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Rapid Communication

Filling gaps via citizen science: *Phyllorhiza punctata* von Lendenfeld, 1884 (Cnidaria: Scyphozoa: Mastigiidae) in Cyprus (eastern Mediterranean Sea)

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Abstract

The Mediterranean Sea is one of the most heavily impacted areas by biological invasions worldwide, with over 650 non-indigenous species (NIS) reported as established in 2019. Information about the distribution of NIS in the basin is often fragmented or non-existent due to factors such as lack of finance, expertise, and appropriate surveillance systems. Citizen science might represent a reliable tool in monitoring the spread of NIS, being able to overcome the challenges of scientific monitoring. In the context of the citizen science project "Is it alien to you? Share it!!!", we hereby first report the presence of the Australian spotted jellyfish *Phyllorhiza punctata* von Lendenfeld, 1884 in the marine waters of Cyprus and review its known distribution in the Mediterranean Sea. Although this taxon does not represent a direct threat to human health or tourism as it bears no painful sting, it already caused important ecological and economic damages in other regions of the world, and thus its further spread in Cypriot waters requires appropriate monitoring.

Key words: biological invasions, jellyfishes, Levant Sea, non-indigenous species (NIS), invasive species

Introduction

The Mediterranean Sea is one of the most heavily impacted areas by non-indigenous species (NIS) worldwide due to a combination of cumulative human stressors which include heavy maritime traffic and strong connectivity with other ecoregions through sea corridors (Coll et al. 2012; Katsanevakis et al. 2013). More than 650 NIS species were reported as established in the Mediterranean by 2019 (Zenetos and Galanidi 2020), including gelatinous planktonic species that often proliferate and create blooms that lead to substantial socioeconomic damage (Purcell et al. 2007;

Boero et al. 2009; Boero 2013). Among them, the cnidarian *Rhopilema nomadica* Galil, Spanier & Ferguson, 1990 and the ctenophore *Mnemiopsis leidyi* A. Agassiz, 1865 are causing the most harm in the Mediterranean Sea, with the former interacting with coastal trawling and purse-seine fishing in the southern and eastern coasts of the basin, and the latter threatening commercially important species such as the anchovy *Engraulis encrasicolus* (Linnaeus, 1758) in the Adriatic and the Black Sea (Knowler 2005; Purcell et al. 2007; Boero et al. 2009; Boero 2013; Malej et al. 2017). Notwithstanding that, little is known about other NIS jellyfishes, or they are still known based on scattered records despite possessing bright and distinctive colors, large sizes, or inhabiting the upper levels of the water column, or even a combination of all these features (e.g. Galil et al. 2010; Mamish et al. 2016; Langeneck et al. 2019; Douek et al. 2020; Mutlu et al. 2020; Badreddine and Bitar 2020).

The Australian spotted jellyfish *Phyllorhiza punctata* von Lendenfeld, 1884 is also encased in this statement. Considered as native from the western Pacific Ocean (Heeger et al. 1992; Graham et al. 2003), this species tolerates a broad range of salinity and temperature and can live in turbid waters around estuaries, lagoons, as well as in embayments and heavily populated areas (Rippingale and Kelly 1995). This taxon is characterized by a roughly semi-spherical umbrella, with an average diameter of 45–50 cm in adult individuals and eight broad and transparent branching mouth arms that culminate in large brown bundles of stinging cells, accentuated by white crystalline inclusions that appear as white spots (Hawaiian Biological Survey 2001). These conspicuous morphological characteristics make the species an apparent and easy target for visual detection, including by citizen scientists and non-specialists (Haddad and Nogueira Júnior 2006). However, while *P. punctata* is widely recorded as a NIS in the eastern Pacific and the western Atlantic, where its spread was presumably facilitated by ships through ballast water or fouling (review in Rosales-Catalán et al. 2021), it is still scarcely recorded in the Mediterranean Sea. In fact, although early records of *P. punctata* in the basin date back to 1965, when a single individual was found off Israel (Galil et al. 1990), and the species had already reached the western Mediterranean Sea (Boero et al. 2009; Gueroun et al. 2015), its presence in several Mediterranean countries (e.g. Lebanon, Libya, Syria, and Italy) is based so far on single or very few recent records, which are themselves often based on single specimens (Boero et al. 2009; Durgham 2011; Crocetta and Bariche in Dailianis et al. 2016; Deidun et al. 2017; Rizgalla and Crocetta 2020).

