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First record and potential trophic impact of *Phyllorhiza punctata* (Cnidaria: Scyphozoa) along the north Tunisian coast (South Western Mediterranean Sea)

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Abstract
The Australian spotted scyphomedusa *Phyllorhiza punctata* was recorded for the first time in Tunisian waters in August 2012, in the lagoon of Bizerte (Tunisia). Metaephyrae and juveniles occurred simultaneously in August 2012. The occurrence of adult medusae was detected from September to November 2012, and from August to October 2013. This is the second record of a reproducing population of *P. punctata* in the Mediterranean Sea. The low abundance of mesozooplankton in summer and autumn 2012 coincides temporally with the highest density of *P. punctata* recorded in the lagoon, suggesting that predation by this alien jellyfish may have been a limiting factor for the mesozooplankton abundance on site.

Keywords: *Non-indigenous species, jellyfish predation, mesozooplankton, Tunisian coasts, Mediterranean Sea*

Introduction

The white spotted Australian jellyfish *Phyllorhiza punctata* von Lendenfeld, 1884 is native to the south-western Pacific (Graham et al. 2003), from Australia to Japan (Heeger et al. 1992). Since the mid-20th century, reports of expansion of its distribution range have increased all over the world, including southern USA (California – Cariton & Geller 1993), Mexico (Garcia 1990; Ocaña-Luna et al. 2010), and the Pacific (Larson & Arnesson 1990) and Atlantic oceans (reviewed in Mianzan & Cornelius 1999). Single or scattered individuals of *P. punctata* have been recorded in the Mediterranean Sea since 1965 along the Israeli coast (Galil et al. 1990), whereas the first established reproducing population was documented in 2005 and 2006 in Vlyho Bay, Greece (Abed-Navandi & Kikinger 2007).

We report here evidence of the first breeding population of *P. punctata* in the western Mediterranean basin. Its potential impact on the mesozooplankton community has been investigated.

Materials and methods

Within the framework of the Tunisian National Program on Jellyfish monitoring launched by the Laboratory of Aquatic Systems Biodiversity and Functioning in 2001 and the ENPI–CBCMED (European Neighbourhood and Partnership Instrument–Cross-Border Coopoeration in the Mediterranean) project MED-JELLYRISK 2012–2015 (http://www.jellyrisk.eu), several coastal zones (Bizerte, Sousse and Monastir) were selected for monitoring jellyfish strandings and outbreaks.

Study area

Bizerte lagoon (120 km^2) is located to the south of Bizerte, along the northern coast of Tunisia. The

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average depth is 7.0 m (maximum depth is 12.0 m). Water exchange between the lagoon and the sea occurs through a single channel (8.5 km long).

Sampling

Medusae were counted using a standard line-transect method, with the transect extending between the following coordinates: N 37°13'31.35", E 9°48'53.33" and N 37°12'22.22", E 9°51'1.35". The observations were carried out from both sides of a boat for a distance of 4 km such that, effectively, a 2-m-wide belt transect was adopted. Metaephyrae and small juveniles were collected with an oblique net haul (700 µm mesh size equipped with a flowmeter, net diameter: 0.75 m). Tows were performed at a speed of 1 knot for 5 min during the daytime. Mesozooplankton was sampled by vertical WP2 net hauls (200 µm mesh size, net diameter: 0.56 m) and immediately preserved in buffered 4% formaldehyde/seawater solution to determine the composition and the abundance of such a community.

Surface sea temperature and salinity values of the lagoon were measured using a multiprobe WTW, Cond 3110/SET model.

Results

The first *Phyllorhiza punctata* specimens (one metaephyra and two small juveniles with bell diameters of 0.9 cm and 5 cm, respectively) were recorded on 15 August 2012 in Bizerte lagoon through net hauls. The white warts on the exumbrella and the elongation and bifurcation of the oral arms confirmed their taxonomic identification as *P. punctata* specimens. Adult medusae (Figure 1) of the species were observed from September 2012 to November 2012, with densities ranging from 4 to 10 individuals (ind.) 1000 m^{-3}. In 2012, a total of 1428 adults of the species were observed along the 4 km transect. In 2013, only six large adults (mean bell diameter approaching 40 cm) were observed within Bizerte lagoon between August and October, with low abundances of up to 1 ind. 1000 m^{-3}. In 2012, the *P. punctata* observed population included specimens with both a brownish and a dark blue bell, while in 2013, only brownish individuals were observed.

