

New Additions to the Jellyfish Fauna of the Sea of Marmara

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ABSTRACT

This manuscript reports on four new jellyfish species in the Sea of Marmara (Turkey) (the scyphozoans *Mawia benovici* and *Drymonema dalmatinum*, hydrozoan *Aequorea forskalea*, and thaliacean *Salpa maxima*) based on plankton collections made in the years 2019–2021. This is the first record of *Mawia benovici* in both Turkish coastal areas and the Sea of Marmara. The jellyfish that was previously recorded as *Drymonema* sp. in the repetition Sea of Marmara was identified at the species level as *D. dalmatinum*. Furthermore, their possible introduction pathways are briefly discussed here.

Keywords: *Aequorea forskalea*, *Drymonema dalmatinum*, *Mawia benovici*, *Salpa maxima*, the Sea of Marmara

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INTRODUCTION

The Sea of Marmara is an inland sea that connects the Mediterranean and the Black Seas via the Çanakkale and Istanbul Straits, respectively, and acts as a biogeographical crossroad that includes elements of both Black Sea and Mediterranean Sea biodiversity. The Sea of Marmara is characterized by a permanent, two-layered water system because of the distinct characteristics of two adjacent basins. The upper layer (on average, <25 m depth) consists of brackish Black Sea water (~18 psu) while the lower layer (below the halocline) consists of saline Mediterranean water (~38 psu) (Beşiktepe, Sur, Özsoy, Latif, & Oğuz, 1994). As a consequence of its geographical and hydrographical properties, it forms a barrier and/or a corridor depending on species' potential to acclimatize (Beşiktepe et al., 1994; Ozturk & Ozturk, 1996).

Recent studies of new species demonstrated that the number of jellyfish in the Sea of Marmara has been rising (Isinibilir, Yilmaz, & Demirel, 2015; Isinibilir, Yüksel, & Dalyan, 2020; Yilmaz,

Isinibilir, Vardar, & Dursun, 2017). *Mnemiopsis leidyi* caused major harm to the ecosystem after it expanded its niche to the Sea of Marmara following its introduction to the Black Sea at the end of 1980 (Isinibilir, Tarkan, & Kideys, 2004; Shiganova, 1998). Ever since, non-indigenous jellyfish species such as *Chrysaora hysoscella*, *Liriope tetraphylla*, *Aequorea vitrina*, *Cotylorhiza tuberculata*, and others have been introduced to the basin (İnanmaz, Bekbolet, & Kideys, 2002; Isinibilir, Yilmaz, & Piraino, 2010; İsinibilir et al., 2020; Yilmaz et al., 2017). In general, jellyfish are important consumers of zooplankton in pelagic ecosystems, although their ecological role is still poorly understood (Lucas, Gelcich, & Uye, 2014). This report aims to contribute to the knowledge of the changing diversity of jellyfish in the Sea of Marmara by presenting the first records of four gelatinous taxa belonging to the classes Hydrozoa, Scyphozoa, and Thaliacea.

MATERIALS AND METHODS

The samples of *Aequorea forskalea* and *Mawia benovici* were collected through deep trawling



during cruises by R/V Yunus-S in the southern and northeastern part of the Sea of Marmara during July 2019 and June 2020. The samples of *Salpa maxima* were collected through scuba diving, with the collaboration of local divers, in the vicinity of the Princes' Islands in the Sea of Marmara in November 2020. The sample of *Drymonema dalmatinum* from the Maltepe coast was caught in large plastic buckets with the help of local fishermen and transported to the faculty laboratory in January 2021. The location of the sampling stations is shown in Figure 1. Specimens were fixed in 96% ethanol solution for the subsequent analysis. Identification of specimens was carried out under stereomicroscope and light microscope in the laboratory. Samples were taken from all species for molecular analysis and stored in the faculty laboratory for further analysis. In this report, DNA barcoding from a single scyphozoan species, namely *Mawia benovici*, was carried out.