Within the framework of a citizen science project, we hereby first report the presence of *P. punctata* in Cyprus, thus filling a gap in the knowledge of its spread in the Mediterranean Sea, and review its known distribution in the basin.

Materials and methods

In 2016, the Greek environmental organization iSea launched an online project named "Is it Alien to you? Share it!!!" where citizen scientists could share sightings of marine organisms unknown to them. Citizens can submit their sightings with photographic material, videos, and other forms of observation, and can complement their records with auxiliary information, such as specimen size, number of specimens, depth of the sighting, location, date, as well as observation type (freediving, underwater photography, shore-based fishing, boat-based fishing, spearfishing, etc.). Following examination by experts, sightings are identified and assessed based on their validity and reliability. In the recent years, the project has further expanded to include a Google Form and a Facebook® group, with the aim of facilitating the data uploading process, and included several taxonomic experts on marine NIS that regularly provide their expertise in identifying the submitted observations (see Giovos et al. 2019 for further details).

When a sighting of potentially major scientific interest is submitted to the platform, a systematic literature review of records published in indexed and grey literature is also carried out through Google Scholar using appropriate keywords based on the species observed.

Results

Since its launch, the "Is it Alien to you? Share it!!!" project received 121 sightings related to native or NIS jellyfish. Specifically, scyphozoan taxa account for 4.23% of the total records, with numbers increasing during the last four years (less than 1% at the end of 2018: see Langeneck et al. 2019) and NIS that comprise ~ 18.2% of the sightings (Table 1). Among them, one pertained a specimen of a spotted jellyfish (Figure 1), found on the 6th of February 2022 by one of the authors (M.S.-O.) during a recreational dive activity. The animal was found drifting at a depth of around 6 m in the Bay of Da Costa (35.008288N; 34.061619E), Protaras, Cyprus. Ambient seawater temperature was 16 °C. No jellyfish aggregations or even single individuals were recorded in the immediate vicinity. The specimen was soon identified by the group experts as *P. punctata* based on its distinctive bell shape and coloration.

The bibliographic review conducted here yielded 20 records from the entire Mediterranean Sea. Among them, a record from Spain was originally reported in newspapers only (see Anonymous 2011), but then included in the scientific literature (Brotz and Pauly 2012; Galil 2012). As no confirmation was ever published by local researchers, and the newspapers never presented images of the alleged outbreak and of the species, we list it with caution as it may result to be incorrect. Results of the bibliographic review are summarized in Table 2 and depicted in a GIS-generated map in Figure 2.

Table 1. Records of native and non-indigenous Scyphozoan species collected in the present project, with: (i) species binomial name; (ii) N – cumulative number of records in the "Is it Alien to you? Share it!!!" project database; (iii) species status (N – native or NIS – non-indigenous species).

Species	N	Status
Family Cassiopeidae Tilesius, 1831		
Cassiopea andromeda (Forskål, 1775)	6	NIS
Family Cepheidae Agassiz, 1862		
Cotylorhiza tuberculata (Macri, 1778)	24	N
Family Rhizostomatidae Cuvier, 1800		
Rhizostoma pulmo (Macri, 1778)	13	N
Rhopilema nomadica Galil, Spanier & Ferguson, 1990	16	NIS
Family Ulmaridae Haeckel, 1880		
Aurelia sp./spp.	6	N
Family Pelagiidae Gegenbaur, 1856		
Chrysaora cf. *achlyos* Martin et al. 1997	1	NIS
Chrysaora hysoscella (Linnaeus, 1767)	11	N
Pelagia noctiluca (Forsskål, 1775)	44	N

Figure 1. *Phyllorhiza punctata* from Da Costa Bay (Cyprus, eastern Mediterranean Sea). Photo Maria Shokouros-Oskarsson.

