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Further spread of the venomous jellyfish *Rhopilema nomadica* Galil, Spannier & Ferguson, 1990 (Rhizostomeae, Rhizostomatidae) in the western Mediterranean

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Abstract

The present paper documents the further spread of the venomous scyphomedusa *Rhopilema nomadica* Galil, Spannier & Ferguson, 1990, which first appeared in the Mediterranean off the Israeli coast in the mid-1970s. This report provides the northernmost and westernmost record of the species in the Mediterranean—from the eastern coast of the Italian island of Sardinia—based on a new record of the species within the Sicily Channel (Aegadian Islands) and provides evidence of its further establishment within Tunisian coastal waters.

Key words: non-indigenous, scyphomedusa, new records, spread

Introduction

Rhopilema nomadica Galil, Spannier & Ferguson, 1990 (Scyphozoa: Rhizostomeae: Rhizostomatidae) is a tropical scyphozoan that purportedly first entered the Mediterranean Sea via the Suez Canal in the late 1970's (Deidun et al. 2011). *Rhopilema nomadica* swarms may have negative impacts on the oligotrophic sea resource (as a planktivorous predator) as well as on human activities in coastal waters, such as aquaculture, fishing and industrial installations and tourism (Galil 2007). *R. nomadica* is venomous and the active toxic substances contained in jellyfish nematocysts inflict painful stings on humans, characterized by erythematous eruptions, itching, and burning sensations, as well as systematic symptoms that include fever, fatigue, and muscular aches (as reviewed in Gusman et al. 1997).

Being labelled as one of the most invasive marine species in the Mediterranean (Streftaris and Zenetos 2006; Zenetos et al. 2010), *R. nomadica* has also been documented as one of the most impacting species in European Seas (Katsanevakis et al. 2014). Ever since its first introduction in the eastern Mediterranean through the Suez Canal in the late 1970's, this Lessepsian newcomer has rapidly expanded westward within the central and western Mediterranean during the past five years. The species was successively recorded from Malta (Deidun et al. 2011), Tunisia (Daly Yahia et al. 2013), the Italian island of Pantelleria (Crocetta et al. 2015), and Sardinia (ICES 2016). While this species had only been occasionally observed in the central and western Mediterranean Sea (only scattered individuals have been recorded), huge swarms have been recorded each summer since the early 1980s along the southeast Levantine coast (Galil et al. 1990).

Scyphozoa outbreaks depend on multiple environment factors during the recruitment stage, such as temperature, light, food quality and quantity,

