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Short communication

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

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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* Monniot, 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 Zeeland 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.

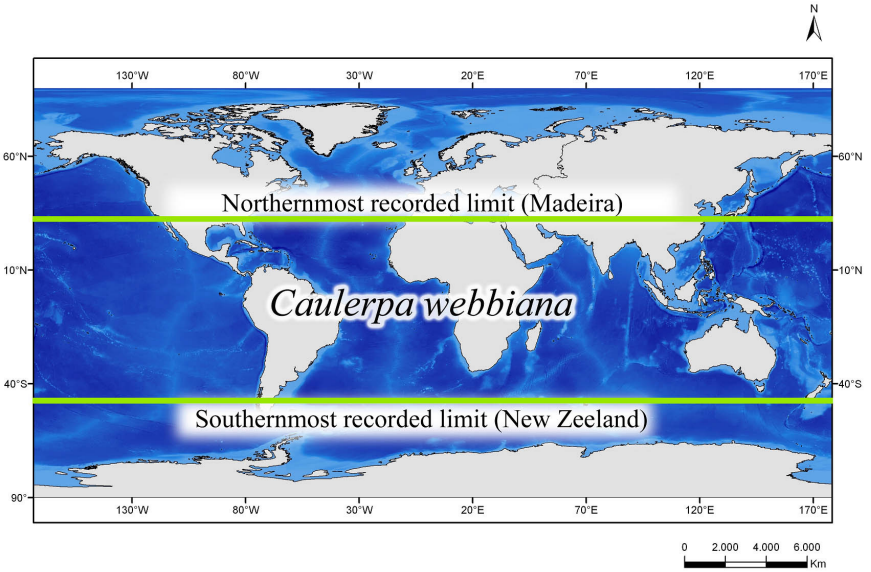

Figure 1. *Caulerpa webbiana* geographical recorded limits.