Discussion

Citizen science is expanding rapidly, as scientists, policymakers, and conservationists widely recognize citizens' contributions in recording, analyzing, and responding species' invasions worldwide (Thiel et al. 2014; Scyphers et al. 2015). In this view, the case of *P. punctata* in the Mediterranean Sea is also notable, as citizen science already proved to be crucial in tracking its spread in the Mediterranean Sea, and records after 2009 were mostly obtained through social media data mining, interviews with fishermen, and above all generalist citizen science projects or even specific campaigns focused on gelatinous species (Boero et al. 2009; Crocetta and Bariche in Dailianis et al. 2016; Deidun et al. 2017; Rabaoui and El Zrelli in Stamouli et al. 2017; Rizgalla and Crocetta 2020).

Table 2. Known records of *Phyllorhiza punctata* in the Mediterranean Sea arranged in temporal order, with: (i) country, locality, coordinates (latitude and longitude), and Marine Strategy Framework Directive (MSFD) subregion; (ii) sighting date (month and year, when known); (iii) number of individuals (N_IND); (iv) method of observation; (v) reference(s). Numbers (N) correspond to sampling locations shown in Figure 2. Abbreviations used: (i) MSFD: CM – central Mediterranean; EM – eastern Mediterranean; WM – western Mediterranean; (ii) Method: SI – scientific investigation; SS – scientific sampling; MC – museum collection; CS – citizen-science; SM – social media data mining; UNK – unknown. Note: * this outbreak is doubtful; moreover, it was incorrectly reported in the scientific literature as happened in 2010 instead of 2011 [Anonymous (2011); see also references in Brotz and Pauly (2012)].

N	Country	Locality	Coordinates	MSFD	Date	N_IND	Method	Reference
1	Israel	Beit Yanai	~ 32.382379N, 34.860442E	EM	1965	1	SI (MC)	Galil et al. (1990)
2	Egypt	El-Arish	~ 31.281151N, 33.865823E	EM	VII.1986	3	stranded	Atta (1991)
3	Israel	Shikmona	32.821626N, 34.9500020E	EM	I.2005	1	stranded (MC)	Galil et al. (2009)
4	Greece	Bay of Vlyho (Lefkada Island)	38.684444N, 20.706389E	CM	IX.2005 and IX.2006	49	SS	Abed-Navandi and Kikinger (2007)
5	Israel	Kiryat Yam (Haifa Bay)	32.836109N, 34.627411E	EM	IX.2006	2	UNK (MC)	Galil et al. (2009)
6	Greece	Igoumenitsa harbour	~ 39.498769N, 20.261977E	CM	IX.2006	> 50	SS	Abed-Navandi and Kikinger (2007)
7	Israel	Ashdod	~ 31.834615N, 34.541251E	EM	VI.2009	12	UNK (bottom trawling)	Galil et al. (2009)
8	Italy	Cala Suaraccia (Sardinia Island)	40.845110N, 9.707275E	WM	X.2009	1	CS campaign	Boero et al. (2009)
9	Turkey	İskenderun Bay	36.742500N, 36.178600E	EM	X.2010	1	SS	Cevik et al. (2011)
10	Italy	Mar Piccolo (Gulf of Taranto)	40.481395N, 17.235006E	CM	VII.2011	1	UNK	Deidun et al. (2017)
11	*Spain	Orihuela (Alicante)	~ 37.932455N, 0.709471W	WM	VII.2011	outbreak	UNK	Anonymous (2011); Brotz and Pauly (2012); Galil (2012)
12	Syria	Lattakia	35.524872N, 35.551716E	EM	VIII.2011	1	SS	Durgham (2011)
13	Turkey	Sülüngür Lake	~ 36.783950N, 28.652441E	EM	IX.2011	10	SS	Gülşahin and Tarkan (2012)
14	Israel	from Caesarea to Nanariya	~ 32.790511N, 34.866857	EM	2012–2017	UNK	UNK	Mizrahi et al. (2021)
15	Tunisia	Bizerte Lagoon	~ 37.194574N, 9.858965E	WM	VIII.2012 (to X.2013)	1434	SS	Gueroun et al. (2015)
16	Tunisia	between El Hicha and Zarrat (Gulf of Gabès)	~ 34.149522N, 10.040956E	CM	since 2012 (to VIII.2017)	common	SS/interviews	Rabaoui and El Zrelli in Stamouli et al. (2017)
17	Libya	Al Dafiniyah	32.443833N, 14.884028E	CM	I.2015	> 1	SM	Rizgalla and Crocetta (2020)
18	Lebanon	Sarafand	33.439316N, 35.200751E	EM	X.2015	1	SM	Crocetta and Bariche in Dailianis et al. (2016)
19	Malta	Salini salt pans (Malta Island)	35.948328N, 14.425425E	CM	X–XI.2016	> 50	SS/CS project	Deidun et al. (2017)
		St. Paul's Bay (Malta Island)	35.949951N, 14.400052E	CM	XI.2016	1	CS project	
		Qawra Point (Malta Island)	35.958673N, 14.426643E	CM	XI.2016	1	CS project	
20	Egypt	Port Said harbour	31.45N, 32.5E	EM	XI.2018	4	stranded	Madkour et al. (2021)
21	Cyprus	Bay of DaCosta	35.008288N, 34.061619E	EM	II.2022	1	CS project	present paper

