BioInvasions Records (2015) Volume 4, Issue 2: 97–102
doi: http://dx.doi.org/10.3391/bir.2015.4.2.05

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Rapid Communication

The invasive caprellid *Caprella scaura* Templeton, 1836 (Crustacea: Amphipoda: Caprellidae) arrives on Madeira Island, Portugal

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Received: 19 December 2014 / Accepted: 11 February 2015 / Published online: 21 February 2015

Handling editor: Vadim Panov

Abstract

A survey to monitor for marine non-indigenous species in two marinas of the Archipelago of Madeira (Portugal) has detected the invasive caprellid *Caprella scaura* Templeton, 1836 in Madeira Island. This species was first described from Mauritius in the western Indian Ocean. During the 20th century, *Caprella scaura* has been detected in numerous locations worldwide (Australia, California, Mediterranean) and most recently reported in southern Europe and northern Africa. Hull fouling was the most likely vector for the introduction of *C. scaura* to Madeira Island.

Key words: first record, non-indigenous species (NIS), hull fouling, marinas, Madeira Island

Introduction

The spread of non-indigenous species (NIS) via global maritime network is still today an inevitable occurrence and represents a great threat to coastal marine ecosystems worldwide (Clarke Murray et al. 2014). The arrival of these NIS into new regions is mainly caused by transport in ships ballast tanks and as hull fouling (Ruiz et al. 2000; Kaluza et al. 2010).

In Madeira Island, located in the north-eastern Atlantic, several NIS have been detected in recent years, particularly in marinas (e.g. Wirtz and Canning-Clode 2009; Canning-Clode et al. 2013; Ramalhosa et al. 2014). Most of these NIS are bryozoans, tunicates, or polychaetes and seem to have been introduced to the island via hull fouling (Canning-Clode et al. 2013).

Caprellid amphipods (commonly known as skeleton shrimps) are small marine crustaceans that are present in many coastal habitats. Caprellids feed mainly on detritus, and thus have an important role in the trophic link between primary producers and higher trophic levels (Woods 2009; Ros et al. 2013). Caprellids have reduced appendages on the abdomen and lack planktonic larval stage and, as a result, the cosmopolitan distribution of these small animals is often explained by their association with fouling communities on floating objects and as hull-fouling on vessels (Thiel et al. 2003; Ros et al. 2013).

The caprellid amphipod *Caprella scaura* was first described in 1836 (Templeton, 1836) as a native species to the western Indian Ocean. The species was described from individuals collected in Mauritius (Rivière Noire); however, its true origin remains unknown (Carlton and Eldredge 2009). *Caprella scaura* was later reported in several ´forms´ from many areas around the globe (Mayer 1890, 1903; McCain 1968; Krapp et al. 2006). *C. scaura* [*sensu lato*] has been described as having a vast geographic distribution with established populations in the mid-latitudes to the tropics in both northern and southern hemispheres, which thus includes all oceans with the exception of the Arctic (Krapp et al. 2006; Ros

