Short communication

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First report of the invasive macroalga *Acrothamnion preissii* (Rhodophyta, Ceramiales) in the Atlantic Ocean

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Abstract: *Acrothamnion preissii* is an invasive species in the Mediterranean Sea, and is listed among the 100 worst non-indigenous species. In July and August 2009, this non-native red macroalga was found for the first time in the Azores (on Santa Maria), and this represents the first record of this species in the Atlantic. Here, we describe the establishment of this invasive species in the Atlantic. In recent surveys, *A. preissii* displayed an invasive behaviour. As suggested for the Mediterranean Sea, hull fouling is the most likely vector for its introduction into the Azores.

Keywords: *Acrothamnion preissii*; Atlantic; invasive; macroalgae; non-indigenous.

Acrothamnion preissii (Sonder) E. M. Wollaston is well distributed in Australia and it has been reported from Korea, Japan, the Philippines and South Africa (Guiry and Guiry 2017). This species exhibits an invasive behaviour in the Mediterranean Sea (Boudouresque and Verlaque 2002) being included in the 100 worst non-indigenous species list (Streftaris and Zenetos 2006) and in the Black List of Marine Invasive Species (Otero et al. 2013). In Mediterranean waters, *A. preissii* was first found at Livorno, Italy, prior to 1969 (Cinelli and Sartoni 1969, Klein and Verlaque 2011), and dispersed towards the western basin, having been found in France in 1982, the Balearic Islands in 1994, Monaco and Sicily in 1996, Croatia in 2008, and Corsica in 2010 (Guiry and Guiry 2017). In the present decade, *A. preissii* has been reported from the Maltese Islands (see Evans et al. 2015). In the Mediterranean, it occurs mainly as an epiphyte on *Posidonia oceanica* (Linnaeus) Delile rhizomes, on almost vertical to overhanging algal-dominated infralittoral walls, and on soft-bottoms and maerl beds, from shallow subtidal zones down to 40 m depth (Ferrer et al. 1994). The aim of the present work is to draw attention to the arrival and establishment of *A. preissii* in the Atlantic by reporting its presence and invasive behaviour in the Azores archipelago.

The Azores is the most remote archipelago in the North Atlantic and is composed of nine volcanic islands and several islets (Figure 1). Specimens were collected in summer from the intertidal and subtidal zones around the island of Santa Maria, Azores, during three sampling trips: 2009 (Biology Department of the University of the Azores), 2013 (Azores Stopover for Marine Alien Species), 2016 (Waitt Foundation expedition) and 2017 (Program on Marine Invasive Species of the Azores). Other islands of the archipelago, namely Corvo, Faial, Graciosa and São Miguel were also surveyed during 2016 and 2017. Specimens were dried on herbarium sheets and deposited at the University of the Azores (Table 1).

Twenty-four specimens identified as *A. preissii* were found in the intertidal zone and down to 20 m depth (Table 1), in 11 sites on the coast of Santa Maria (Figure 1). Despite an extensive survey (an average of 40 dives per island), the species was not observed in the other islands surveyed (four of the nine islands).

