recreational fishing (about 50 groups have shared at least once a post of the project, with approximately 80.000 accounts from the two countries), diving (6 groups, approximately 6.000 accounts), aquarium trade (10 groups, approximately 20.000 accounts), and naturalists (10 groups, approximately 10.000 accounts). In addition, 9 diving centres have signed a collaboration agreement and report the observations of their dives to the project on a regular basis.

Furthermore, the project's dedicated webpage numbers 5.000 visits of unique users, while other relevant pages of the iSea website, like articles in the latest news section, press releases, etc., number another 4.000 visits from unique users. Posts on the social media of iSea related to the project reach an average of 10.000 views with this number increasing up to 50.000 in some cases. The project has contributed with 13 original scientific articles and two press releases, and >150 articles in the Greek and Cypriot mass media.

Discussion

The analysis of the iSea dataset and its comparison with the ELNAIS and EASIN databases revealed the

substantial contribution of this citizen science effort to complement scientific data on the distribution and dynamics of NIS, but also its limitations. This is the first large-scale citizen science effort in Cyprus and Greece and within only 2 years managed to collect important information depicting the range expansion of many NIS, complemented with several first national and/or Mediterranean records. Yet, the iSea database includes a lower number of species compared to national or European databases such as ELNAIS and EASIN respectively. This is most possibly attributed to (1) information almost exclusively from citizens (recreational fishers, divers, etc.) largely unfamiliar with taxonomic groups other than fish; (2) recent effort compared to EASIN and ELNAIS (initiated in 2012 and 2017 respectively). Finally, the low number of Mollusca records should be attributed to a parallel Facebook network of Greek amateur conchologists (Table 1).

The iSea citizen science project has proven to be very effective in monitoring marine megafauna such as most of the Pisces and large molluscs such as *A. dactylomela*, while it displays limitations in species whose life characteristics and morphological features do not allow photo-identification. For example, species like penaeid prawns and caridean shrimps which are quite hard to be positively identified through underwater photos, were commonly overlooked or misidentified (Kampouris et al. 2018b). A dedicated communication campaign focusing on species of less reported taxa can assist in collecting information on less or no reported species. This campaign should further instruct citizen-scientists how to photograph the specimens for facilitating identification by Taxonomic Experts. However, some taxa will remain largely inaccessible to citizen scientists. Another limitation of the project that must be taken into consideration is the low participation of professional fishers. This is a challenge that potentially requires a different approach. Professional fishers in Greece are on average of old age (European Maritime and Fisheries Fund 2018), and are not very familiar with the use of social media. To overcome such limitation, port surveys can be conducted, utilizing the local ecological knowledge of the fishers (Azzurro et al. 2018).

Identifying limitations and setting clear goals when designing and executing citizen science projects is of imperative value for securing data quality and credibility. The latter is a key challenge for most citizen science projects (Freitag et al. 2016) and the main reason why citizen science may receive criticism (Bradshaw 2003; Wiggins et al. 2013; Freitag et al. 2016). However, recently a vast amount of scientific research is based on citizen science data, and citizen science progressively influences more natural resource management and environmental protection decisions and policies (McKinley et al. 2015). For example, Aceves-Bueno et al. (2015) assessed 83 citizen science projects and found that in more than 40% of the projects, the generated data were used in policy making. Citizen science can provide valuable data, which would require huge budgets if collected through funded scientific surveys. Theobald et al. (2015) reviewed 388 biodiversity citizen science projects and estimated that ~1.3 million volunteers participated contributing up to 2.5 billion USD in-kind annually.

The effective monitoring of marine bioinvasions should be based on integrated efforts that combine more than one monitoring tool, e.g. local ecological knowledge, citizen science and research surveys (Azzurro et al. 2018). The project of iSea arose as an important complementary tool, which once combined with other efforts, like ELNAIS and EASIN, can help improving our knowledge on the distribution of NIS in the region. Such information contributes to the assessment of the good environmental status (GES) of marine waters of EU member states, required by the Marine Strategy Framework Directive (MSFD; EU 2017/848), as the 'trends in the number of new alien species in national waters' is one of the applied indicators of GES (Fig. 6). In fact, to date records of 21 new species in Greek waters are attributed to citizen science (3 of them were collected by the iSea project), which raises the contribution of citizen science to 9.2% from 6% reported in 2015 (Zenetos et al. 2015). In Cyprus the respective contribution of citizen science reaches 7.4% (12 out of 163 species, according to EASIN). Citizen science data are important resources for marine monitoring, in particular for global change research, as they are readily available, commonly at higher rates than data collected by professional scientists (Hampton et al. 2013; Theobald et al. 2015).