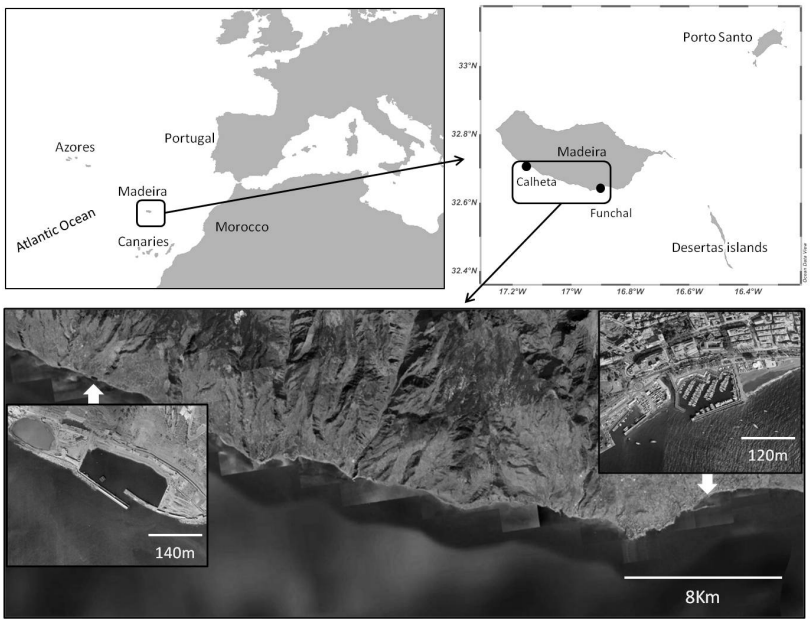

Figure 1. Map of Madeira Island indicating the two marina locations where samples were collected.

et al. 2014; Cabezas et al. 2014). A recent study (Cabezas et al. 2014) provides molecular evidence that the various 'forms' of *C. scaura* represent three distinctive species: *C. scaura*, *C. californica* Stimpson, 1856 and *C. scauroides*. In addition, Cabezas et al. 2014 also suggest that *C. scaura typica* and *C. scaura scaura* correspond to the same subspecies while *C. scaura spinirostris* and *C. scaura diceros* could merit species rank.

Recently, Ros et al. (2014) performed a comprehensive survey searching for *C. scaura* populations in 94 marinas: 88 along the Iberian Peninsula coast and North Africa in 2011, and an additional 6 marinas in the Mediterranean during 2012. *Caprella scaura* was detected in 31 marinas and some of these findings represented first records, particularly those in Corsica (France), Crete (Greece) and Morocco (Ros et al. 2014). Furthermore, *Caprella scaura* was present in 14 marinas along the Mediterranean coast of the Iberian Peninsula and in 10 marinas on the Atlantic coast. In addition, their study also revealed the absence of *Caprella scaura* in the north Atlantic coast of Spain and suggests an upper distribution limit on the eastern Atlantic coast at Cascais, Portugal. *Caprella scaura* was most frequently associated with bryozoans such as *Bugula neritina* (Linnaeus, 1758), *Zoobotryon verticillatum* (Delle Chiaje, 1822), and *Tricellaria inopinata* d'Hondt and Occhipini Ambrogi, 1985 (Ros et al. 2014; Cabezas et al. 2014).

This study represents the first record of the invasive caprellid *Caprella scaura* for Madeira Island, north-eastern Atlantic Ocean.

Methods

We have been investigating the identity and abundance of fouling assemblages in Madeira Island since 2006 (Canning-Clode et al. 2008, 2009, 2013) by deploying settling plates in marinas. In July 2010, we deployed 10 polyvinylchloride (PVC) settling plates (14 × 14 × 0.3 cm) at approximately 1-meter depth from pontoons at the marina of Calheta (32°43'N, 17°10'W) (Figure 1). Another set of 10 plates was deployed in the marina of Funchal (32°38'N, 16°54'W) (Figure 1) in June 2014 (see Ramalhosa et al. 2014). Settling plates were collected for fouling species identification in August 2013 for Calheta samples, and in November 2014 for Funchal samples. Samples collected from both marinas were preserved in 95% ethanol for later species determination. Specimens were examined with the aid of a stereomicroscope (Leica Wild-M3 Heerbrugg), and digital photographs were taken using a Sony DSC-W55 camera. The identification of specimens was based on the morphological description presented by Krapp et al. (2006), Martínez and Adarraga (2008) and Minchin et al. (2012). Body length of specimens of *Caprella scaura* was determined with the image software CPCe (Kohler and Gill 2006).