The species identity of specimens of *Mawia benovici* was also confirmed by a DNA-barcoding approach using the cytochrome oxidase subunit I (COI) mitochondrial marker. DNA was extracted using Qiagen DNeasy Blood & Tissue Kits, according to the manufacturer's handbook. Partial COI sequences were amplified by polymerase chain reaction (PCR), setting the parameters as in Furfaro, Oliverio, and Mariottini (2017) (PCR profile: 5 min denaturation step at 94°C; 35 cycles of 94°C/30 s, 48°C/60 s, 72°C/60 s; 7 min. final extension at 72°C), using the universal primers LCO1490 and HCO2198 (Folmer, Black, Hoeh, Lutz, & Vrijenhoek, 1994). Amplicons were sequenced by the European Division of Macrogen Inc. (Amsterdam, The Netherlands). A BLASTN (Altschul, Gish, Miller, Myers, & Lipman, 1990) search was conducted to rule out sample contamination. Sequence homology was investigated by comparing newly produced sequences with the ones already available in GenBank.

RESULTS AND DISCUSSION

In the present study, three jellyfish species (one scyphozoan, one hydrozoan, and one thaliacean) were reported for the first time and the genus *Drymonema* was identified at the species level in the Sea of Marmara (Figure 1). Bouillon et al. (2004), Van Soest (1974), and Piraino et al. (2014) have been used as the primary sources for taxonomic identification and description of characteristics of the species. Notes related to their spatial distribution are reported below.

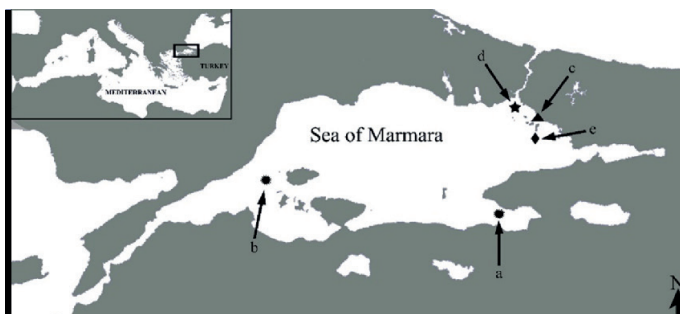


Figure 1. Map of the Sea of Marmara and sampling locations of the specimens (a, b: *Mawia benovici*; c: *Drymonema dalmatinum*; d: *Aequorea forskalea*; e: *Salpa maxima*).

Class: Scyphozoa
Subclass: Discomedusae
Order: Semaestomeae
Family: Pelagiidae
Genus: *Mawia*

Mawia benovici (Piraino, Aglieri, Scorrano & Boero, 2014)

Mawia benovici specimens were collected as bycatch during trawl surveys from 71 m (st. MD22, Figure 1, Station a) and 108 m (st. MD13A, Figure 1, Station b). In the survey, four living specimens were collected. The first specimen was observed on November 2, 2019 at the MD22 station (Figure 1, Station a) and the other three specimens on November 3, 2019 at the MD13A station (Figure 1, Station b). The umbrella diameters ranged from 60 to 70 mm and were hemispherical to somewhat flattened with a thin transparent mesogleal layer. The exumbrella was yellow ochre in color and was covered by conspicuous cnidocyst warts; eight marginal tentacles; 16 marginal lappets; 16 unbranched, simple radial septa terminating between sense organs and tentacles, as in the genus *Pelagia*; and 8 tentacular and 8 rhopalial separate pouches. The manubrium had a whitish, transparent, very short mouth tube and sharp, long, delicate mouth arms. The gonads were milky white in color, horseshoe shaped, and developed on the subumbrellar surface (Figure 2A, B).

