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Rapid Communication

Back with a bang – an unexpected massive bloom of *Cassiopea andromeda* (Forskaal, 1775) in the Maltese Islands, nine years after its first appearance

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Abstract

The upside-down jellyfish—*Cassiopea andromeda* (Forsskål, 1775)—is considered an established alien within the eastern Mediterranean Sea, but the species exhibits a highly sporadic occurrence further west within the basin. This study reports the second documented bloom of the species within coastal waters in the Maltese Islands and the third bloom of the species in the westernmost part of the eastern Mediterranean, a full nine years after its first appearance in this part of the Mediterranean.

Key words: jellyfish, non-indigenous species, Lessepsian migrant, eastern Mediterranean

Introduction

Cassiopea andromeda (Forsskål, 1775) was one of the first Levantine species to be recorded from the Mediterranean since the opening of the Suez Canal in 1869, being just one of at least six non-indigenous scyphozoan species known to date from the Mediterranean basin [together with *Rhopilema nomadica* Galil, 1990; *Phyllorhiza punctata* Lendenfeld, 1884; *Marivagia stellata* Galil and Gershwin, 2010; *Cotylorhiza erythraea* Stiasny, 1920 and *Pelagia benovici* Piraino et al., 2014 also alternatively represented as *Mawia benovici* (Avian et al. 2016)]. Its native range extends throughout most of the Red Sea and the Indian Ocean (Mariottini and Pane 2010).

Keller (1888) first reported *C. andromeda* from waters within the Suez Canal and from adjoining lagoons south of Lake Timsah in 1886, whilst the first Mediterranean record for the species was made in Cyprus by Maas (1903). Since then, this scyphozoan species has colonised extensive swathes of the Levantine Basin and Aegean Sea, and is considered an invasive species (Katsanevakis 2011) probably by virtue of its ability to form large blooms numbering in the hundreds of individuals within a short temporal scale. For example, Zenetos et al. (2011) reported a maximum density of 20 individuals/m^2 within blooms around the Greek island of Paros in the Aegean Sea.

Within the central and western Mediterranean, *C. andromeda* has been less successful in spreading, and the only records are from Malta (Schembri et al. 2010) and northern Tunisia (Amor et al. 2016). A recent publication (Cillari et al. 2018) reported the occurrence of two specimens found in 2014 in the harbour of Palermo (Sicily), which has since resulted in an established population. Here, we report the second published record of *C. andromeda* from Maltese waters and document the third massive outbreak within the westernmost eastern Mediterranean.

Material and methods

The Salini Nature Reserve, designated by Malta within the Natura 2000 network as a Special Area of Conservation (SAC), is a bird sanctuary and home to the country's largest salt marsh habitat. The reserve,

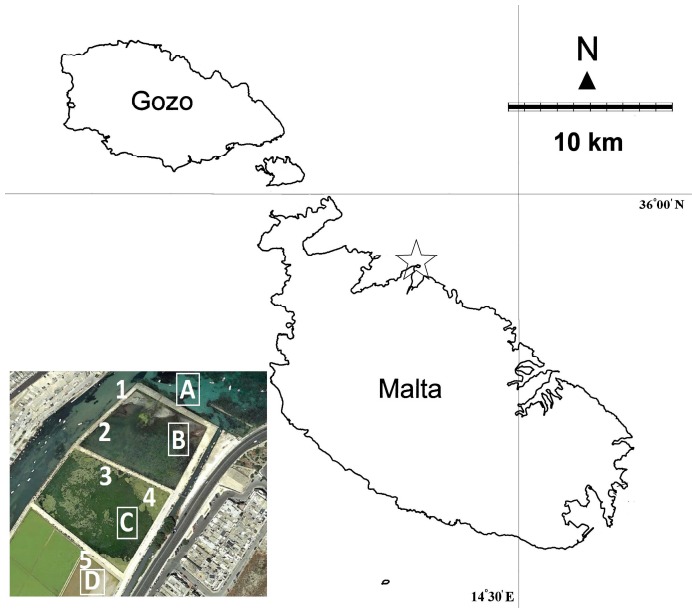

Figure 1. Map of the Maltese Islands indicating (denoted by a star) the coastal location of the Salini Nature Reserve. Inset: zoomed in aerial photograph of the outermost extent of the reserve, indicating open sea ("A"), the outermost water reservoirs/salt pans ("B" and "C") where *Cassiopea andromeda* specimens were recorded, and the smaller water reservoirs further inland ("D"). Also shown are the locations ("1"–"5") where water physico-chemical measurements were made. Source: Google Earth.

Table 1. Physico-chemical parameter values for water sampled within different Salini Nature Reserve sampling stations.