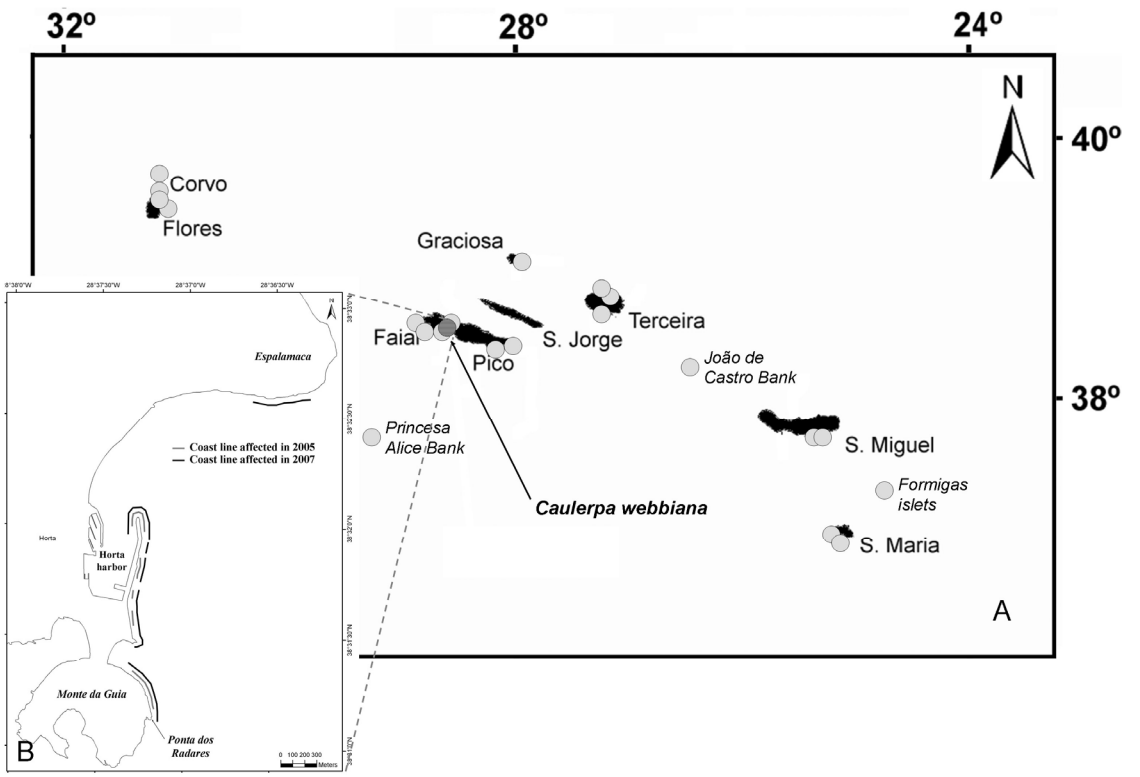

Figure 2. Diving observation sites around the Azores archipelago from 2003 to 2005, with indication where *C. webbiana* was (dark grey circle) and was not (clear grey circles) registered (A). Coastline affected by the presence of *C. webbiana* in 2005 (grey line) and in 2007 (black line) (B).

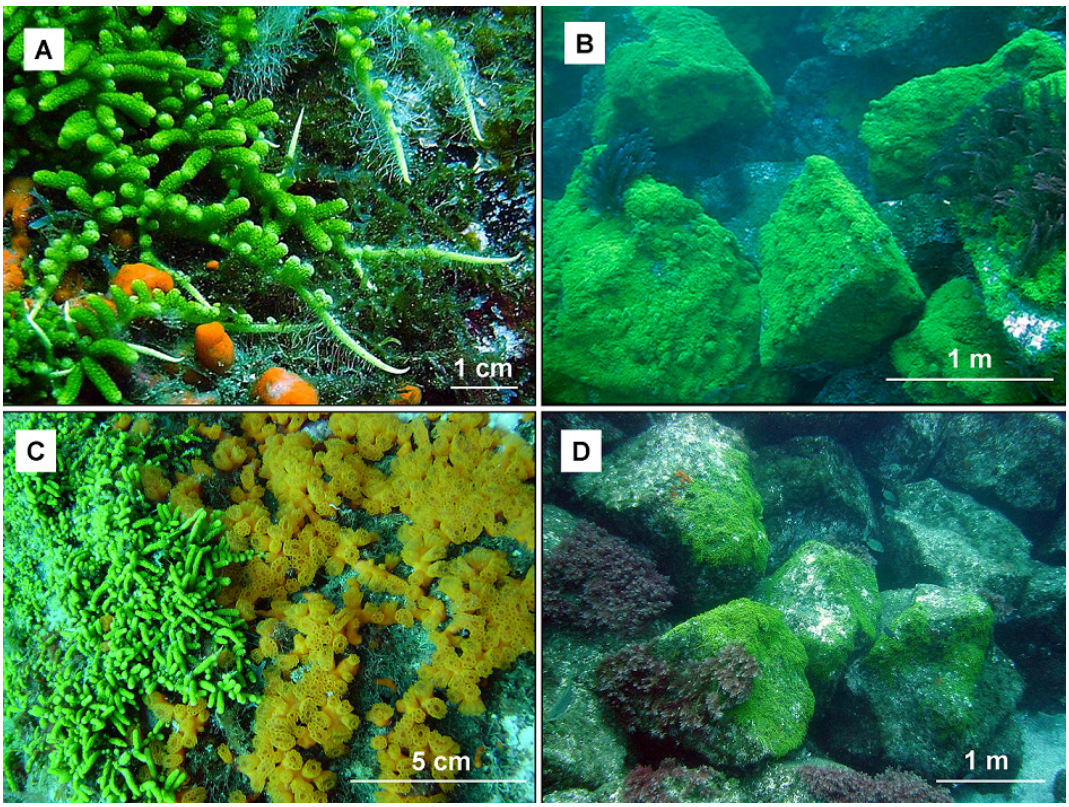

Figure 3. Close up of *C. webbiana* assimilators and stolons (A), Example of an area (behind the seawalls of Horta harbour) densely colonized by *C. webbiana* (B), *C. webbiana* and *Distaplia corolla* (C), *C. webbiana* and *Asparagopsis taxiformis* (D) (Photographs by J. N. Amat).

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/), 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.