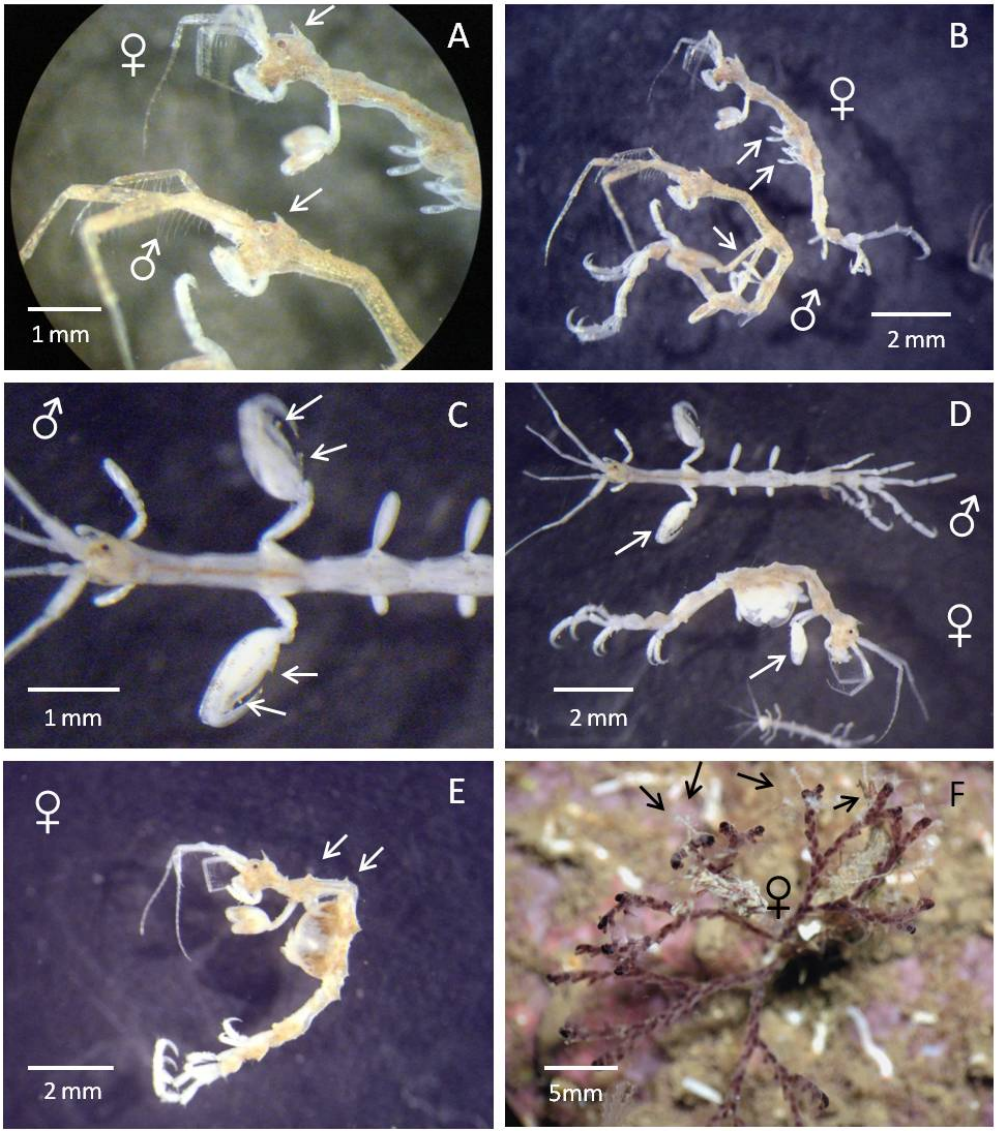

Figure 2. Specimens of *Caprella scaura* from marina of Funchal (A-B) and marina of Calheta (C-F). Morphology aspects: (A) adult male and female with occipital projection on the head, dorsal view; (B) gills of adult male and female, entire animal, dorsal view, male 8.3mm and female 5.7mm; (C) gnathopod of adult male with two strong teeth, dorsal view; (D) gnathopods of adult male, dorsal view and from ovigerous female, lateral view, male 6.1mm and female 6.5mm; (E) largest ovigerous female with developed knobs on pereonites, lateral view, 8.2mm; (F) adult female with juveniles (pointed with black arrows) associated with the bryozoan *Bugula neritina*. All of the white-coloured arrows point to the prominent characters characteristic of this species. Photographs by P. Ramalhosa.

