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Rapid Communication

On the importance of citizen-science: the first record of *Goniobranchnus obsoletus* (Rüppell and Leuckart, 1830) from Cyprus (Mollusca: Gastropoda: Nudibranchia)

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Abstract

The Mediterranean Sea faces unprecedented challenges by the increasing of non-indigenous species (NIS) introductions. Cyprus is the first European country affected by Lessepsian immigration, being along the natural pathway of many of the Indo-Pacific taxa spreading from the Red Sea; thus, it has a pioneer role in detecting alien species and in demonstrating that a concerted action is necessary at early stages of invasion, as required by the recent EU Regulation on NIS (EC/1143/2014). This study reports for the first time the presence of the nudibranch *Goniobranchnus obsoletus* from Cyprus and confirms its spread in the basin, after its first sightings in Israel. Moreover, the records were collected in the context of a citizen project, this taxon being first detected by a scuba diver and then posted on a dedicated Facebook group. This study, therefore, proves once more the importance of technology utilization in early detection of non-indigenous species and suggests that citizen-science can form an integral tool for the implementation of the EU Regulation and should be further promoted by the national and international management authorities.

Key words: non-indigenous species, alien spreading, Levantine Sea, Suez Canal, Red Sea

Introduction

The semi-enclosed Mediterranean Sea offers a wide range of climate, hydrology, and habitat niches which historically contributed to the co-occurrence and survival of both temperate and subtropical organisms and the definition of the above mentioned basin as a “biodiversity hotspot” (Coll et al. 2010). Driven by climate change and increasing human pressures, however, the Mediterranean is currently facing an unprecedented threat due to the introduction of non-indigenous species (NIS) and the alteration of ecosystem structures and functions (Katsanevakis et al. 2014). An

increasing trend in new arrivals has been observed since 1950, which provides a worrisome picture of a “besieged sea” and indicates a failure of management to provide adequate control measures (Galil et al. 2018a).

The most recent review of NIS in the Mediterranean records 821 multicellular taxa, with at least 613 being considered as established (Zenetos et al. 2017). The number of NIS is substantially greater in the eastern Mediterranean, particularly in the Levantine, due to its proximity with the Suez Canal and the influx of Lessepsian immigrants after its opening/enlargement (Galil et al. 2018b). Being one of the most invaded ecosystems in the world, the Levantine’s continental shelf has been facing dramatic changes and degradation over the past decades, mostly attributed to climate change, fishery depletion, and increasing numbers of NIS (Edelist et al. 2012; Corrales et al. 2017).

To effectively manage NIS that can potentially cause detrimental impacts, the European Union (EU) Regulation on the prevention and management of the introduction and spread of invasive alien species (EC/1143/2014) adopted the Union List to ensure that priority is given to few species whose inclusion on the list would effectively prevent, minimise, or mitigate their adverse impact in a cost efficient manner. Species for inclusion can be proposed from the European Commission or the Member States. Given the lack of knowledge about the ecology of many species from the Red Sea, countries of the eastern Mediterranean basin have a crucial role in providing sufficient and accurate early-warning information about the presence, spread, and potential impacts of new invaders.

Cyprus’ sentinel location near the Suez Canal is amongst the first of the Mediterranean countries, and the first EU country, to be affected by Lessepsian immigrations; thus, it has a pioneering role in the early detection and the understanding of introduced species’ dynamics. However, Cyprus NIS records are substantially fewer compared to countries of the Levantine, possibly due to the absence of targeted field studies (Crocetta et al. 2015). In this article, we contribute to the knowledge of bioinvasions in the Mediterranean Sea by reporting the first record of the nudibranch *Goniobranchus obsoletus* (Rüppell and Leuckart, 1830) from Cyprus.