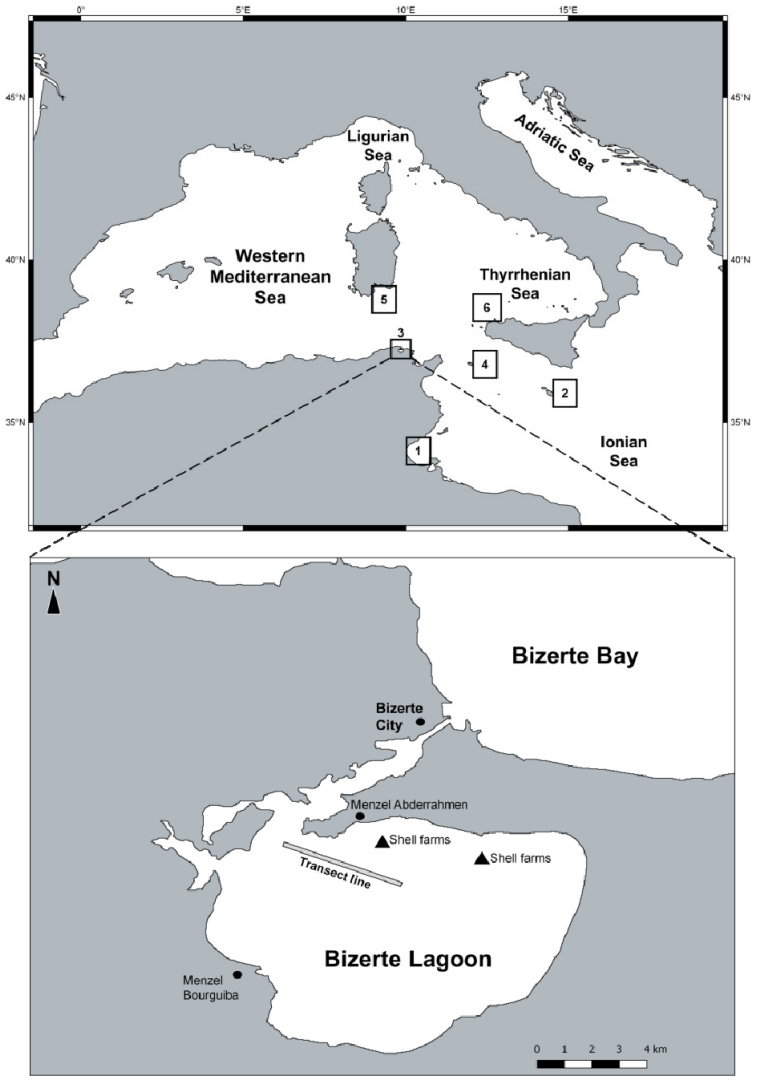

Figure 1. Geographical locations of the central and western Mediterranean sites referred to in this study, arranged in chronological order in terms of year of first sighting of *Rhopilema nomadica*. 1 = Gulf of Gabes, Tunisia (2008); 2 = Maltese Islands (2011); 3 = Bizerte lagoon (2011); 4 = Pantelleria Island (Italy, 2015); 5 = Poetto, Cagliari (Sardinia Island, Italy, 2015); 6 = Levanzo (Aegadian archipelago, Italy, 2016).

and substrate availability (Holst and Jarms 2007; Liu et al. 2009; Purcell et al. 2012; Song et al. 2013; Gambill et al. 2016). For *Rhopilema nomadica*, temperature seems to control the strobilation process (Lotan et al. 1994). Both Deidun et al. (2011) and Daly Yahia et al. (2013) reconstructed the chrono-geonomic map for *Rhopilema nomadica* in the Mediterranean. These maps need to be revised on the basis of findings reported in this study.

Material and methods

In Italy, an informal marine citizen-science campaign is maintained, parallel to more formal initiatives such as Jellywatch (e.g. Boero et al. 2009), along southern Italian shores (Figure 1) by some of the authors (PB, AS). This network operates by keeping regular contact with coastal and marine stakeholders, such as organizers of recreational events and competitions at sea, fishermen, boat owners, and SCUBA divers.

In Tunisia, within the framework of the Tunisian National Program on jellyfish monitoring and the MED-JELLYRISK project (2013–2015; www.jellyrisk.eu), the Laboratory of Aquatic Systems Biodiversity and Functioning of the University of Bizerte conducted jellyfish stranding and outbreaks monitoring in the Bizerte area (north Tunisia; Figure 1). Surveys were conducted monthly to semi-monthly in the Bizerte Lagoon, depending on the weather conditions. For each survey, sea sub-surface (−0.5 m) temperature, and salinity were recorded using

Figure 2. Specimen of *Rhopilema nomadica* from Poetto (Italy). Lower part of mouth arm divided in two triangular flaps, each flap distally tripartite and terminating in claw-like digitate processes (photo: Alessandro Spiga).

a WTW multi-parameter probe (Cond 3110/SET model, Xylem Analytics, Germany). Jellyfish abundance (ind. km^{-2}) was estimated through visual counts of the numbers of jellyfish from a small boat. The boat was run at a constant speed (1.85 km h^{-1}) for a fixed distance (4.54 km) and all medusae observed were counted. Only individuals lying within two meters on either side of the boat bow were counted. Small individuals (bell diameter <15 cm) were sampled by a hand net for taxonomic verification. Vertical net tows using a WP2 net (0.56 m mouth diameter, 200 µm mesh size) were also performed. The net samples were immediately fixed with buffered 4% formalin in sea water and analyzed under a Leica MZ125 stereomicroscope so as to detect the presence of ephyrae.

Results and discussion

On the 26 October 2015, a large specimen of *R. nomadica* (with an umbrella of ~40 cm in diameter, Figure 2) was sighted at the surface at Poetto (Supplementary material Table S1). The specimen, identified through observation and photographic documentation, was recorded during the regattas of the Techno 293 World Windsurfing Championship, with the sea temperature on the day being that of 26 °C. The sighting of this single individual was reported in a local newspaper on 27 October 2015 (http://lanuovasardegna.gelocal.it/cagliari/cronaca/2015/10/27/news/avvistata-nelle-acque-della-sardegna-una-pericolosa-medusa-gigante-del-mar-rosso-1.12340691) and within the non-scientific literature through the ICES Working Group on Introductions and Transfers of Marine Organisms (ICES 2016).