Results

Specimens of *Caprella scaura* were collected on settling plates from both marinas. Specimens of both sexes presented the distinctive characteristic of the occipital projection on the head (Figure 2A). The gills in both males and females had an elliptical shape but were shorter and less elongated in females (Figure 2B). Male specimens exhibited an elongated propodus of gnathopod, palms with proximal spine with two strong teeth (Figure 2C). Female specimens had a less elongated propodus of gnathopod (Figure 2D), palms with proximal spine and distal tooth (present but not visible in figures). Additionally, females showed developed knobs on pereonites (Figure 2E). All specimens collected were associated with the erect bryozoan *Bugula neritina* (Figure 2F).

Table 1. List of *Caprella scaura* body lengths (mm) / Mean ± SD collected in different regions and their seasonality.

Country	Collected site	Date	Sex	N	Body length (mm) / Mean ± SD	Reference
South Carolina, USA	Charleston	February 2002	Male	30	18	Foster et al. 2004
			Female	15	8	
South Carolina, USA	Charleston	July 2002	Male	21	10	Foster et al. 2004
			Female	5	5	
Spain	Chipiona	December 2009	Male	35	11.8 ± 3.7	Guerra-Garcia et al. 2011
			Female	35	7.4 ± 0.6	
Spain	Cádiz	June 2009	Male	35	5.2 ± 2.6	Guerra-Garcia et al. 2011
			Female	35	5.4 ± 0.8	
Canary islands, Spain	Tenerife	May 2009	Male	35	9.6 ± 3.9	Guerra-Garcia et al. 2011
			Female	35	7.5 ± 0.8	
Canary islands, Spain	Lanzarote	March 2012	Male	9	7.1 - 16.1	Minchin et al. 2012
			Female	9	4.9 - 8.7	
Madeira, Portugal	Calheta	August 2013	Male	1	6.1	This paper
			Female	4	6.5 - 8.2	
			Juveniles	20	< 2	
Madeira, Portugal	Funchal	November 2014	Male	1	8.3	This paper
			Female	2	4.4 - 5.7	

The specimens examined from Calheta included 1 male with a body length of 6.1mm (Figure 2C and D), 4 ovigerous females with body lengths from 6.5 to 8.2mm (Figures 2D, 2E and 2F) and 20 juveniles with body length less than 2mm (Figure 2D and 2F). Specimens from Funchal included 1 male with body length of 8.3mm and 2 females with 4.4mm and 5.7mm (Figure 2A and 2B). The measurements of *C. scaura* body lengths described herein were from head to the last part of pereonite 7 - we did not include the lengths of the antennae.

All specimens of *Caprella scaura* collected from marina of Calheta (n = 25) and marina of Funchal (n = 3) were deposited at the Museu Municipal (História Natural) in Funchal, Madeira, as vouchers MMF44289 and MMF44290, respectively.

Discussion

This study represented the first record of the invasive caprellid *Caprella scaura* for Madeira Island. *Caprella scaura* seems to be already established in Madeiran waters, as we collected four ovigerous females and some juveniles.

The sample size in this study was too small to evaluate whether there is a difference in maximum body length between male and females; however, the body lengths observed (Table 1) were within range of the ones recently found in Lanzarote, Canary Islands (Minchin et al. 2012). In a separate study, Guerra-García et al. 2011 showed males were larger than females at two sites and about the same size in a third while males were noticeably larger in two samples from a site in North America (Foster et al. 2004). Some of the largest specimens are reported by McCain (1968) with males of 21 mm and females of 12 mm. Foster et al. (2004) suggested that size differences may be a seasonal effect because males during winter were larger than those observed during summer months in coastal waters of South Carolina. These differences may be attributable in part to a decrease in predation pressure and reduced reproductive activity during colder months (Guerra-García et al. 2011).