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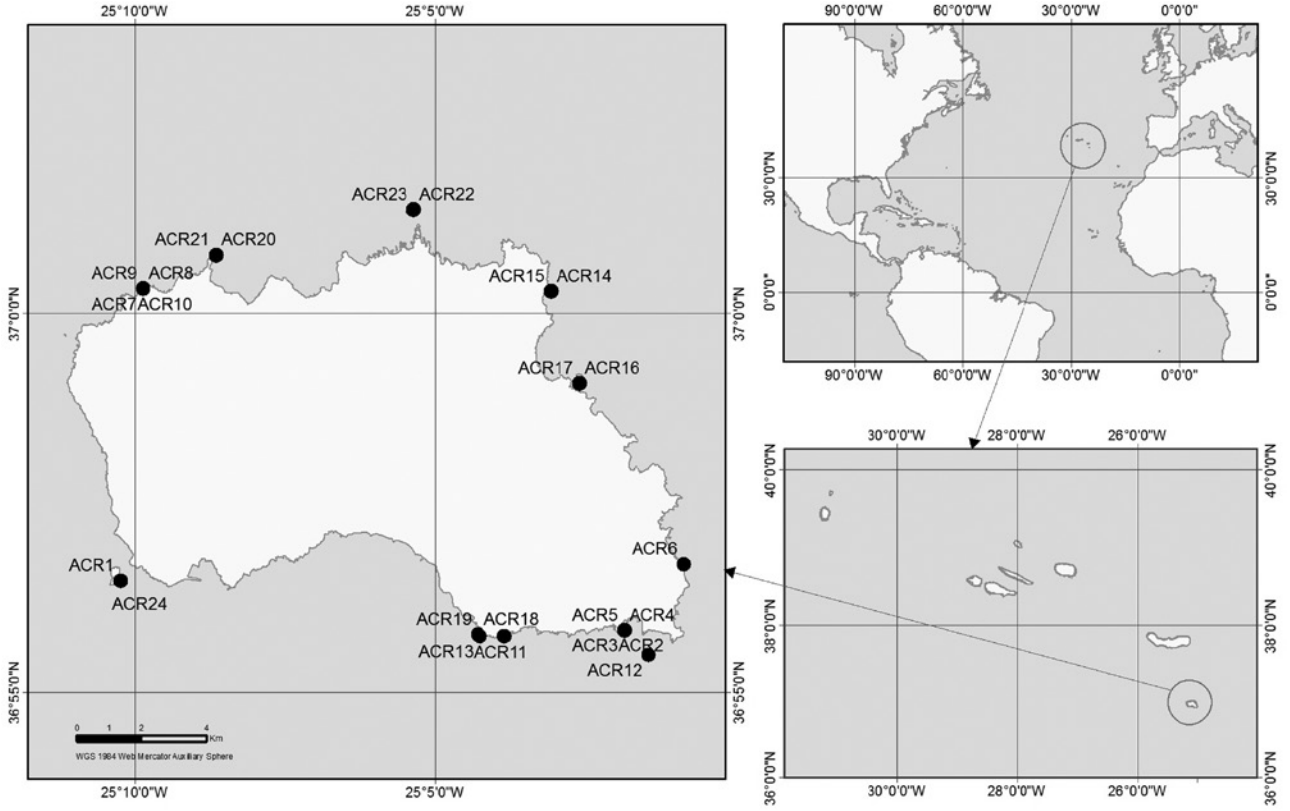


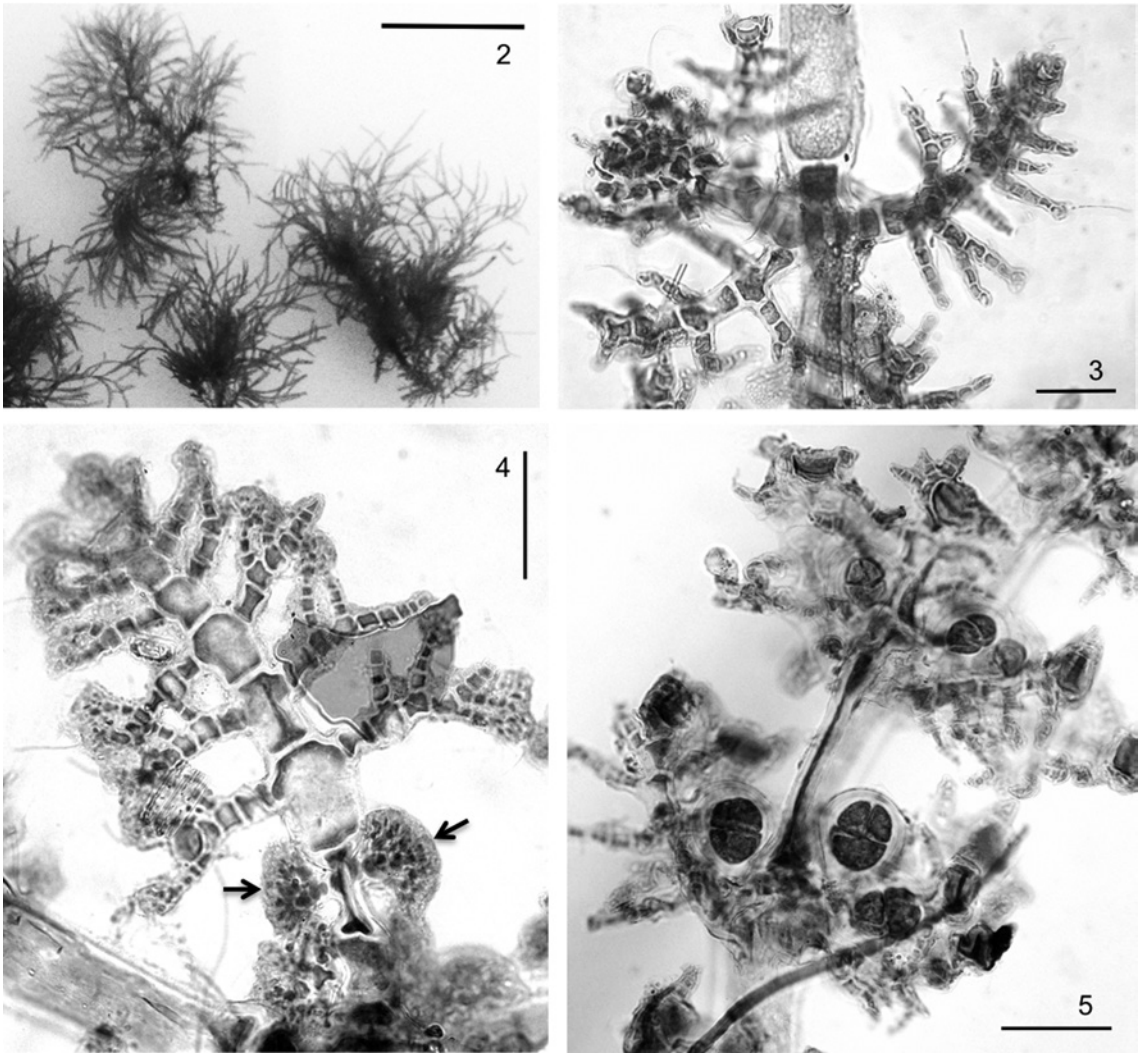
Figure 1: Location of Santa Maria Island in the Atlantic with dots marking the sites where *Acrothamnion preissii* was found (main rectangle) and position of the Azores archipelago in the Atlantic (inset rectangle).
For key to site codes, see Table 1.

