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

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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...
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 Ambrogli, 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 stereo-microscope (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).
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          |
| South Carolina, USA | Charleston | July 2002      | Male | 21 | 10 | Foster et al. 2004          |
| Spain | Chipiona | December 2009   | Male | 35 | 11.8 ± 3.7 | Guerra-Garcia et al. 2011 |
| Spain | Cádiz | June 2009       | Male | 35 | 7.4 ± 0.6 | Guerra-Garcia et al. 2011 |
| Canary islands, Spain | Tenerife | May 2009       | Male | 35 | 5.2 ± 2.6 | Guerra-Garcia et al. 2011 |
| Canary islands, Spain | Lanzarote | March 2012     | Male | 9  | 7.1 - 16.1 | Minchin et al. 2012 |
| Madeira, Portugal | Calheta | August 2012    | Male | 1  | 6.1 | This paper                  |
| Madeira, Portugal | Funchal | November 2014  | Male | 1  | 8.3  | This paper                  |

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-Garcia 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-Garcia 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 (see 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 (Sconfitti and Danesi 1996; Mizzan 1999) and then spread widely around the Mediterranean and south-eastern Atlantic Regions (Krapp et al. 2006; Martinez 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 (Sconfitti and Danesi 1996; Cabezas et al. 2014). Secondly, *Caprella scaura* could have been dispersed to other regions from ships’ ballast water, fish cage movements, and as hull fouling (Krapp et al. 2006; Martinez 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.

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References

Austadillo JC, Bravo M, Dumont CP, Thiel M (2009) Detached aquaculture buoys in the SE Pacific: potential dispersal vehicles for associated organisms. *Aquatic Biology* 5: 219–231, http://dx.doi.org/10.3354/ab00151

Cabezas MP, Xavier R, Branco M, Santos AM, Guerra-García JM (2014) Invasion history of *Caprella scaura* Templeton, 1836 (Amphipoda: Caprellidae) in the Iberian Peninsula: Multiple introductions revealed by mitochondrial sequence data. *Biological Invasions* 16: 2221–2245, http://dx.doi.org/10.1007/s10530-014-0660-y

Canning-Clode J, Kaufmann M, Molis M, Lenz M, Wahl M (2008) Influence of disturbance and nutrient enrichment on early successional fouling communities in an oligotrophic marine system. *Marine Ecology: an Evolutionary Perspective* 29: 115–124, http://dx.doi.org/10.1111/j.1439-4856.2007.00210.x

Canning-Clode J, Bellou N, Kaufmann MJ, Wahl M (2009) Local-regular richness relationship in fouling assemblages – effects of succession. *Basic and Applied Ecology* 10: 745–753, http://dx.doi.org/10.1016/j.baae.2009.05.005

Canning-Clode J, Fofonoff P, Riedel GF, Torchin M, Ruiz GM (2011) The effects of copper pollution on fouling assemblage diversity: a tropical-temperate comparison. *Plos ONE* 6(3): e18026, http://dx.doi.org/10.1371/journal.pone.0018026

Canning-Clode J, Fofonoff P, McCann L, Carlton JT, Ruiz G (2013) Marine invasions on a subtropical island: Fouling studies and new records in a recent marina on Madeira Island (Eastern Atlantic Ocean). *Aquatic Invasions* 8: 261–270, http://dx.doi.org/10.3391/ai.2013.8.3.02

Carlton JT (1996) Biological invasions and cryptogenic species. *Ecology* 77: 1653–1655, http://www.jstor.org/stable/2265767

Carlton JT, Eldredge LG (2009) Marine Bio-invasions of Hawaii: The introduced and cryptogenic marine and estuarine animals and plants of the Hawaiian archipelago. *Bishop Museum Bulletin in Cultural and Environmental Studies* 4: 1–203