Materials and methods

On 10 November 2018, during scuba diving (25 °C sea-water surface temperature) in a submerged cave located at the depth of 1.1 m off Ayia Napa (i.e., Cavo Greco) in Cyprus (34.978300°N; 34.022129°E) (Figure 1A), a citizen diver (Werner Wolf) noticed and subsequently photographed two sea slug individuals moving around encrusting macrophytes (i.e., Corallinales), sponges [*Dysidea avara* (Schmidt, 1862), *Terpios gelatinosus* (Bowerbank, 1866), *Spirastrella cunctatrix* Schmidt, 1868, and *Sycon* sp.], and hydroids

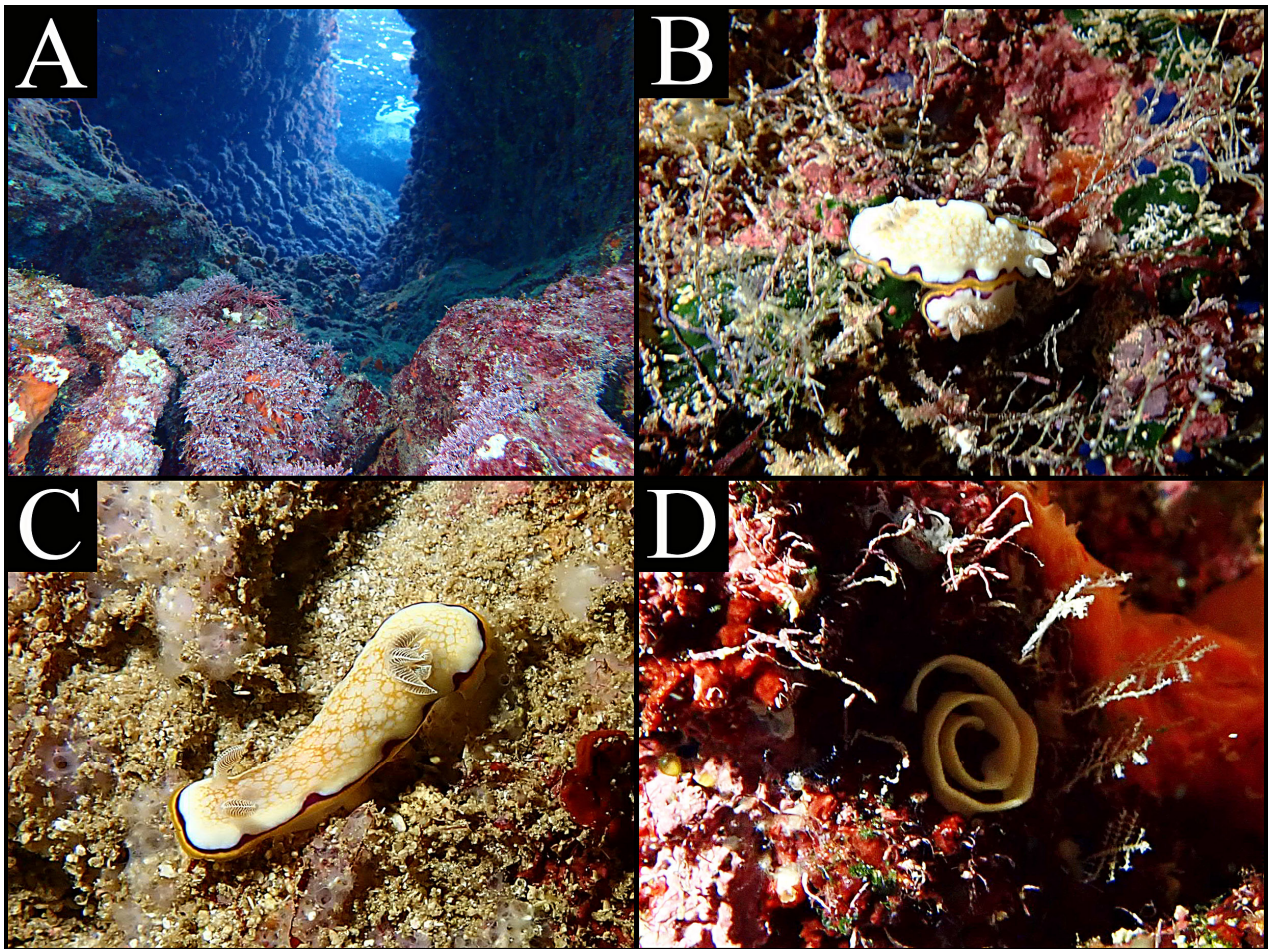


Figure 1. *Goniobranchus obsoletus* (Rüppell and Leuckart, 1830) from Cyprus. A. The submerged cave off Ayia Napa. B, C. The recorded individuals. D. The egg ribbon found in the cave. Photographs: Werner Wolf.