Table 1: *Acrothamnion preissii*. List of records in the Azores with collection sites, coordinates, depth and date of collection.

Date	Site	Latitude	Longitude	Depth (m)	Code
July 2009	Ilhéu da Vila do Porto	36.9412	−25.1706	16	ACR1
	Maia	36.9448	−25.0144	Intertidal	ACR6
	Rocha Alta	36.9304	−25.0310	7	ACR2
				7	ACR3
				7	ACR4
				7	ACR5
August 2013	Anjos	37.0055	−25.1644	Intertidal	ACR7
				Intertidal	ACR8
				Intertidal	ACR9
				Intertidal	ACR10
September 2016	Baía de São Lourenço	36.9847	−25.0434	15	ACR16
				10	ACR17
	Baixa da Cré	36.9289	−25.0644	20	ACR11
	Baixa do Sul	36.9249	−25.0242	20	ACR12
	Ilhéu das Lagoínhas	37.0229	−25.0894	18	ACR22
				10	ACR23
	Malbusca	36.9290	−25.0711	20	ACR13
		36.9294	−25.0715	20	ACR18
				10	ACR19
	Ponta dos Frades	37.0129	−25.1443	20	ACR20
				10	ACR21
	Ponta do Mormo	37.0049	−25.0513	20	ACR14
				10	ACR15
July 2017	Ilhéu da Vila do Porto	36.9412	−25.1706	21	ACR24

Our specimens possessed filamentous thalli, rose red in colour, up to 9 cm high (Figures 2–5) and displayed the characteristics of large transversely oval gland cells, terminal on the rachis of pinnae, 3–4 lateral branches per axial cell (Figure 3), and decussate tetrasporangia (Figure 4). Spermatangia with numerous spermatia in fan-like clusters were spread over determinate branches (Figure 5), but were much more numerous close to the base. The observed specimens displayed the characters reported in previous descriptions of the species (see Agardh 1892, Wollaston 1968, Wollaston and Womersley 1998) except for the tetrasporangia, which correspond to those depicted by Piazzi et al. (1996) for this species. Reproductive stages of this species have been previously reported (e.g. Thélin 1984, Cinelli and Sartoni 1970, Piazzi et al. 1996); nevertheless, to the best of our knowledge, this is the first time that male sexual structures have been found outside the native range of the species.