The present record from the Bay of Da Costa constituted the first record of the species from Cyprus and thus fills a gap at a country level in the known invaded range of *P. punctata* in the Mediterranean. On one hand, it serves to reaffirm the importance of scientific data obtained through citizen science, but also raises questions regarding its possible pathway(s) of arrival. Galil et al. (2009) reported the existence of sexually mature specimens throughout the entire year, suggesting that established populations persist at least in certain regions of the Mediterranean Sea. This is in agreement with the high number of specimens reported in Greece and in

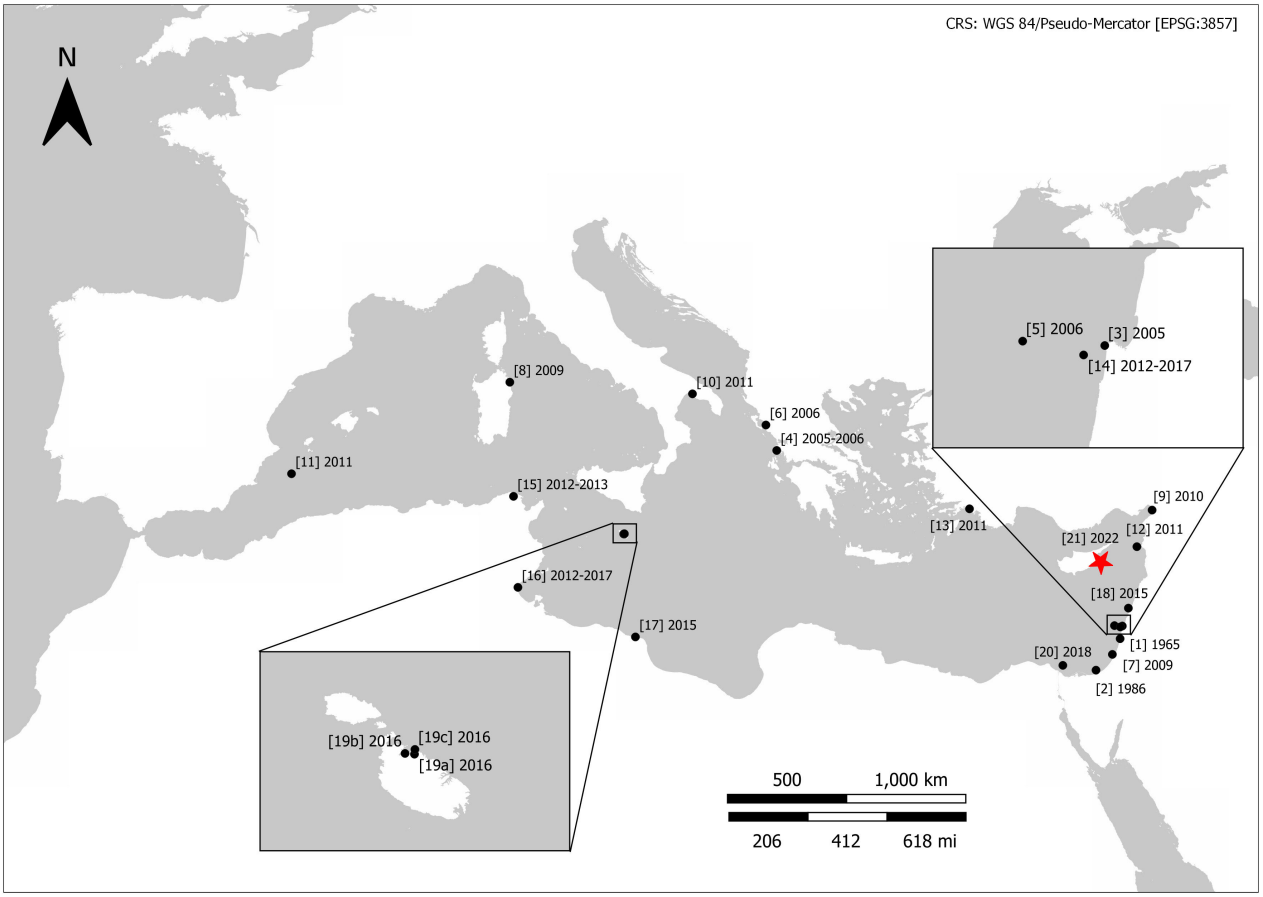

Figure 2. The known distribution of *Phyllorhiza punctata* in the Mediterranean Sea. Numbers within square brackets refer to references listed in Table 2. Red star refers to the present record. Note: the record [11] from Spain is doubtful.

Tunisia (Abed-Navandi and Kikinger 2007; Gueroun et al. 2015; Rabaoui and El Zrelli in Stamouli et al. 2017). Moreover, as the species is characterized by possessing an asexually reproducing benthic polyp and a sexually reproducing pelagic medusa, it may easily remain in the inconspicuous polyp phase for long periods before blooming when environmental conditions are favorable (Eldredge and Smith 2001). Therefore, as *P. punctata* has already invaded almost the entirety of the Mediterranean Sea in the last decades, it is possible that it was already present in Cyprus but went undetected due to absence of field studies. In agreement with that, a recent horizon scanning of invasive species in Cyprus scored as "very high" the likelihood of arrival of *P. punctata* (Peyton et al. 2019), whereas a recent study