Mawia benovici (formerly described *Pelagia benovici*) was recorded in several locations, such as the northern Adriatic (Trieste to Chioggia (Venice)), the Central Adriatic (near Numana, Ancona), and the Ionian Sea (Igoumenitsa Bay) (Avian, Ramšak, Tirelli, D'ambra, & Malej, 2016; Chartosia et al., 2018; Piraino et al., 2014) in the Mediterranean. However, it has not been recorded in the eastern part of the Mediterranean so far. This species, which

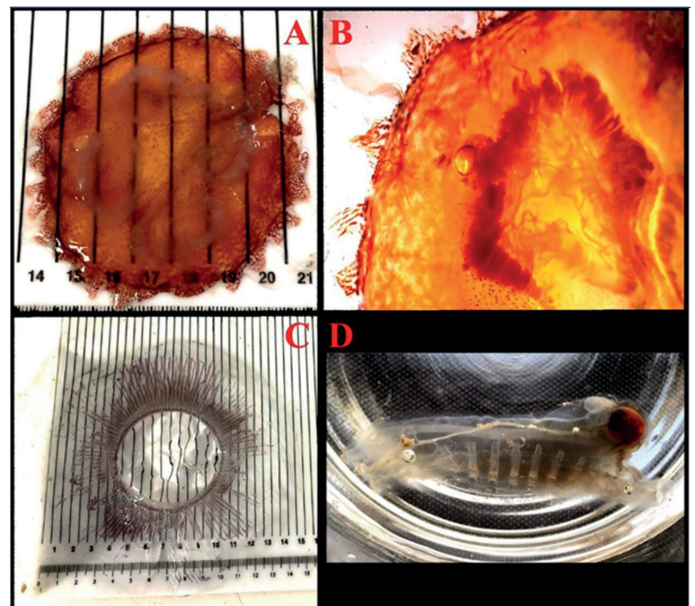


Figure 2. Photographs of the new jellyfish records in the Sea of Marmara. (A) and (B) *Mawia benovici*; (C) *Aequorea forskalea*; (D) *Salpa maxima*.

is assumed to be non-indigenous to the Mediterranean, has also been recorded on the coast of Senegal (Bayha, Collins, & Gaffney, 2017). According to Bayha et al. 2017, the species which was found in the Mediterranean might have originated from the western coast of Africa and been introduced as a result of commercial shipping or fishing. As suggested by Piraino et al. (2014), this species was probably introduced into the Adriatic Sea by ship translocation through ballast waters.

Little information is still available concerning the establishment of *M. benovici* in the Adriatic Sea and, more generally, in the Mediterranean basin. DNA sequences (GenBank COI accession numbers OU193096 and OU193097) were obtained from two specimens collected at the MD13A station (Figure 1, Station b). DNA barcoding analysis revealed 100% of homology with COI sequences already present in GenBank and ascribed to *Mawia benovici* (in GenBank as *Pelagia benovici*), definitively confirming that the two collected specimens belong to this rare species. As a result, this is the first record of the species in both Turkish coastal areas and the Sea of Marmara.

Class: Scyphozoa
Subclass: Discomedusae
Order: Semaestomeae
Family: Cyaneidae
Genus: *Drymonema*

***Drymonema dalmatinum* Haeckel, 1880**

The large-sized semaestome jellyfish *Drymonema dalmatinum* has recently been reported in various regions of the Mediterranean, especially the Adriatic Sea. Earlier records of *Drymonema dalmatinum* (the only *Drymonema* species in the Mediterranean Sea) go back to 1892 in the Gulf of Izmir (Antipa, 1892). This genus was recorded without species identification for the first time in the Sea of Marmara as *Drymonema sp.* in 2020 (Öztürk, 2020). One year later, the occurrence of *D. dalmatinum* was reported in a fishermen's observation on January 18, 2021 on the Maltepe coast in the northeastern Sea of Marmara (Figure 1, Station c). The jellyfish was found near the sea surface, with a bell diameter of approximately 120 cm. The orientation of the umbrella was upwards; the bell was milkfish white, shield-shaped, and flatly rounded with a thicker central part (Figure 3). The numerous tentacles were longer