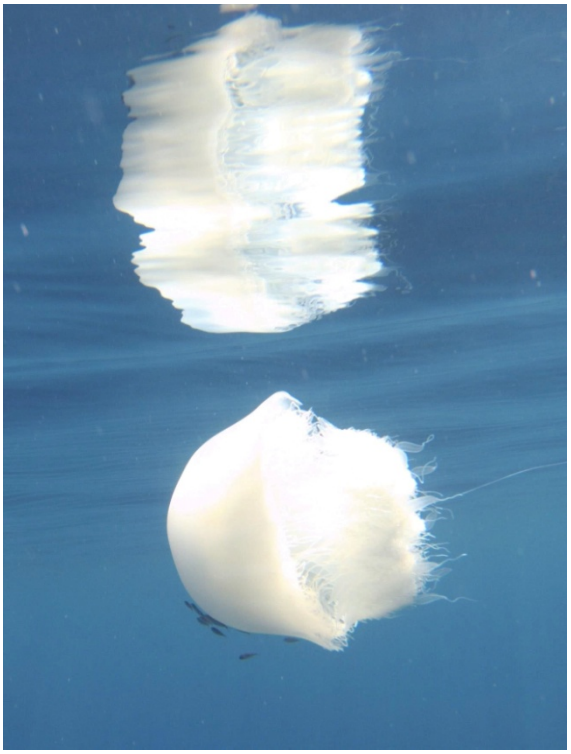

Figure 3. Specimen of *Rhopilema nomadica* spotted at the surface within Cala Minnola on the island of Levanzo within the Aegadian archipelago (photo: Martina Taddei, Egadi Scuba Diving).

On the 22 September 2016, a single *R. nomadica* individual (shown in Figure 3), having an estimated bell diameter of 25 cm, was spotted at the surface within Cala Minnola on the island of Levanzo within the Aegadian archipelago off the western coast of Sicily (Supplementary material Table S1). The water

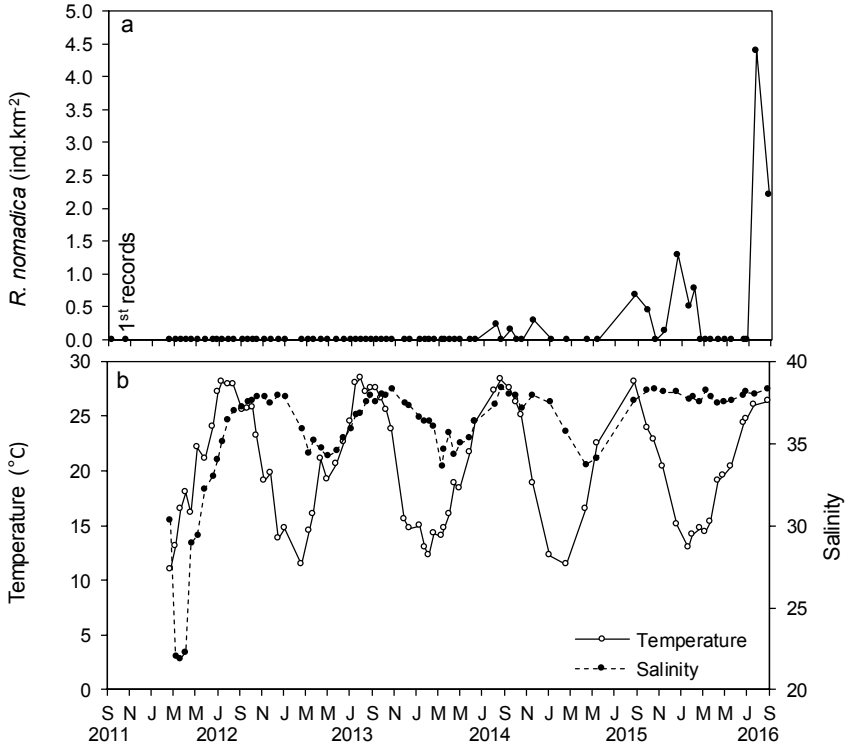

Figure 4. (a) *Rhopilema nomadica* individual abundance in Bizerte Lagoon between 2011 and 2016, along with (b) the variation in sea temperature (°C) and salinity values.

temperature recorded on the day was that of 21–22 °C. This sighting was made by the main SCUBA diving centre within the archipelago (Egadi Scuba Diving, based on the island of Favignana) and was obtained from social media with the owner's permission.