The annual water temperature in Bizerte Lagoon varied between 11°C in February 2012 and 28°C ± 0.1°C in July 2012, and between 11.4°C in February 2013 and 27.5°C in July 2013. The lagoon salinity values ranged between 22 ± 0.05 psu in March 2012 and 37.9 psu in December 2012 and between 34.4 ± 0.2 psu in May 2013 and 37.5 psu in September 2013 (Figure 2).

Copepods, cladocerans, appendicularia and mollusc larvae were the principal taxonomic composition of mesozooplankton within Bizerte lagoon during the study period. Mesozooplankton abundance varied between a minimum of 351 ind. m^{-3} in August 2012 and a maximum of 7619 ± 4880 ind. m^{-3} in September 2013 (Figure 3).

Mesozooplankton abundance showed a noticeable decrease during summer 2012, particularly in August 2012, when the abundance did not exceed 351 ind. m^{-3}. This decline coincided with the period of recruitment and high abundance of *P. punctata*. Mesozooplankton abundance remained low during the occurrence of *P. punctata* and then increased after the drop in medusa abundance. Mesozooplankton populations showed a higher abundance in summer 2013, when *P. punctata* abundances were low.

Discussion

Phyllorhiza punctata is a jellyfish native to the tropical western Pacific (Graham et al. 2003). The pattern and chronology of its entry into and spread within

Figure 1. *Phyllorhiza punctata* in Bizerte lagoon in September 2012 (left; photo by C. LAFABRIE) and on 27 September 2013 (right; photo by S.K.M. GUEROUN).

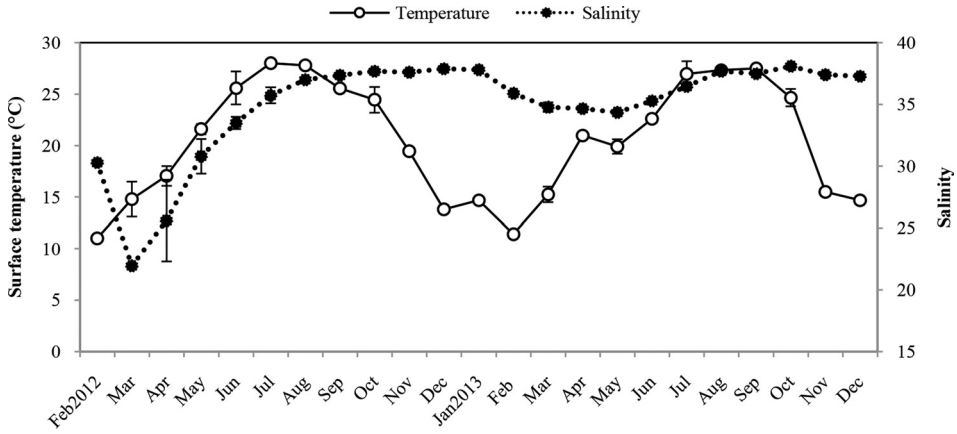

Figure 2. Sea surface temperature and salinity in Bizerte Lagoon between 2012 and 2013.