Clarke Murray C, Gartner H, Gregr EJ, Chan K, Pakhomov E, Therriault TW (2014) Spatial distribution of marine invasive species: environmental, demographic and vector drivers. *Diversity and Distributions* 20: 824–836, http://onlinelibrary.wiley.com/doi/10.1111/ddi.12215/pdf
Coles SL, DeFelice R, Eldredge L, Carlton J (1999) Historical and recent introductions of non-indigenous marine species into Pearl Harbor, Oahu, Hawaiian Islands. Marine Biology 135: 147–158, http://link.springer.com/article/10.1007/s002270050612#page-1
Dana J (1853) Crustacea Part II. United States Exploring Expedition 14, pp 689–1618
Fonseca LCD, Guerreiro J, Gil J (1995) Note on the macrozoobenthos of the upper level sediments of Porto Santo Island (Madeira, Portugal). Boletim do Museu Municipal do Funchal 804-A: 233–252
 Foster JM, Heard RW, Knott DM (1999) Historical invasions of marine species. Trends in Ecology and Evolution 14: 325–331
Fonseca LCD, Guerreiro J, Gil J (1995) Note on the macrozoobenthos of the upper level sediments of Porto Santo Island (Madeira, Portugal). Boletim do Museu Municipal do Funchal 804-A: 233–252
Fernández L, Adarraga I (2008) First record of invasive caprellid (Crustacea: Amphipoda) in the eastern Pacific Ocean. Marine Biology Research 4: 669–670, http://dx.doi.org/10.1080/17451000.2008.1042411
Kaluza P, Kölzsch A, Gastner MT, Blasius B (2010) The complex network of global cargo ship movements. Journal of the Royal Society Interface 7: 1093–1103, http://dx.doi.org/10.1098/rsif.2009.0495
Kohler KE, Gill SM (2006) Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences 32: 1259–1269, http://dx.doi.org/10.1016/j.cageo.2005.11.009
Krapp T, Lang C, Libertini A, Melzer RR (2006) The Caprellidea from the Florida Gulf Coast and in South Carolina. Gulf and Caribbean Research 16: 65–70
Guerra-García J, Takeuchi I (2003) The Caprellidae from the Madeira Island. Boletim do Museu Municipal do Funchal 168: 261–2622, http://dx.doi.org/10.1017/S1755267200230154:TCMAF-MJ.2.0.CO;2
Guerra-García J, Takeuchi I (2004) The Caprellidea (Crustacea: Amphipoda) from the western North Atlantic. US Natural Museum Bulletin 278: 1–116
Minchin D, Lodola A, Occhipinti-Ambruosi A (2012) The occurrence of Caprella scabra (Amphipoda: Caprellidae) in marinas in Lanzarote Island (Canary Archipelago, Macaronesia). Marine Biodiversity Records 5: e113, http://dx.doi.org/10.1017/S175526721200098X
Mizzan L (1999) Le specie alloctone del macrozoobenthos della Laguna di Venezia: il punto della situazione. Bollettino del Museo Civico di Storia Naturale di Venezia 49: 145–177
Piola RF, Johnston EL (2006) Differential tolerance to metals among populations of the introduced bryozoan Bugula neritina. Marine Biology 148: 997–1010, http://dx.doi.org/10.1007/s00227-006-0156-5
Ramalhoa P, Camacho-Cruz K, Bastida-Zavala R, Canning-C1ode J (2014) First record of Branchioma bairdi McIntosh, 1885 (Annelida: Sabellidae) from Madeiran Island, Portugal (northeastern Atlantic Ocean). Biodiversions Records 3: 235–239, http://dx.doi.org/10.1038/srep.2014.3.4.04
Ros M, Guerra-García JM, González-Macias M, Saaavedra Á, López-Fe CM (2013) Influence of fouling communities on the establishment success of alien caprellids (Crustacea: Amphipoda) in Southern Spain. Marine Biology Research 9: 261–273, http://dx.doi.org/10.1080/17451000.2012.739695
Ruiz GM, Fofonoff PW, Carlton JT, Wonham MJ, Hines AH (2000) Invasion of coastal marine communities in North America: apparent patterns, processes, and biases. Annual Review of Ecology and Systematics 31: 481–531, http://www.jstor.org/stable/26374
Sconetti R, Dainesi P (1996) Variazioni strutturali in comunità di peracaridi agli estremi opposti del bacino di Malamocco (Laguna di Venezia). Società Italiana di Ecologia Atti 17: 407–410
Stock JH, Abreu AD (1992) Three new species of Pseudoniphargus (Crustacea: Amphipoda) from the Madeira archipelago. Boletim do Museu Municipal do Funchal 44 (241): 131–155, http://publications.cm-funchal.pt/handle/100/1101
Stock JH (1993) Gammarsus and Chaetogammarus (Crustacea, Amphipoda) from Madeiran Island. Boletim do Museu Municipal do Funchal 45 (247): 41–52, http://publications.cm-funchal.pt/handle/100/1042
Stock JH (1994) A new member of the family Bogidiellidae (Crustacea, Amphipoda) from a histologically altered coral in Madeira. Boletim do Museu Municipal do Funchal 171: 1–8, http://publications.cm-funchal.pt/handle/100/1613
Templeton, 1836 into southern Europe and northern Africa: a complicated taxonomic history. Mediterranean Marine Science 15: 145–155, http://dx.doi.org/10.12681/mms.469
Vázquez LM (2014) The spreading of the non-native caprellid (Capitella scabra) along the Pacific coast of continental Chile. Revista Chilena de Historia Natural 107: 15–50, http://www.scielo.cl/pdf/rchnat/v107n1/art2.pdf
Wirtz P, Canning-Clode J (2009) The invasive bryozoan Bugula neritina verticillatum has arrived at Madeira Island. Aquatic Invasions 4: 669–670, http://dx.doi.org/10.1080/17425802.2009.4.4.11
Woods C (2009) Caprellid amphipods: An overlooked marine finfish aquaculture resource? Aquaculture 289: 199–211, http://dx.doi.org/10.1016/j.aquaculture.2009.01.018