Citizen science is a twofold approach, in which citizens can pursue sound research but at the same time increase their knowledge and awareness on

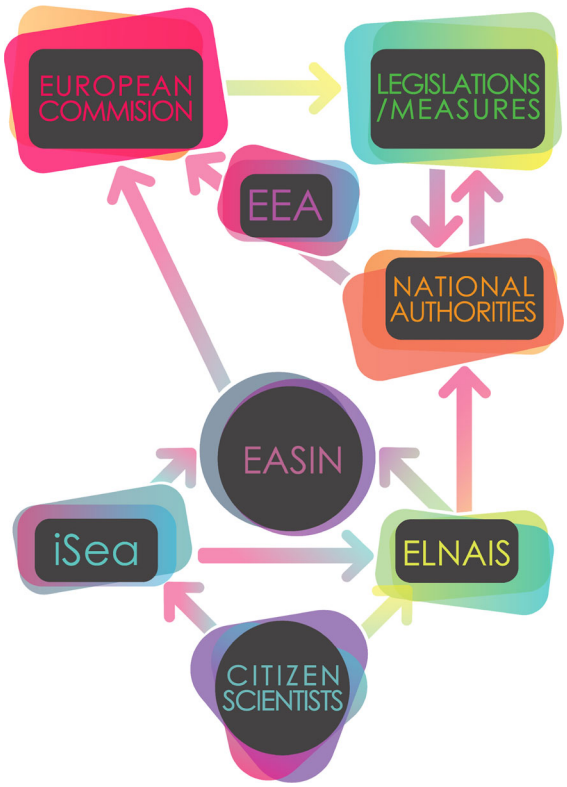

Fig. 6 How data collected from citizen scientists in Greece reach policy makers and incorporated in the production of legislations and measures for tackling invasive alien species

specific topics (Theobald et al., 2015; Bonney et al. 2015). Hence, citizen science can improve social licence advancing the implementation of conservation and environmental policies (Kelly et al. 2017). The iSea project invests in the education of the public and related stakeholders. The growing numbers of citizens which are involved directly or indirectly, and the direct communication between citizens and scientists, manifest the potential to educate the public and increase awareness on marine biological invasions. In addition, the interaction of the project with different communities found on social media (recreational fishers, divers, naturalists etc.) gives the potential to assist in the early warning and rapid response mechanism for marine biological invasions in the two countries.

Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of invasive alien species, calls for regional cooperation between Member States and the neighbouring countries. In its 2 years of life, the iSea project, lined with the Regulation, has established collaborations with initiatives and projects taking place in the Mediterranean Sea. The collaborations include exchange of knowledge, protocols, and practices. In addition, up to date, 29 scientists have contributed to the 14 scientific publications and the 5 conference communications of the project. Some of these scientific publications contribute to the inventory and the range of NIS species in neighboring countries, namely Albania, Libya, and Turkey. The project is a data provider to EASIN and ELNAIS and jointly with other Mediterranean entities, including NGOs, projects, research institutes, and others, initiates the production of press releases regarding NIS species. Communication activities are promoted by IUCN Med, EASIN, and other global networks like INVASIVESNET (Lucy et al. 2016).

Conclusions and future steps

The Mediterranean Sea is highly impacted by biological invasions (Katsanevakis et al. 2014a). Greece and Cyprus are among the countries that receive many NIS, primarily of Indo-Pacific origin. Timely and accurate information on NIS is vital for the management of biological invasions and the implementation of relevant policies (Katsanevakis et al. 2015). Citizen science can be an effective complementary tool to scientific monitoring (Cigliano et al. 2015) with the potential to additionally promote social licence for the acceptance of environmental policies (Kelly et al. 2017). Recently, citizen science is increasingly developing in the Mediterranean, substantially influenced by the recent technological advancements (Dickinson et al. 2012; Newman et al. 2012). Despite certain limitations, the iSea project "Is it Alien to you? Share it !!!" in 2 years' time has produced significant knowledge regarding biological invasions in Greece and Cyprus, and at the same time contributed in raising the awareness of the public and in promoting cooperation among scientists and projects. In the future the project will focus on collecting observations of species of less reported taxa. A targeted awareness campaign and the application of other methods, such as port surveys, could help in enlarging and diversifying the project's database. Additionally, the potential of the virtual community developed in the

Facebook group of the project must be explored in contributing to other topics such as the monitoring of rare or threatened species. Lastly, the project should explore the possibility of developing a mobile application that could boost data collection, given the vast use of smartphones.

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