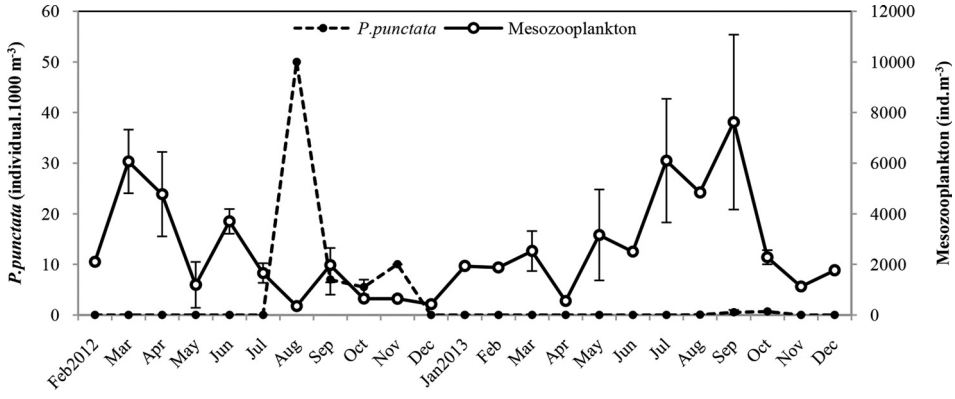

Figure 3. *Phyllorhiza punctata* and mesozooplankton abundance in Bizerte lagoon between 2012 and 2013.

the Mediterranean Sea are not very clear. The first record of the species within the Mediterranean was made along the Israeli coast in 1965 by Galil et al. (1990). Then, following a long temporal gap, the following subsequent records of the same species were made within the Mediterranean: 2009 in Greece, Italy and Israel (Abed-Navandi & Kikinger 2007; Boero et al. 2009; Galil et al. 2009), 2010 and 2011 in Turkey (Cevik et al. 2011; Gülşahin & Tarkan 2012) and 2011 in Syria (Durgham 2011). The *P. punctata* population in Bizerte lagoon represents the highest adult density ever recorded for the species in the Mediterranean, as 1428 adults were observed along only a 4-km transect, between September and November 2012. Previously, a single aggregation of more than 50 adult specimens was recorded in the Igoumenitsa harbour (Ionian Sea) (Abed-Navandi & Kikinger 2007). Galil et al. (1990) suggested that the white-spotted jellyfish may have entered the Mediterranean Sea either via the Suez Canal, or been transported into the Mediterranean Sea via vessels, as opposed to a drift entry into the Basin. In fact, shipping traffic is thought to be a primary vector for marine invasions worldwide (Bolton & Graham 2004). Indeed, the life history of *P. punctata* includes a sessile polypoid stage, and the introduction of this species in the Mediterranean might have been easily mediated through the translocation of polyps, as a component of the hull-dwelling communities of ships, rather than through medusa-stage transport (Galil et al. 2009). The harbour of Bizerte is subject to substantial oil-related and other commercial activities (Hazelton et al. 2001) with an average transit of 500 vessels each year, which supports the hypothesis of a ship-mediated mode of introduction of *P. punctata* polyps into the Bizerte lagoon.

P. punctata is the third alien jellyfish species to be recorded along the Tunisian coast in recent years, following the occasional record of *Stomolophus meleagris* L. Agassiz, 1862 (Daly Yahia et al. 2003) and the recent extension of the distribution range of *Rhopilema nomadica* Galil, 1990 (Daly Yahia et al. 2013). Little is known about the Mediterranean life

cycle of *P. punctata*. Potentially, this species might be present also along other North African coastal waters, to the east of Tunisia (e.g. off Libya), where jellyfish species may largely go undetected as a result of a lack of adequate studies within these waters.

A single record of a reproducing population of *P. punctata* in the Mediterranean Sea has been previously reported in Vlyho Bay along the Greek coast (Abed-Navandi & Kikinger 2007). The occurrence of metaephyrae and juveniles in 2012 and of a new generation in 2013 at Bizerte lagoon suggests that *P. punctata* has established a breeding population also in the western Mediterranean Sea. The observation of metaephyrae and juveniles of the species in August 2012 and, since September 2012, of adults is symptomatic of recruitment of *P. punctata* individuals within Bizerte lagoon. The presence of mussel farms in Bizerte lagoon may provide potential substrates for polyp fixation.