The true original range of *Caprella scaura* remains unknown (Carlton and Eldredge 2009), and it often occurs with other non-native species associated with fouling communities; e.g., the bryozoan *Bugula neritina* (Ros et al. 2013; Ros et al. 2014; this study). This bryozoan is noteworthy because shows tolerance to heavy metals such as copper and zinc that compose several antifouling paints, which allows it to attach to ship hulls (Piola and Johnston 2006; Canning-Clode et al. 2011); consequently, it is often associated with epifaunal communities transported among marinas by recreational vessels, or other floating structures and buoys (Astudillo et al. 2009).

Caprella scaura was first described in Mauritius, Indian Ocean (Templeton in 1836), but its potential native range subsequently increased, as it was also found in Brazil in 1838 (Dana 1853), Australia

in 1890 (Mayer 1890), Caribbean Sea in 1866, and Japan in 1903 (Mayer 1903). Given its broad range, *C. scaura* could not be classified as native or non-native in any of these regions, and was therefore considered a cryptogenic species (unknown origin) (Carlton 1996).

During the last decades *Caprella scaura* has extended its non-native distribution: to Hawaii in 1996 (Coles et al. 1999); to the Caribbean Sea, Florida Gulf coast, and South Carolina in 1998 (Foster et al. 2004); and to western Australia and Tasmania from 1978–1993 (seen here with questionable status) (Guerra-García and Takeuchi 2003; 2004). In 1994, *C. scaura* was first detected in the Mediterranean Sea in the Lagoon of Venice, Italy (Sconfietti and Danesi 1996; Mizzan 1999) and then spread widely around the Mediterranean and south-eastern Atlantic Regions (Krapp et al. 2006; Martínez and Adarraga 2008; Guerra-García et al. 2011; Minchin et al. 2012; Ros et al. 2014). The main vector of introduction to the Mediterranean is thought to be hull fouling on ships and recreational vessels, most likely coming from the Indian Ocean through the Suez Canal (Sconfietti and Danesi 1996; Cabezas et al. 2014). Secondarily, C*aprella scaura* could have been dispersed to other regions from ships' ballast water, fish cage movements, and as hull fouling (Krapp et al. 2006; Martínez and Adarraga 2008; Guerra-García et al. 2011; Minchin et al. 2012; Ros et al. 2014).

To better understand the invasion history of *Caprella scaura* to the Iberian peninsula, direct sequencing of mitochondrial DNA was used by Cabezas et al. 2014 to compare genetic composition in native and introduced populations. Their data suggests that Iberian populations could have originated from the Pacific Australian and Indian Ocean populations, passed through Suez Canal and was either transported directly or, more likely, there was a series of stepping-stone events from central Mediterranean populations (Cabezas et al. 2014).

In the Madeira Archipelago, only few studies have been conducted to investigate amphipods (Stock and Abreu 1992; Stock, 1993; 1994), most of which are from freshwater and poikilohaline waters. To the best of our knowledge, only one study has reported the presence of a *Caprella* species (Fonseca et al. 1995) in Porto Santo. The results of this study indicate systematic surveys to evaluate the marine amphipod fauna are warranted.

Hull fouling seems to be the most likely vector for the introduction of *Caprella scaura* in Madeiran waters, as it was found in two marinas of the Madeira archipelago, one of them located inside the main harbour of the island. Moreover, the close proximity of Madeira Islands to the Canary Islands, eastern regions of Morocco, Portugal, and the Mediterranean Sea, and the high maritime recreational traffic arriving from those neighbouring regions, are evidence in support of this hypothesis.

Acknowledgements

We thank A. Marchini at the University of Pavia, Italy for confirming the identification of *Caprella scaura.* We wish to thank the administration of the two marinas used for this study (Porto Recreio da Calheta, and the Marina do Funchal). Financial support of P. Ramalhosa was provided by ARDITI - Agência Regional para o Desenvolvimento da Investigação Tecnologia e Inovação. J. Canning-Clode was supported by a starting grant in the framework of the 2014 FCT Investigator Programme (IF/01606/2014). We further thank three anonymous reviewers for their valuable comments that improved the manuscript. This is contribution number 28 of Marine Biology Station of Funchal.

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