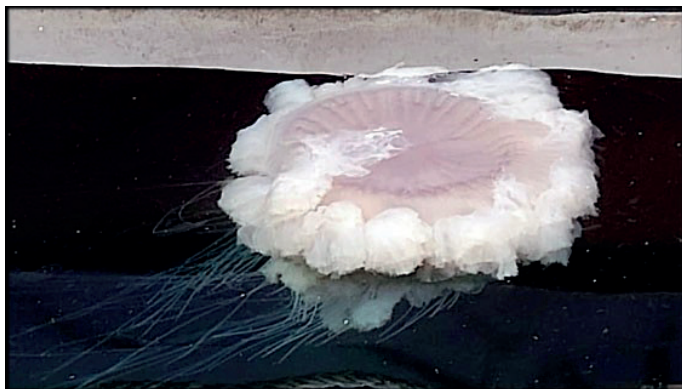


Figure 3. *Drymonema dalmatinum* in the Sea of Marmara.

than the diameter of the bell and of unequal lengths and thickness, and were not grouped in separated clusters.

Class: Hydrozoa
Subclass: Hydroidolina
Order: Leptothecata
Family: Aequoreidae
Genus: *Aequorea*

***Aequorea forskalea* Péron & Lesueur, 1810**

Although *Aequorea forskalea* is a common and abundant hydro-medusan species in the Mediterranean (Bouillon et al., 2004) and has been recorded in Turkish coastal areas (Gürlek, Yağlıoğlu, Ergüden, & Turan, 2013; Topcu, Martell, & İsinibilir, 2017), it was not encountered in zooplankton samples from the Sea of Marmara before the present study. Two specimens were first sampled in June 2020 from the lower layer of the northeastern Sea of Marmara (off the coast of Tuzla; sampling depth 80m) (Figure 1, Station d). The umbrella was large, up to 140 mm wide, saucer shaped, and thick in the center. It had 120 simple and dark colored radial canals and 120 tentacles. The medusa had tube-shaped tentacle bulbs (Figure 2C). In the coastal waters of Turkey, four species of *Aequorea* have been reported: *Aequorea forskalea* (Péron & Lesueur, 1810), *Aequorea globosa* (Eschscholtz, 1829), *Aequorea pensilis*, and *Aequorea vitrina* (Gosse, 1853) (Gürlek et al., 2013; Onmuş, Bakir, & Katağan, 2016; Topcu et al., 2017; Turan, Gürlek, Yağlıoğlu, & Seyhan, 2011; Yılmaz et al., 2017). In the Mediterranean, *A. forskalea* is distributed in the eastern and western Mediterranean, including the Adriatic and Aegean Seas (Bouillon et al., 2004; Topcu et al., 2017; Yılmaz & İsinibilir, 2016). So far, no records of *A. forskalea* were available from the Sea of Marmara (Yılmaz et al., 2017).

Class: Thaliacea
Order: Salpida
Family: Salpidae
Subfamily: Salpinae
Genus: *Salpa*

***Salpa maxima* Forskål, 1775**

Although *Salpa maxima* is known as a common species in the Mediterranean Sea (Durgham & İkhtiyar, 2013; Mutlu, 2005; Peinert & Miquel, 1994; Topcu et al., 2017), it had not been recorded in the Sea of Marmara before. Many colonies of *S. maxima* have been observed and one of them was sampled through scuba diving, with the collaboration of local divers in the vicinity of the Princes' Islands in the Sea of Marmara (Figure 1, Station e). The solitary forms have an 8 cm length with a smooth body with shallow longitudinal depressions. Because of its extreme thickness, the appearance is not completely transparent. There are a total of nine muscles along the dorsal side of the body. The colonies were impressively long (Figure 4), reaching up to 2 m in length, and were seen by fishermen and scuba divers.

Because of its geographical and hydrological characteristics, the Sea of Marmara is a vulnerable ecosystem. This eutrophic sea is

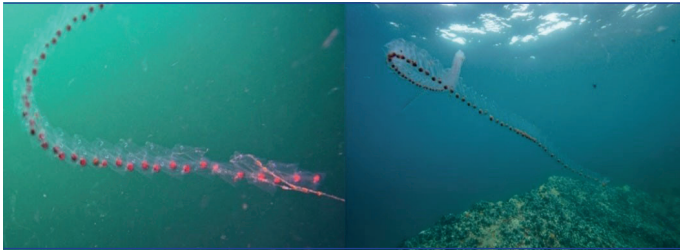


Figure 4. Chains of *Salpa maxima* in the waters of the Princes' Islands (Photograph: İsmail Cem Odabaşı).