Acrothamnion preissii is epiphytic on other macroalgae and, in the Azores, occurs mainly on the abundant *Zonaria tournefortii* (Lamouroux) Montagne found between 7 and 20 m depth on basaltic rocky substrata covered by multi-species algal mats. The species was frequent in the sites where it was collected but its abundances were always low before 2017, when extensive overgrowth of the native algal mats was observed. Currently *A. preissii* overgrows *Z. tournefortii* extensively in large areas on Ilhéu da Vila do Porto, shading out the underlying macroalgae. The



Figures 2–5: *Acrothamnion preissii* morphology and anatomy.
(2) Habit, scale bar = 1 cm. (3) Carpogonia and trichogynes in the same pinnae, scale bar = 50 mm. (4) Branches bearing spermatangial clusters, spermatangia with numerous spermatia, scale bar = 200 mm. Arrows indicate spermatangial clusters. (5) Adaxial tetrasporangia located close to the base of determinate branches, scale bar = 200 mm.

dynamics of *A. preissii* invasion, in shallow rocky habitats, suggests steady establishment (it was collected from many sites all around the island in 2016) and rapid spread as extensive patches were observed in Ilhéu da Vila do Porto in 2017, revealing a large increase in biomass since 2009 when it was first collected in this site.

The discovery of the Indo-Pacific species *A. preissii* in the Azores extends its distribution westward, and represents the first record in the Atlantic Ocean. The distribution of *A. preissii* in the Azores seems to be restricted to Santa Maria, as it was not found in recent field surveys of other islands. The west to east circulation of main Atlantic currents at Azores latitudes (see Santos et al. 1995, Johnson and Stevens 2000), does not favour natural dispersal from the Mediterranean, the closest location where *A. preissii* is known to be present. A possible explanation for the arrival of this species in Santa Maria is through maritime traffic from the Mediterranean, an introduction vector suggested by Verlaque et al. (2015) for the introduction of *A. preissii* in this sea. In fact, hull fouling accounts for 69% of the introduced macroalgae (n = 26) in the Azores (Micael et al. 2014). Verlaque et al. (2015) also suggested aquarium release as another possible vector for the introduction of *A. preissii* into the Mediterranean, but this is unlikely in the Azores, where private aquaria are uncommon. A detailed molecular study with samples representing the distribution range of the species (including its type locality, native and non-natural occurrence) should be performed to clarify the connectivity between the different populations of *A. preissii*.

This report of *A. preissii* in the Azores raises the already high number of non-indigenous filamentous red algae to 14 species (55% of all introduced macroalgae; Micael et al. 2014, Chainho et al. 2015). Moreover, the known distributional range for this species is significantly expanded. The presence of *A. preissii* in the Azores raises particular concern because of its ability to reproduce asexually by fragmentation, its opportunistic behaviour (see Williams and Smith 2007), and its history of invasiveness in the Mediterranean. Moreover, since the Azores is a stopping point for yachts crossing the Atlantic, it poses an increased risk for dispersal to ports around the North Atlantic.

Acrothamnion preissii outcompetes some native algal species, and so threatens the biodiversity of native species in the Mediterranean (Piazzi et al. 2002, Piazzi and Cinelli 2003, Otero et al. 2013). Considering the structuring role of macroalgae in Azorean habitats, the impact of increasing populations of this species in the future could be significant for local marine communities.

Other non-indigenous Mediterranean macroalgae that are also established in the Azores include *Asparagopsis armata* Harvey, *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, *Bonnemaisonia hamifera* Hariot, *Grateloupia turuturu* Yamada and *Codium fragile* (Suringar) Hariot, all included in the short list of the 100 worst non-indigenous species in the Mediterranean Sea (Streftaris and Zenetos 2006). All these species have been reported on Santa Maria but none of them is restricted to this island.

There are no reported control measures for this or other filamentous algae, and even hand removal does not seem to be an effective method to eliminate *A. preissii* from Santa Maria. Thus, we can only focus on the prevention of its spread to other islands and the control of hull-fouling before vessels depart from Santa Maria is advised. Also early detection survey programs, focused on marinas and harbours on other islands, can probably contribute to a relatively low-cost management of this and other eventual introduced species. Nevertheless, it will be very difficult to avoid the spread of this filamentous species and, therefore, it is possible that it will reach other islands in the near future.

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