These two new records for Italian waters further support the invasive potential of *R. nomadica* and the hypothesis that the Levantine current has a role in the westward spread of the species in the Mediterranean (Deidun et al. 2011). By crossing over to the western half of the Mediterranean Basin, *Rhopilema nomadica* has joined an increasing list of Lessepsian migrants [e.g. *Lagocephelaus sceleratus* (Gmelin, 1789), *Saurida lessepsianus* Russell, Golani and Tikochinski, 2015, *Sargocentron rubrum* (Forsskal, 1775), *Fistularia commersonii* Ruppell, 1838, *Stephanolepis diaspros* Fraser-Brunner, 1940, *Siganus luridus* (Ruppell, 1829), *Melibe viridis* Kelaart, 1858, *Cassiopea andromeda* Forsskal, 1775 and *Phyllorhiza punctata* von Lendenfeld, 1884] that have managed to breach the Sicily Channel, which has traditionally been viewed as a biogeographical barrier to the spread of such species, restricting them to the eastern half of the Basin (e.g. Quignard and Tommasini 2000). In view of the prevailing patterns of surface-water currents in the central Mediterranean, where the main Atlantic surface current bifurcates into a Tyrrhenian flow spreading northwards in an anti-clockwise fashion along the Italian coast and into a south-bound flow traversing the Sicily Channel (Millot 1987), one can anticipate that further future sightings of *R. nomadica* will be made within the Tyrrhenian Sea, especially along the south-western coast of the Italian peninsula.

Further south, within Tunisian waters, the Jellyfish survey conducted annually in Bizerte Lagoon between 2011 and 2016 showed a marked change over the years in both the occurence period and abundance of *Rhopilema nomadica* individuals, since the first sighting of the species in the Gulf of Gabes in 2008. Prior to the current study, the species was only sporadically recorded along different sections of the Tunisian coast (Daly Yahia et al. 2013). For instance, the species was consistently recorded each summer since 2010 to the date of the Daly Yahia et al. (2013) publication within the Gulf of Tunis, whilst further north along the Tunisian coast, within the Bizerte area, the species was not recorded during the 2012 and 2013 summer seasons after its first record within the same location in September and October 2011 (Figure 4). The latter phenonmenon could be due to a pronounced decrease in water salinity (below 25) recorded within the Bizerte Lagoon at the start of 2012.

Since 2014, *R. nomadica* has been recorded within Bizerte Lagoon during summer. While the occurences were restricted to summer and autumn seasons in 2014 (last recorded specimen during that year was in November 2014), the population recorded during summer 2015 was present until February 2016. In terms of abundance, while *R. nomadica* was sporadically observed in 2014, with individual abundance values ranging between 0.1 and 0.3 ind. km^{-2}, the jellyfish were continuously observed between August 2015 and February 2016 at higher abundance values, ranging from 0.1 to 1.1 ind. km^{-2}. The highest individual abundance within Bizerte Lagoon of *R. nomadica* after 2013 was recorded in July 2016, reaching 4.4 ind. km^{-2}.

It should be noted that no ephyrae of the species were ever identifed in the net samples, while specimens observed during January and February 2016 were all juveniles (bell diameter <10 cm). During the *R. nomadica* occurence period, the water surface temperature ranged from 13 °C (January 2016) to 28.1 °C (August 2015), and the water surface salinity varied from 37 to 38.2.

Since the first records of *Rhopilema nomadica* in the Bizerte area in 2011 (Daly Yahia et al. 2013), its annual occurrence between 2014 and 2016 within the same area as well as the presence of juveniles of the species within the same waters indicate the establishment of a reproducing population. *Rhopilema nomadica* is the third non-indigenous scyphozoan species established in the Bizerte Lagoon with *Phyllorhiza punctata* and *Aurelia solida* Browne, 1905, being previously recorded from the same waters (Gueroun et al. 2014; Gueroun 2016). The late population onset of *R. nomadica* (two years after the first record of the species) may be explained by a possible competition with *Phyllorhiza punctata*, with whom it shares the same occurrence period (summer–autumn). Further investigation is needed to assess the factors that support *Rhopilema nomadica* proliferations as well as its impact on the Bizerte Lagoon trophic resources and on other gelatinous species populations.

It is interesting to note that whilst the occurrence of *R. nomadica* has only been documented through single individuals in the Maltese Islands, Pantelleria, and Sardinia, the species has attained viable populations further west, within Tunisian waters, suggesting that advection is the major driving force behind the dispersal of the vagrant individuals observed along the northern shores of the Sicily Channel. The establishment of a viable *R. nomadica* population within the Bizerte lagoon, as opposed to a more ephemeral occurrence within the other central Mediterranean sites, could be attributable to the peculiarities that such a lagoon environment presents, both in trophic terms (less oligotrophic in nature that the non-lagoon sites) and by virtue of the sheltered nature of the lagoon (compared to the intense hydrodynamism of the non-lagoon sites). This viable population established along the northern extremity of Africa along the entrance to the western basin of the Mediterranean is expected to serve as a springboard for a further westward spread of the species.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Records of *Rhopilema nomadica* in the central and western Mediterranean.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2017/Supplements/BIR_2017_Balistreri_etal_Supplement.xls