Short communication

The recent northern introduction of the seaweed *Caulerpa webbiana* (Caulerpales, Chlorophyta) in Faial, Azores Islands (North-Eastern Atlantic)

Jaen Nieto Amat*, Frederico Cardigos and Ricardo Serrão Santos

*IMAR and Department of Oceanography and Fisheries (DOP) of the University of the Azores, PT-9901-862 HORTA, Portugal
E-mail: jnietoamat@uac.pt

*Corresponding author

Received: 18 April 2008 / Accepted: 30 October 2008 / Published online: 18 December 2008

Abstract

Until recently, introduced species did not seem to have a significant adverse impact on the Azorean marine native flora and fauna. Nevertheless, one of the recent alien species listed for this region belongs to a genus with high invasive potential: *Caulerpa* (Caulerpales, Chlorophyta). *Caulerpa webbiana* was first detected in 2002 near the main yachting harbour of the Azores, Horta, in Faial. Through the years it has rapidly extended its colonized area and the density of colonies encountered have increased in the harbour and adjacent areas. The establishment of the seaweed represents a northern extension of its distribution and may have been facilitated by changes in climate. However, the actual pattern of *C. webbiana* distribution seems to indicate that this new species was possibly introduced by maritime traffic rather than reaching the island through natural rafting. There is an urgent need to address the issue of this seaweed in the Azores.

Key words: *Caulerpa webbiana*, invasive alien species, Azores

Until recently, introduced species did not seem to have a significant adverse impact on Azorean marine native flora and fauna (Morton and Britton 2000), especially when compared with terrestrial counterparts (Silva et al. 2000). However, this situation may be changing due to transatlantic boat traffic which has increased considerably over the last decade (Cardigos et al. 2006). Among the 55 introduced marine taxa listed by Cardigos et al. (2006), four species are considered invasive alien species (IAS): the ascidians, *Clavelina oblonga* Herdman, 1880 (first registered in 1971) and *Distaplia corolla* Monnot, 1975 (first registered in 1971) and the macrophytes, *Asparagopsis armata* Harvey 1855 (first registered in 1928) and *Caulerpa webbiana* Montagne, 1837. This last IAS is now a major concern and the object of concerted research since, (i) *Caulerpa* has attributes that lead species of that genus to have great invasive potential (Collado-Vides and Ruesink 2002) and (ii) *C. webbiana* is colonizing and dominating marine bottom at a great rhythm (our observations).

*C. webbiana* is a pan-tropical species; the localities where it inhabits are summarized in Annex 1. The northern and southernmost limits of occurrence, which regards Madeira and New Zealand respectively, are represented in Figure 1. *C. webbiana* was only recently registered northern to this previous limit (Madeira) in 2002, near Horta’s harbour, Faial (Cardigos et al. 2006).

Since the first detection of *C. webbiana*, empirical observations made by scuba divers from 2003 to 2005 around the archipelago enabled to delimit *C. webbiana* presence to the surroundings of the harbour of Faial Island, were it was first detected in 2002 (Figure 2). Subsequently, in 2005, 43 dives were carried out to assess its distribution along the all archipelago during a five month monitoring period (from July to November). This confirmed that its occurrence was restricted to Faial Island. The affected coast line in 2005 comprised portions of the seawall harbour as well as a segment of *Monte da Guia* coast (Figure 2). No colonies were observed south or north of this area.
Figure 1. Caulerpa webbiana geographical recorded limits.