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References

Augier H (1985). Première contribution à l'étude et à la cartographie des biocénoses marines benthiques de l'île de Madère. *Boletim do Museu Municipal do Funchal* 37 (168): 86-129

Børgesen F (1925) Marine algae from the Canary Islands, especially from Tenerife and Gran Canaria. I. Chlorophyceae. *Kongelige Danske Videnskabernes Selsakab, Biologiske Meddelelser* 5 (3): 1-123

Boudouresque CF (1999) Introduced species in the Mediterranean: routes, kinetics and consequences. Proceedings of the workshop on invasive *Caulerpa* species in the Mediterranean. MAP Technical Reports Ser., UNEP, Athens, pp 51-72

Cardigos F, Tempera F, Ávila S, Gonçalves J, Colaço A, Santos RS (2006) Non-indigenous marine species of the Azores. *Helgoland Marine Research* 60: 160-169, http://dx.doi.org/10.1007/s10152-006-0034-7

Collado-Vides L, Ruesink J (2002) Morphological Plasticity and Invasive Potential. International *Caulerpa taxifolia* Conference Proceedings, January 31 – February 1, 2002, Williams E, Grosholz E (eds) C.A. California Sea Grant College Program, U.C. San Diego, La Jolla, C.A., pp 88-118

Coppejans E, Leliaert F, Dargent O, De Clekck O (2001). Marine green algae (Chlorophyta) from the north coast of Papua New Guinea. *Cryptogamie Algologie* 22: 375-443, http://dx.doi.org/10.1016/S0181-1568(01)01070-4

De Clerck, O., Bolton JJ, Anderson RJ, Coppejans E (2005) Guide to the seaweeds of KwaZulu Natal. *Scripta Botanica Belgica* 33: 1-294

Guiry MD, Guiry GM (2008) AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org (Accessed on 7 October 2008)

Haroun RJ, Gil-Rodríguez MC, Díaz de Castro J, Prud'homme van Reine WF (2002) A checklist of the marine plants from the Canary Islands (central eastern Atlantic Ocean). *Botanica Marina* 45: 139-169, http://dx.doi.org/10.1515/BOT.2002.015

Haroun Tabraue RJ, Gil-Rodríguez MC, Afonso-Carrillo J, Wildpret de la Torre W (1984) Estudio ecológico y fenológico de algunas especies del género *Caulerpa* Lamouroux presentes en el archipiélago Canario. In: Monteiro Marques V (ed). Actas IV Simposio Ibérico de Estudios Benthos Marinho, vol 3. Faculdade de Ciencias de Lisboa, pp 75-82

Huisman JM, Borowitzka MA (2004) Marine benthic flora of the Dampier Archipelago, Western Australia. *Records of the Western Australian Museum, supplement* 66: 61-68

John DM, Prud'homme van Reine WF, Lawson GW, Kostermans TB, Price JH (2004) A taxonomic and geographical catalogue of the seaweeds of the western coast of Africa and adjacent islands. *Nova Hedwigia* 127: 1-339

Kraft GT (2007) Algae of Australia: Marine Benthic Algae of Lord Howe Island and the Southern Great Barrier Reef, 1. Green algae. ABRS, Canberra; CSIRO Publishing, Melbourne

Litter DS, Litter MM (2003) South Pacific Reef Plants. A divers' Guide to the Plant Life of South Pacific Coral Reefs. OffShore Graphics Inc publ, Washington, DC, 331 pp

Litter DS, Litter MM (2000) Caribbean Reef Plants. An Identification Guide to the Reef Plants of the Caribbean, Bahamas, Florida and Gulf of Mexico. OffShore Graphics Inc publ, Washington, DC, 542 pp

McNeely JA, Mooney HA, Neville LE, Schei P, Waage JK (2004) A Global Strategy on Invasive Alien Species. IUCN Gland, Switzerland, and Cambridge, UK, x + 50 pp

Meñez EG, Calumpong HP (1982) The genus *Caulerpa* from Central Visayas, Philippines. *Smithsonian Contribution to the Marine Sciences* 17: iii + 21

Morton B, Britton JC (2000) Origins of the Azorean intertidal biota: the significance of introduced. *Arquipelago, Life and Marine Sciences, supplement* 2A: 29-51

Prud'homme van Reine WF, Haroun RJ, Kostermans LBT (2005) Checklists on seaweeds in the Atlantic Ocean and in the Cape Verde Archipelago. IV Simpósio Fauna e Flora das Ilhas Atlânticas. Ministério do Ambiente, Agricultura e Pescas publ, pp 13-26

Ruitton S, Javel F, Culiolo JM, Meinesz A, Pergent G, Verlaque M (2005) First assessment of the *Caulerpa racemosa* (Caulerpales, Chlorophyta) invasion along the French Mediterranean coast. *Marine Pollution Bulletin* 50: 1061-1068, http://dx.doi.org/10.1016/j.marpolbul.2005.04.009