[*Pennaria disticha* Goldfuss, 1820 and *Eudendrium racemosum* (Cavolini, 1785)] (Figure 1B, C). In addition, a yellowish-coloured egg ribbon was also found attached to an adjacent rock (Figure 1D). The photographs were subsequently posted in an online data repository of the iSea's project "Is it Alien to you? Share it!!!" that was established in 2016, in which citizen scientists can easily upload photographic material along with specimen and location information, and may then obtain identification of the posted material by expert taxonomists (<https://isea.com.gr/activities/programs/alien-species/is-it-alien-to-you-share-it/?lang=en>).

Results

Both sea slug specimens were identified by the project's experts as *Goniobranchus obsoletus*, mostly based on their external diagnostic characters (e.g., milky white dorsum with orange reticulations, dorsal margin orange with a thick purple-blue sub-marginal border, rhinophores and gills tinged with brown-orange, translucent white-edged lamellae on both) which clearly distinguish this taxon from the other congeneric species (Yonow 2008). Our bibliographic research revealed that this taxon

was so far only recorded in the Mediterranean Sea off Israel in 2015 (Halevy et al. 2015), and therefore our finding demonstrates the establishment and successful spread of this species in the basin. In addition, according to Nithyanandan (2012), the species is poorly known, mostly found on coral reefs and subtidal rocks in the eastern Arabian peninsula states, and feeds on encrusting sponges. These environmental data are generally in agreement with our shallow-water finding in Cyprus.

On the contrary, the egg ribbon cannot be ascribed with certainty to any species. In fact, Nithyanandan (2012) first illustrated a pale brown coloured egg ribbon which he suspected to belong to *G. obsoletus*, but it is clearly different from that found by us. On the contrary, our egg ribbon is very similar to another one being laid by a *G. obsoletus* specimen in Qatar (Pia 2016). However, direct observations are needed to identify it with certainty.

Discussion

National programmes often face constraints on resources available, and organized frameworks and infrastructures are required to facilitate early detection of NIS. However, citizen-science is widely acknowledged as an effective way to ensure high quality societal engagement while collecting important data and enhancing surveillance of NIS (Ricciardi et al. 2017). Increasingly available innovative reporting and analysing tools, along with the development of social-media and the increased connectivity amongst people, have in fact revolutionized NIS monitoring (Roy et al. 2018).

Noteworthy, for the past two years, the area of Cavo Greco has been monitored under a national scheme using visual census by scientists. After more than 2100 transects ($\times 25$ m) and 450 random photoquadrats during day light in different habitats (i.e., *Posidonia* meadows, and rocky and soft substrates), no new records of alien species have been obtained. On the other hand, several new alien species have been sighted in the past years for the first time from Cyprus based on the volunteered contributions of citizen-scientists. These include the sea slug *Plocamopherus ocellatus* Rüppell and Leuckart, 1828, the crab *Atergatis roseus* (Rüppell, 1830), the fish *Cheilodipterus novemstriatus* (Rüppell, 1838) (Crocetta et al. 2015), the sea urchin *Diadema setosum* (Leske, 1778) (Gerovasileiou et al. 2017), and the sea slug *Haminoea cyanomarginata* Heller and Thompson, 1983 (Yokeş et al. 2018). Similarly, in the present case, *Goniobranchus obsoletus* was first found by a marine enthusiast and not by an expert. Citizen science therefore constitutes a particularly useful and effective tool in meeting the targets of programs that need to monitor large geographical areas with high frequency, such as those dealing with early detection of invasive alien species (Hecker et al. 2018). All these strongly highlight that citizen science should be further promoted by the national and international management authorities.

With regards to the findings of the present study, several species belonging to Chromodorididae Bergh, 1891 are known to occur in the Red Sea (Yonow 2008). Among them, *Goniobranchus annulatus* (Eliot, 1904) already invaded the Mediterranean Sea, and, after its first record in 2000 (Crocetta et al. 2013), it rapidly expanded in the entire eastern Mediterranean, becoming one of the most widespread NIS species of the EU (Cardeccia et al. 2016). The present records of *G. obsoletus* confirm the establishment and spread of this taxon in the Levantine, and suggest that a similar fate may happen with this species.