Turkey's second commercially important fishing ground (Yılmaz, Akay, & Gümüş, 2008). As a result, any increase in jellyfish populations could have negative consequences for fisheries (İsinibilir & Yılmaz, 2016). With its unique properties, the Sea of Marmara also serves as a barrier and/or transitional acclimatization zone for biological organisms. Shipping and currents are two potential routes for jellyfish introduction in this Sea. Salps can feed on all sizes of phytoplankton, from viruses to protists, thus being in direct competition with crustaceans (Bone, 1998). Therefore, bloom of *Salpa maxima* may cause depletion of phytoplankton and adversely impact the food web (Boero, 2013). The presence of *Aequorea forskalea* in Turkish coastal waters may be related to its migration from the western Mediterranean, where it is common. *Aequorea forskalea* prey mainly on copepods and amphipods (Zavolokin, Glebov, & Kosenok, 2008), hence the bloom of this jellyfish may threaten commercially important fish stocks through food competition.

Mawia benovici could have been transported via ballast waters from the Mediterranean Sea or introduced through the lower layer flow of the Çanakkale Strait, because it already existed in the Mediterranean Sea. The life cycle of this species is still unknown. However, the medusa can reproduce by fission, a common asexual reproduction method in cnidarians (Chartosia et al., 2018). For this reason, the possible effect of its invasion is still unclear, and monitoring is necessary to understand the ecological consequences.

On the other hand, the Sea of Marmara, besides acting as a transition zone between the Black Sea and the Mediterranean, has important ports and most of them are located in the northeastern part. All species except *M. benovici* were recorded for the first time in the vicinity of Istanbul, thus suggesting the arrival of these species through ships' ballast waters. However, higher prey availability in the upper layer of the northeastern part of the Sea of Marmara may also have been an important factor in the availability of this species.

CONCLUSION

Recent studies have demonstrated that the environmental changes caused by intensive anthropogenic activity (e.g. eutrophication, overfishing, translocations, habitat modification, coastal development, etc.) and climate change due to global warming increase jellyfish blooms all over the world (Dong, Liu, & Keesing, 2010; Purcell, Uye, & Lo, 2007; Richardson, Bakun, Hays, & Gibbons, 2009). Overfishing may also result in increased jellyfish populations due to the removal of jellyfish predators and competitors.

As the Sea of Marmara has a long history of overfishing (Zengin & Mutlu, 2000), the potential effects on jellyfish populations cannot be ignored. Other human activities can also influence jellyfish populations. Similar to the effects of eutrophication, increased coastal urban development may ultimately lead to more jellyfish due to an increase in prey and substrate for the establishment of their polyps (Brotz & Pauly, 2012). Warning signs of ecological deterioration such as algae blooms, marine mucilage events, and jellyfish blooms have increased significantly in the Sea of Marmara in recent years (İsinibilir, 2012; İşinibilir-Okyar, Üstün, & Orun, 2015; Turkoglu, 2013; Yılmaz, 2014). In addition, the number of jellyfish species recorded from the Sea of Marmara increased in the last decades and is still increasing (İnanmaz et al., 2002; İsinibilir et al., 2010; İsinibilir et al., 2020; Yılmaz et al., 2017). The rise of new jellyfish species might represent a future threat for the region by switching available trophic resources from zooplankton to unfavorable jellyfish biomass, thus eventually affecting fisheries and triggering changes in the functioning of the pelagic food web. Intensive and continuous monitoring of the Sea of Marmara is recommended in order to obtain updated information and predict the ecological effects of jellyfish on marine coastal ecosystems.

Conflicts of interest: The authors have no conflicts of interest to declare.

Ethics committee approval: The authors declare that this study does not include any experiments with human or animal subjects.

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