P. punctata densities displayed interannual variability in the lagoon of Bizerte, being significantly more abundant ($p \leq 0.001$) in 2012 than in 2013. For a tropical species such as *P. punctata*, low water temperature and low salinity may be limiting factors to polyp budding and strobilation. Water temperature measurements made during the February–June period indicated that water temperature was warmer in 2012 (18.8 ± 4.5°C) than in 2013 (17.9 ± 4°C), and higher water temperature might favour *P. punctata* strobilation. The same pattern was observed along the coast of the state of Georgia in the US during 2007 and 2008, when the *P. punctata* population was more abundant during the years characterized by higher water temperatures (Verity et al. 2011). Paradoxically, the average surface salinity recorded in the same period in 2012 (28.2 ± 4.7 psu) was lower than in 2013 (34.9 ± 4.0 psu). Rippingale and Kelly (1995) suggested that the polyps of *P. punctata* might survive through the low-salinity period in the high-salinity refuge of deeper water. The presence of *Aurelia* sp. jellyfish in July 2013, with an abundance of 0.1 ind. m^{-3}, (Gueroun et al. unpublished data) and its absence since May in 2012 might also explain the difference in *P. punctata* abundance over the 2 years. *Aurelia* sp. might limit the recruitment of *P. punctata* ephyrae either as a competitor for zooplankton or as direct predator of *P. punctata* ephyrae. Even if *Aurelia* sp. rarely feed on other jellyfish, Purcell (1991) reported interspecific predation commonly occurs among scyphozoan medusae.

The life history of *P. punctata* within Vlyho Bay in Greece was characterized by strobilation in September (Abed-Navandi & Kikinger 2007). We assume that in 2012, *P. punctata* within Bizerte lagoon underwent strobilation in July and early August since juveniles were already found in mid-August. In 2013, strobilation may have occurred even earlier (June–July) than in the previous year, since 40-cm specimens (bell diameter) were recorded in August 2013.

Phyllorhiza punctata has a relatively mild sting potential and therefore it may represent a limited danger for tourism (Graham et al. 2003). However, high densities of jellyfish may have negative impacts on other human activities in coastal waters, such as aquaculture, fishing and industrial installations (e.g. by clogging the water intake of cooling systems) (Burnett 2001; Graham & Bayha 2007; Purcell et al. 2007; Boero 2013). The occurrence of *P. punctata* adults within Bizerte lagoon caused some economic losses for local fishermen (pers. comm. with local fishermen) by dirtying and clogging fishing nets.

Phyllorhiza punctata, like most tropical rhizostomae scyphomedusae (e.g. *Cassiopea* spp., *Mastigias* spp.), associates with algal endosymbiotic (zooxanthelleae) which contribute to the nutritional requirements of the jellyfish species (Garcia & Durbin 1993) through the direct transfer of algal photosynthates (Hofmann & Kremer 1981) to the host. This symbiosis gives *P. punctata* its brownish colour. In Bizerte Lagoon, dark-blue-coloured *P. punctata* specimens were observed, similar to the morphotypes recorded in Laguna Joyunda, Puerto Rico (Bolton & Graham 2004). These specimens lack zooxanthelleae and may completely depend on a zooplanktivorous diet to meet their nutritional needs.

Phyllorhiza punctata jellyfish mostly feed on larval bivalves, adult copepods, fish eggs and loricate tintinnids (Graham et al. 2003) in Lake Borgne (Louisiana, USA). The copepod *Acartia tonsa* represents the dominant prey of *P. punctata* in Laguna Joyuda (Puerto Rico), where its prey clearance rates may have a potentially negative impact on zooplankton population abundances (García & Durbin 1993). However, the direct effect of *P. punctata* predation may not fully account for the large decrease in zooplankton abundance observed in summer 2012 in Bizerte Lagoon. Graham et al. (2003) suggested that *P. punctata* may change the chemical or physical properties of the water by releasing concentrated mucus and nematocysts that may affect zooplankton growth and impinge on copepod reproduction. Further investigation is needed to assess whether the white-spotted jellyfish may induce significant changes in the biological water quality to impact the mesozooplankton of the Bizerte lagoon.

The occurrence and apparent spread of *P. punctata* in Bizerte Lagoon represents a new case of alien jellyfish introduction in the southwestern Mediterranean

Sea. Climate change, environmental modification and increasing shipping traffic generally enhance non-indigenous species introduction and establishment, leading to new, unexpected discoveries even in highly investigated areas (Piraino et al. 2014). This phenomenon will probably increase in the future and will have even more insidious economic and environmental repercussions (Galil et al. 2014).

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