assessing the invasiveness of 45 jellyfish species in the Mediterranean ranked *P. punctata* even among the top three species (Killi et al. 2020). However, based on the available data, the possibility of a recent arrival in the area also cannot be excluded. This could have happened through adult passive drifting from nearby populations in the Levant Sea, but also with early life stages being transported in ballast waters or clinging to vessel hulls, as already speculated by Deidun et al. (2017) for records in the central Mediterranean Sea.

Apart from these uncertainties, the potential of establishing permanent large-scale populations of *P. punctata* in Cyprus, as well as the consequences this establishment may incur, should not be underestimated. In fact, although this taxon does not represent a direct threat to human health or tourism industry (Boero et al. 2009), it has already caused significant impacts to fisheries (i.e. clogging nets) and the ecosystem (i.e. large clearance rates of zooplankton) (Garcia 1990; Perry et al. 2000; Silveira and Cornelius 2000; Graham et al. 2003; Rosales-Catalán et al. 2021), and thus regular blooms of this species might constitute an additional stressor for local fisheries.

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Authors' contribution

Conceptualization, A.K. and F.C.; methodology, A.K. and F.C.; validation, J.L., F.T., and F.C.; investigation, A.K., M.S.-O., V.M., and P.K.; data curation, A.K., V.M., and F.C.; writing – original draft preparation, A.K. and F.C.; writing – review and editing, A.K., M.S.-O., V.M., J.L., P.K., F.T. and F.C.; supervision, F.C. All authors have read and agreed to the published version of the manuscript.

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