Figure 2. Diving observation sites around the Azores archipelago from 2003 to 2005, with indication where C. webbiana was (dark grey circle) and was not (clear grey circles) registered (A). Coastline affected by the presence of C. webbiana in 2005 (grey line) and in 2007 (black line) (B).
The highest density of colonies was recorded along the seawall of the harbour, while along Monte da Guia, colonies were sparse. A new monitoring period started in October 2007. The present situation is clearly different, reinforcing the idea that this seaweed is now rapidly spreading: *C. webbiana* is now found to Ponta dos Radares and 26 isolated colonies were identified on the Espalamaca side of the harbour (Figure 2). Furthermore, density of colonies encountered along the affected coast line had also increased (example of this huge density of colonization in Figure 3B) considering visual census. A fixed transect installed in 2005 enabled to quantify the increased density of colonies, which revealed a growth from 0.23 m$^2$ (November 2005) to 5 m$^2$ area (November 2007) in two years, thus approximately 21 times higher than that observed in 2005.

*C. webbiana* was found on natural and artificial rocky bottoms, sometimes covered by sand and shell fragments, between 4 and 27 meters deep. *C. webbiana* does not appear to demonstrate preference for a particular slope or rock plane: colonies were seen on vertical, inclined and horizontal planes. *C. webbiana* was commonly seen “sharing” the same substratum with other introduced species, usually *Asparagopsis* spp. (Figure 3B and 3D) and *Distaplia corolla* (Figure 3A and 3C).

Growth, decay and resting periods may exist for *C. webbiana*, as they are known to occur for *C. racemosa var. cylindracea* on the French Mediterranean Coast (Ruitton et al. 2005). In fact, Haroun et al. (1984) noted the decline of *C. webbiana* in the Canary Islands with falling temperature. In the Azores, no annual cycle has yet been registered because monitoring has not been consistent throughout a complete year. Sexual reproduction, however, seems to take place from late spring until early autumn, as demonstrated by whitening of colonies during that period.

Cardigos et al. (2006) suggest boat hulls or rafting as probable vectors for the introduction of *C. webbiana*. If *C. webbiana* had arrived by
rafting, it would not be an introduced case but a natural dispersal one. *C. webbiana* would then certainly have been found elsewhere around Faial coast and on other Azorean islands; as it happened with other organisms that arrived through the complex system of currents – accompanied by episodic anomalies – that surrounds this archipelago located in the middle of the Atlantic Ocean (Santos et al. 1995). The fact that colonies were (i) only found near Horta harbour and (ii) were denser close to the harbour than in farther zones, disappearing beyond, reflects species introduction dynamics (Boudouresque 1999). *C. webbiana* presence in the Azores is likely to be the consequence of a human-mediated introduction than the result of a natural extension range, though some change in the natural environment (possibly caused by climate change) may have facilitated its installation. Also, it is reasonable to think that maritime traffic could be involved in this introduction since the Azores are a crossroad in the middle of the Atlantic (Santos et al. 1995). Horta harbour is the main yachting marina of the Azores, which is “visited” by pleasure boats. Boat hulls are one of the probable vectors of introduction (Cardigos et al. 2006); in addition, some of the boat race can also be considered as potential vectors of introduction due to their non regulated discharges of ballast water. The International Convention on Ballast Water (see GloBallast, [http://globallast.imo.org/](http://globallast.imo.org/)), adopted in 2004 to go through the ratification process, is rather recent and its enforcement and verification on which concerns yachting is far from perfect. More research is needed to assess the potential vectors of introduction of *C. webbiana* in order to manage its spread and its possible establishment to other islands. Genetic analysis is in process and may help to elucidate the origin and geographic affinities of the Azorean colonies of *C. webbiana*.

*C. webbiana* does not seem to be an invasive species elsewhere in the world, however, it is difficult to predict the pervasions and future evolution of this introduced species in the Azores. Considering that (i) *C. webbiana* has already shown invasive behaviour, (ii) it still seems confined to the island of Faial and (iii) eradication of IAS has proven feasible in other small islands (McNeely 2004), there is an urgent need to address the issue (eradication or at least control) of *C. webbiana* in this region.

**Acknowledgements**

We would like to acknowledge the two entities that had provided financial support for the ongoing project on *C. webbiana*: SRAM/ DRA - Direcção Regional do Ambiente/Azores and ARENA – Agência Regional da Energia e Ambiente da Região Autónoma dos Açores (project InterRegIIIB/Feder – BIONATURA). Thanks to Brigitte Amat, Christopher Pham and Ruth Higgins for the English review of the present invasion note.