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References

- Cardeccia A, Marchini A, Occhipinti-Ambrogi A, Galil B, Gollasch S, Minchin D, Narščius A, Olenin S, Ojaveer H (2016) Assessing biological invasions in European Seas: Biological traits of the most widespread non-indigenous species. *Estuarine, Coastal and Shelf Science* 201: 17–28, <https://doi.org/10.1016/j.ecss.2016.02.014>
- Coll M, Piroddi C, Steenbeek J, Kaschner K, Lasram FBR, Aguzzi J, Ballesteros E, Bianchi CN, Corbera J, Dailianis T, Danovaro R, Estrada M, Froglija C, Galil B, Gasol JM, Gertwagen J, Gil J, Guilhaumon F, Kesner-Reyes K, Kitsos MS, Koukouras A, Lampadariou N, Laxamana E, de la Cuadra CML, Lotze HK, Martin D, Mouillot D, Oro D, Raicevich S, Rius-Barile J, Saiz-Salinas JI, San Vicente C, Somot S, Templado J, Turon X, Vafidis D, Villanueva R, Voultsiadou E (2010) The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats. *PLoS ONE* 5: e11842, <https://doi.org/10.1371/journal.pone.0011842>
- Corrales X, Coll M, Ofir E, Piroddi C, Goren M, Edelist D, Heymans JJ, Steenbeek J, Christensen V, Gal G (2017) Hindcasting the dynamics of an Eastern Mediterranean marine ecosystem under the impacts of multiple stressors. *Marine Ecology Progress Series* 580: 17–36, <https://doi.org/10.3354/meps12271>
- Crocetta F, Zibrowius H, Bitar G, Templado J, Oliverio M (2013) Biogeographical homogeneity in the eastern Mediterranean Sea - I: the opisthobranchs (Mollusca: Gastropoda) from Lebanon. *Mediterranean Marine Science* 14: 403–408, <https://doi.org/10.12681/mms.404>
- Crocetta F, Agius D, Balistreri P, Bariche M, Bayhan YK, Çakir M, Ciriaco S, Corsini-Foka M, Deidun A, El Zrelli R, Ergüden D, Evans J, Ghelia M, Giavasi M, Kleitou P, Kondylatos G, Lipej L, Mifsud C, Özvarol Y, Pagano A, Portelli P, Poursanidis D, Rabaoui L, Schembri PJ, Taşkın E, Tiralongo F, Zenetos A (2015) New Mediterranean Biodiversity Records (October 2015). *Mediterranean Marine Science* 16: 682–702, <https://doi.org/10.12681/mms.1477>
- Edelist D, Rilov G, Golani D, Carlton JT, Spanier E (2012) Restructuring the Sea: profound shifts in the world's most invaded marine ecosystem. *Diversity and Distributions* 19: 69–77, <https://doi.org/10.1111/ddi.12002>
- Galil BS, Marchini A, Occhipinti-Ambrogi A (2018a) Mare Nostrum, Mare Quod Invaditur—The History of Bioinvasions in the Mediterranean Sea. In: Queiroz A, Pooley S (eds), *Histories of Bioinvasions in the Mediterranean*. Cham, Springer, pp 21–49, https://doi.org/10.1007/978-3-319-74986-0_2
- Galil BS, Marchini A, Occhipinti-Ambrogi A (2018b) East is east and West is west? Management of marine bioinvasions in the Mediterranean Sea. *Estuarine, Coastal and Shelf Science* 201: 7–16, <https://doi.org/10.1016/j.ecss.2015.12.021>
- Gerovasileiou V, Akel EHKh, Akyol O, Alongi G, Azevedo F, Babali N, Bakiu R, Bariche M, Bennoui A, Castriota L, Chintiroglou CC, Crocetta F, Deidun A, Galinou-Mitsoudi S, Giovos I, Gökoğlu M, Golemaj A, Hadjioannou L, Hartingerova J, Insacco G, Katsanevakis S, Kleitou P, Korun J, Lipej L, Malegue M, Michailidis N, Mouzai Tifoura A, Ovalis P, Petović S, Piraino S, Rizkalla SI, Rousou M, Savva I, Şen H, Spinelli A, Vougioukalou KG, Xharahi E, Zava B, Zenetos A (2017) New Mediterranean Biodiversity Records (July 2017). *Mediterranean Marine Science* 18: 355–384, <https://doi.org/10.12681/mms.13771>
- Hecker S, Haklay M, Bowser A, Makuch Z, Vogel J, Bonn A (2018) *Citizen science: Innovation in Open Science, Society and Policy*. London, UCL Press, 543 pp, <https://doi.org/10.2307/j.ctv550cf2>