Sampling station reference (Figure 1)	Geographical coordinates	Distance from mouth/open water – m	Location within Salini Reserve	% oxygen saturation	Salinity	Temp / °C
1	35.949083ºN, 14.424198ºE	0	A	90.16	38.72	14.49
2	35.948264ºN, 14.423719ºE	100	B	86.68	39.06	13.49
3	35.947889ºN, 14.423900ºE	125	C	86.82	39.26	13.40
4	35.947660ºN, 14.424642ºE	150	C	86.04	38.93	13.36
5	35.946992ºN, 14.423763ºE	225	D	89.63	79.99	13.36

located along the north-east coast of Malta (Figure 1 – coordinates of centre-point of reserve: 35.947161ºN; 14.423619ºE), consists of a number of salt-harvesting pans along the eastern flank dating back to the time of the Knights of St. John (i.e. seventeenth century). On the western flank, a 40 m-wide channel is connected to the open sea and flushes the salt marsh with freshwater during the rainy season. The northernmost two salt pans, situated closest to the connection with the open sea, are also the largest, measuring over 10,000 m^2 each, whilst contiguous salt pans further within the nature reserve are considerably smaller (Figure 1). The innermost extremities of the seawater channel are colonised by halophytic vegetation and flanked by an afforested recreational area.

On the 9th of January 2018, two observers, who were wardens within the Salini Nature Reserve, observed a large bloom of *Cassiopea andromeda* within the outermost extremity of the reserve and submitted a report to the Spot the Jellyfish citizen science campaign (campaign online portal: www.ioikids.net/jellyfish). This online reporting system allows citizens to document the occurrence of indigenous and non-indigenous gelatinous species (e.g. *Rhopilema nomadica* – Deidun et al. 2011) within Maltese waters. Further observations were also made to characterise water physico-chemical parameters (i.e., oxygen % saturation, salinity, pH, temperature) through the use of a hand-held CTD instrument (YSI EXO2 model) which was deployed on site just two days after the first sighting of the bloom.

Results

The bloom, which consisted of an estimated 800 jellyfish individuals, was restricted to the two outermost large reservoirs/salt pans within the reserve, closest to the open sea (Figure 1).

Values for the water physico-chemical parameters measured *in situ* are summarised in Table 1. The diameter of *Cassiopea andromeda* individuals recorded on site ranged between 2 cm and 10 cm, with a marked chromatic difference observed between the bell of younger (< 3 cm diameter) *C. andromeda* stages, which was largely blue in colour, and that of older (> 3 cm diameter) stages, which assumed a dark yellow

Figure 2. Different aspects of the *Cassiopea andromeda* bloom recorded at the Salini Nature Reserve in January 2018. Individuals with a bell diameter < 3cm were blue in colour, with a progressively darker yellow coloration with increasing bell diameter (Photos: AS, NM).

colour (Figure 2). Approximately 15% of *C. andromeda* individuals had a small (10 mm diameter) pore-like opening running from the top of the bell to the opening of the mouth (Figure 3).

No other areas besides the outermost water reservoirs within the Salini Nature Reserve contained *C. andromeda* individuals; the main water channel and innermost reservoirs were totally devoid of the species. A large (> 300 individuals) concomitant bloom of early (< 2 cm diameter) stages of the native jellyfish *Pelagia noctiluca* was, however, observed within the main water channel. The bottom of the two outermost water reservoirs was covered by very fine sand, with water depth within the same reservoirs ranging between 0.5 m and 1.0 m.

Discussion and Conclusions

Here, we report only the second occurrence of the non-native jellyfish *Cassiopea andromeda* in Maltese waters and a third massive outbreak of this species in the westernmost eastern Mediterranean Sea. Another non-indigenous gelatinous species of Lessepsian origin—*Phyllorhiza puncata*—was reported in autumn 2016 within the outermost reservoirs of the Salini Nature Reserve and nearshore waters just off the reserve (Deidun et al. 2017). This might suggest that the Salini Nature Reserve supports the establishment of non-indigenous marine species of tropical origin by virtue of its unique aquatic physico-chemical characteristics (e.g. relatively high salinitiies) and sheltered conditions.

Figure 3. *Cassiopea andromeda* individuals exhibiting a small (10 mm diameter) pore-like opening running from the top of the bell to the opening of the mouth (Photos: AS).