**References**


Caulerpa webbiana in Azores Islands


Annex 1. Localities were *C. webbiana* has been recorded.

<table>
<thead>
<tr>
<th>Localities</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>East Atlantic</strong></td>
<td></td>
</tr>
<tr>
<td>Canaries</td>
<td>Borgesen (1925), Haroun et al. (2002)</td>
</tr>
<tr>
<td>Cape Verde</td>
<td>Prud'homme et al. (2005)</td>
</tr>
<tr>
<td>Madeira</td>
<td>Augier (1985)</td>
</tr>
<tr>
<td>Salvage</td>
<td>John et al. (2004)</td>
</tr>
<tr>
<td><strong>Red Sea and West Indian Ocean</strong></td>
<td></td>
</tr>
<tr>
<td>Egypt</td>
<td>Papenfuss (1968) in Guiry and Guiry (2008)</td>
</tr>
<tr>
<td>Somalia</td>
<td>Silva et al. (1996)</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Silva et al. (1996)</td>
</tr>
<tr>
<td>Seychelles</td>
<td>Silva et al. (1996)</td>
</tr>
<tr>
<td>Madagascar</td>
<td>Silva et al. (1996)</td>
</tr>
<tr>
<td>Reunion</td>
<td>Silva et al. (1996)</td>
</tr>
<tr>
<td>Mauritius</td>
<td>Silva et al. (1996)</td>
</tr>
<tr>
<td><strong>South Africa</strong></td>
<td></td>
</tr>
<tr>
<td>KwaZulu-Natal (South Africa)</td>
<td>De Clerck (2005)</td>
</tr>
<tr>
<td>Lord Howe Island (Australia)</td>
<td>Kraft (2007)</td>
</tr>
<tr>
<td>Queensland (Australia)</td>
<td>Kraft (2007)</td>
</tr>
<tr>
<td>Dampier Archipelago (Australia)</td>
<td>Huisman and Borowitzka (2004)</td>
</tr>
<tr>
<td>Southern Great Barrier Reef (Australia)</td>
<td>Kraft (2007)</td>
</tr>
<tr>
<td>Houtman Abrolhos Island (Australia)</td>
<td>Kraft (2007)</td>
</tr>
<tr>
<td><strong>East Indian and West Pacific Oceans</strong></td>
<td></td>
</tr>
<tr>
<td>Federated States of Micronesia</td>
<td>Tsuda (2006)</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>Coppejans et al. (2001)</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Littler and Littler (2003)</td>
</tr>
<tr>
<td>Philippines</td>
<td>Menez and Calumpong (1982)</td>
</tr>
<tr>
<td><strong>Yucatan (Mexico)</strong></td>
<td></td>
</tr>
<tr>
<td>Florida</td>
<td>Littler and Littler (2000)</td>
</tr>
<tr>
<td>Caribbean</td>
<td>Littler and Littler (2000)</td>
</tr>
<tr>
<td>Cuba</td>
<td>Suares (2005)</td>
</tr>
<tr>
<td>Jamaica</td>
<td>Taylor (1960)</td>
</tr>
<tr>
<td>Lesser Antilles</td>
<td>Taylor (1960)</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>Taylor (1960)</td>
</tr>
<tr>
<td>Virgin</td>
<td>Taylor (1960)</td>
</tr>
<tr>
<td>Bahamas</td>
<td>Littler and Littler (2000)</td>
</tr>
<tr>
<td>Gulf of Mexico</td>
<td>Littler and Littler (2000)</td>
</tr>
<tr>
<td>Brazil</td>
<td>Taylor (1960)</td>
</tr>
<tr>
<td>Pernambuco (Brazil)</td>
<td>Williams and Blomquist (1947)</td>
</tr>
</tbody>
</table>