- Halevy Y, Barchana D, Twina K, Lavi Y, Zvi E, Rorthman S, Mienis H (2015) First records of *Goniobranchus obsoletus* from the Mediterranean coast of Israel. *Triton* 32: 4–5
- Katsanevakis S, Coll M, Piroddi C, Steenbeek J, Lasram BRF, Zenetos A, Cardoso AC (2014) Invading the Mediterranean Sea: biodiversity patterns shaped by human activities. *Frontiers in Marine Science* 1: 32, <https://doi.org/10.3389/fmars.2014.00032>
- Nithyanandan M (2012) New and rare nudibranch records from Kuwait, Arabian Gulf (Mollusca: Opisthobranchia). *Marine Biodiversity Records* 5: e115, <https://doi.org/10.1017/S1755267212000954>
- Pia A (2016) *G. obsoleta* laying eggs. Nudibranch Central. Available from: <https://www.facebook.com/groups/1488080524784020/permalink/1728017934123610/>
- Ricciardi A, Blackburn TM, Carlton JT, Dick JTA, Hulme PE, Iacarella JC, Jeschke JM, Liebhold AM, Lockwood JL, MacIsaac HJ, Pyšek P, Richardson DM, Ruiz GM, Simberloff D, Sutherland WJ, Wardle DA, Aldridge DC (2017) Invasion science: a horizon scan of emerging challenges and opportunities. *Trends in Ecology & Evolution* 32: 464–474, <https://doi.org/10.1016/j.tree.2017.03.007>
- Roy H, Groom Q, Adriaens T, Agnello G, Antic M, Archambeau A, Bacher S, Bonn A, Brown P, Brundu G, López B, Cleary M, Cogălniceanu D, de Groot M, De Sousa T, Deidun A, Essl F, Fišer Pečnikar Ž, Gazda A, Gervasini E, Glavendekic M, Gigot G, Jelaska S, Jeschke J, Kaminski D, Karachle P, Komives T, Lapin K, Lucy F, Marchante E, Marisavljevic D, Marja R, Martín Torrijos L, Martinou A, Matosevic D, Mifsud C, Motiejūnaitė J, Ojaveer H, Pasalic N, Pekárik L, Per E, Pergl J, Pesic V, Pocock M, Reino L, Ries C, Rozyłowicz L, Schade S, Sigurdsson S, Steinitz O, Stern N, Teofilovski A, Thorsson J, Tomov R, Tricarico E, Trichkova T, Tsiamis K, van Valkenburg J, Vella N, Verbrugge L, Véték G, Villaverde C, Witzell J, Zenetos A, Cardoso A (2018) Increasing understanding of alien species through citizen science (Alien-CSI). *Research Ideas and Outcomes* 4: e31412, <https://doi.org/10.3897/rio.4.e31412>
- Yokeş MB, Andreou V, Bakiu R, Bonanomi, S, Camps J, Christidis G, Crocetta F, Giovos I, Gori A, Juretić T, Karhan SU, Katsanevakis S, Kytinou E, Langeneck J, Lipej L, Maximiadi M, Michailidis N, Mitsou E, Nicolaidou A, Petović S, Prado P, Santín A, Teneketzis K, Thasitis I, Tirelli V, Trkov D, Troplini E, Tsiamis K, Vannucci A (2018) New Mediterranean Biodiversity Records (November 2018). *Mediterranean Marine Science* 19: 673–689, <https://doi.org/10.12681/mms.19386>
- Yonow N (2008) Sea slugs of the Red Sea. Sofia-Moscow, Pensoft, 304 pp
- Zenetos A, Çinar ME, Crocetta F, Golani D, Rosso A, Servello G, Shenkar N, Turon X, Verlaque M (2017) Uncertainties and validation of alien species catalogues: the Mediterranean as an example. *Estuarine, Coastal and Shelf Science* 191: 171–187, <https://doi.org/10.1016/j.ecss.2017.03.031>