The occurrence of *C. andromeda* over a wide size range (2–10 cm) in the Salini Nature Reserve may be indicative of a repeated introduction event rather than a single episode, assuming that medusa diameter is an indication of individual age. Straehler-Pohl and Jarms (2010) report a mean total ephyra diameter of 0.379 cm for *C. andromeda*, confirming that all the individuals of the species recorded within the current study were adult medusae. As reported by Widmer (2008), "*Cassiopea* sp. jellyfish are prime candidates for accidental introduction as a non-native species in places where they do not belong. They are very prolific, and you will shortly find polyps in the reservoir and any other system that it is connected with the reservoir." Moreover, Bolton and Graham (2006) documented the occurrence of *Cassiopea* spp. polyps on live rocks imported to the USA from Indo-Pacific reefs and highlighted the international trade in aquarium live rocks as a vector for jellyfish introductions as these rocks are not subject to quarantine restrictions. In this respect, it is worth noting that a tropical live aquaria holding *C. andromeda* individuals, along with two other species, were put on public display at the Malta National Aquarium in autumn 2017. The Aquarium is one kilometre from the Salini Nature Reserve and is proximal to the sea, although it deploys a water re-circulation system (Figure 4). The embayment at Salini is exposed to north-easterly winds, and water located near the Aquarium is hydrodynamically connected with the inner salt pans (Figure 4). Sea surface current values, obtained through the Mediterranean Forecasting System available within COPERNICUS, suggest that these currents generally move north to south, thus

Figure 4. Aerial photograph showing the close proximity between the Salini Nature Reserve and the Malta National Aquarium, which holds rearing tanks for *Cassiopea andromeda*.

propelling any surface propagules discharged from the Aquarium towards the Salini embayment (Copernicus 2018).

One might also speculate that *C. andromeda* propagules entering the Salini system completed their development within the outermost reservoirs due to specific environmental conditions there. Given the photosymbiotic relationship *C. andromeda* has with zooxanthellae hosted in its oral arms and subumbrellar tissues, the species has a preference for warm, well-lit waters in shallow, sheltered environments, typically with soft muddy or sandy substrates (Schembri et al. 2010), which occur in the two outermost reservoirs at Salini. The high salinity values (between 38.72 and 39.26 for the areas where the species was recorded) could have favoured an *in situ* blooming event or, at least, in case the bloom originated elsewhere, supported the persistence of the observed adult individuals within the reservoirs. No jellyfish individuals were recorded within the smaller water reservoirs (denoted by "5" in Figure 1), almost certainly due to the anomalously high salinity values (79.99) recorded there which could putatively have acted as a salinity barrier. There are no literature records, in fact, of *C. andromeda* persisting at such high water salinity values.

The recorded temperature values in the outermost reservoirs (from 13.36 °C to 14.49 °C) are not considered conducive for a bloom of a thermophilic species as *C. andromeda*. Hofmann et al. (1978), in fact, report that water temperature is the most important variable in controlling the onset of strobilation and that this process was not demonstrated by polyps reared in laboratory conditions until the water temperature reached 24 °C ± 1 °C. This may substantiate the hypothesis that polyp strobilation and production of ephyrae may have occurred at a nearby warmer habitat, such as the Aquarium, rather than at distant locations with consequent transportation of propagules through advection. However, nearshore waters off Salini shelter a number of recreational vessels, which are possibly another vector for the introduction of *C. andromeda* to this region. Therefore, further analyses will be required to conclusively determine the origin of *C. andromeda* jellyfish observed at Salini.

The largest specimens (Figure 3) were found pierced on upper side of the umbrella and devoid of gonads, damage similar to selective predation by the Mediterranean bogue *Boops boops* on *Pelagia noctiluca* gonads (Milisenda et al. 2014). However, the damaged jellyfish specimens were still vital, apparently undergoing regeneration of the umbrella. Since this part of the jellyfish is in direct contact with the seabed, predation by organisms other than fish (e.g., nudibranchs, polychaetes, crabs) might be possible. There was no additional damage due to abrasion or water movement, as the Salini reservoirs are highly sheltered basins.

This is the first record of *C. andromeda* within Maltese waters since 2009, possibly due to a dearth of shallow, well-lit, sheltered sandy seabed environments, considered the preferred habitat for the species, within the Maltese Islands. The species is, in fact, commonly sighted in the Indo-Pacific within shallow sandflats, lagoons and mangroves (Çevik et al. 2006). The first record of the species from Maltese waters was, in fact, made within a harbour environment (Marsamxett Harbour), at water depths ranging between 3.5 m and 6.0 m (Schembri et al. 2010). It is interesting to note that just 50 individuals of the species were recorded in 2009, markedly less than the 800 individuals reported within the current study.

The considerable hiatus between successive occurrences of *C. andromeda* within a particular area has been corroborated by other authors. For instance, Nicolaidou et al. (2012) reported an estimated 300 live individuals of *C. andromeda* within tidepools along a rocky coastline on a small islet off the north-eastern coast of Rhodes, but none in the surrounding waters (similar to findings within the current study). They explained the interesting finding through a combination of isolation of the individuals from the surrounding area and a consequent increase in water temperature. This is not the case in our study, given that no water temperature anomalies were recorded during the blooming event.

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