Santos RS, Hawkins S, Monteiro LR, Alves M, Isidro EJ (1995) Marine research, resources and conservation in the Azores. *Aquatic Conservation: Marine and Freshwater Ecosystems* 5(4): 311-354, http://dx.doi.org/10.1002/aqc.3270050406

Silva L, Tavares J, Smith CW (2000) Biogeography of Azorean plant invaders. *Arquipelago, Life and Marine Sciences,* supplement 2A: 19-27

Silva PC, Basson PW, Moe RL (1996) Catalogue of the benthic marine algae of the Indian Ocean. *University of California Publications in Botany* 79: 1-1259

Skelton PA, South GR (2004) New records and notes on marine benthic algae of American Samoa - Chlorophyta and Phaeophyta. *Cryptogamie Algologie* 25: 291-312

Suáres AM (2005) Lista de las macroalgas marinas cubanas. *Revista de Investigación Marina* 26(2): 93-148

Taylor WR (1960) Marine algae of the eastern tropical and subtropical coasts of the Americas. University of Michigan Press, Ann Arbor, 870 pp

Tsuda R (2006) Checklist and bibliography of the marine benthic algae within Chuuk, Pohnpei, and Kosrae States, Federated States of Micronesia. Marine Introduced Species Workshop Report, Chuuk, Pohnpei, and Kosrae States, Federated States of Micronesia, 39 pp

Williams LG, Blomquist HL (1947) A collection of Marine Algae from Brazil. *Bulletin of the Torrey botanical Club* 74: 383-397, http://dx.doi.org/10.2307/2482061

Young LIQ, Díaz MM, Espinoza JA (1998) *Caulerpa webbiana* (Chlorophyta: Caulerpaceae) en la Península de Yucatán, México. Ampliaciones de ámbito. *Revista de Biología Tropical* 46(3): 847-848

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

	Localities	Reference
East Atlantic	Canaries	Børgesen (1925), Haroun et al. (2002)
	Cape Verde	Prud'homme et al. (2005)
	Madeira	Augier (1985)
	Salvage	John et al. (2004)
Red Sea and West Indian Ocean	Egypt	Papenfuss (1968) in Guiry and Guiry (2008)
	Saudi Arabia	Papenfuss (1968) in Guiry and Guiry (2008)
	Somalia	Silva et al. (1996)
	Mozambique	Silva et al. (1996)
	Seychelles	Silva et al. (1996)
	Madagascar	Silva et al. (1996)
	Reunion	Silva et al. (1996)
	Mauritius	Silva et al. (1996)
East Indian and West Pacific Oceans	South Africa	Silva et al. (1996)
	KwaZulu-Natal (South Africa)	De Clerck (2005)
	New Zealand	Adams (1994) in Guiry and Guiry (2008)
	Lord Howe Island (Australia)	Kraft (2007)
	Queensland (Australia)	Kraft (2007)
	Dampier Archipelago (Australia)	Huisman and Borowitzka (2004)
	Southern Great Barrier Reef (Australia)	Kraft (2007)
	Houtman Abrolhos Island (Australia)	Kraft (2007)
	American Samoa	Skelton (2004)
	Easter	Santelices (1987) in Guiry and Guiry (2008)
	Federated States of Micronesia	Tsuda (2006)
	Fiji	N'Yeurt (1996) in Guiry and Guiry (2008)
	Hawaii	Abbott (2004) in Guiry and Guiry (2008)
	Solomon	Womersley and Bailey (1970) in Guiry and Guiry (2008)
	Papua New Guinea	Coppejans et al. (2001)
	Indonesia	Littler and Littler (2003)
	Philippines	Menez and Calumpong (1982)
Continent of America	Yucatan (Mexico)	Young et al. (1998)
	Florida	Littler and Littler (2000)
	Caribbean	Littler and Littler (2000)
	Cuba	Suares (2005)
	Jamaica	Taylor (1960)
	Lesser Antilles	Taylor (1960)
	Puerto Rico	Taylor (1960)
	Virgin	Taylor (1960)
	Bahamas	Littler and Littler (2000)
	Gulf of Mexico	Littler and Littler (2000)
	Brazil	Taylor (1960)
	Pernambuco (Brazil)	Williams and Blomquist (1947)
	Chile	Santelices (1989) in Guiry and Guiry (2008)