Available online at www.sciencedirect.com
ScienceDirect
Estuarine, Coastal and Shelf Science 74 (2007) 549–556
ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ecss

First report of *Caulerpa taxifolia* (Bryopsidales, Chlorophyta) on the Levantine coast (Turkey, Eastern Mediterranean)

Cem Cevik [a], Mehmet Baki Yokes [b,*], Levent Cavas [c], Levent Itri Erkol [a], Osman Baris Derici [a], Marc Verlaque [d]

[a] *Çukurova University, Faculty of Fisheries, Balcali Campus, Adana, Turkey*
[b] *Haliç University, Faculty of Arts and Sciences, Department of Molecular Biology and Genetics, Ahmet Vefik Pasa Cd. Findikzade, 34093 Istanbul, Turkey*
[c] *Dokuz Eylul University, Faculty of Arts and Sciences, Department of Chemistry (Biochemistry Division), Izmir, Turkey*
[d] *UMR 6540, COM, Université de la Méditerranée, Campus de Luminy, F13288 Marseille cedex 9, France*

Received 22 December 2006; accepted 21 May 2007
Available online 16 July 2007

Abstract

Since its first accidental introduction into the Mediterranean Sea, *Caulerpa taxifolia* (Vahl) C. Agardh has spread to six Mediterranean countries and has become a major ecological problem. On the basis of morphological and molecular studies (nuclear ribosomal internal transcribed spacer (ITS)), we report for the first time *C. taxifolia* on the Levantine coast (Gulf of Iskenderun, SE Turkey). Phylogenetic analysis revealed that the Iskenderun isolate differs from the invasive aquarium strain first observed in Monaco, and falls in another SW Pacific clade (NE Australia, New Caledonia). The introduction in Turkey by shipping (ballast waters or anchor gears of oil tankers) is possible because *C. taxifolia* was found in the Gulf of Iskenderun, which is a major Eastern Mediterranean petrochemical region. On the other hand, *C. taxifolia* strains are available in aquarium shops in Turkey, suggesting aquarium dumping as another possible cause. As far as the intense maritime traffic of the region is concerned, further dispersals of this exotic *C. taxifolia* strain in the Mediterranean Sea are to be expected.

Keywords: *Caulerpa taxifolia*; Bryopsidales; Chlorophyta; introduced species; ITS; rDNA; Turkey; Mediterranean

1. Introduction

Unintentional introductions of non-indigenous species are a growing concern in environmental management, especially for marine ecosystems, because of their environmental and economic impacts on biodiversity, through habitat alteration and competition with native species (Murphy and Schaffelke, 2003; Schaffelke et al., 2006). The number of marine species introductions is increasing everyday; leading to a biological pollution recognized as a worldwide problem (Carlton, 1996; Kolar and Lodge, 2001). One of the most publicized marine introduced species is the tropical green alga *Caulerpa taxifolia* (Vahl) C. Agardh. It first escaped from an aquarium in Monaco in 1984 (Jousson et al., 1998; Olsen et al., 1998; Meusnier et al., 2001), *C. taxifolia* has been distributed to six countries in the Mediterranean Sea: Croatia, France, Italy, Monaco, Spain and Tunisia (Meinesz and Hesse, 1991; Meinesz et al., 2001). In 2000, *C. taxifolia* was reported for the first time in California (Dalton, 2000; Kaiser, 2000). Shortly afterwards, new introduced populations of *C. taxifolia* were recognized in Australia (New South Wales), approximately 600 km south of the known range for native populations (Millar, 2001; Schaffelke et al., 2002). Molecular studies, based on nuclear rDNA internal transcribed spacer (ITS) and chloroplast marker as well as DNA fingerprints, have revealed that the Mediterranean (except for Tunisia), Californian, and SE Australian populations are of Australian origin (Queensland) and that spread has been human-mediated through the aquarium trade. This invasive strain is now known as the ‘‘invasive aquarium strain’’

* Corresponding author.
E-mail address: bakiyokes@halic.edu.tr (M.B. Yokes).

0272-7714/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecss.2007.05.031

(Jousson et al., 1998, 2000; Olsen et al., 1998; Meusnier et al., 2001, 2002, 2004; Wiedenmann et al., 2001; Murphy and Schaffelke, 2003; Stam et al., 2006; Walters et al., 2006). On the other hand, molecular studies showed that the Tunisian strain is different from the invasive aquarium strain, highlighting a second introduction event in the Mediterranean Sea (Jousson et al., 2000; Famà et al., 2002; Meusnier et al., 2004; Stam et al., 2006).

Caulerpa taxifolia has not yet been reported from the Levantine coast (Middle East, Eastern Mediterranean). But in 2006, a small feather-like *Caulerpa* species has appeared for the first time in the Gulf of Iskenderun (SE Turkey, observation: Cem Cevik). In the present study, we carried out morphological and molecular analyses (ITS1-5.8S-ITS2 rDNA sequences) to identify the taxon as well as its possible origin and vector of introduction.

2. Materials and methods

2.1. Specimen collection and herbariums

Specimens of *Caulerpa* were hand-collected by SCUBA diving in June 2006 in the Gulf of Iskenderun, SE Turkey, (Fig. 1) and preserved in buffered 4% formaldehyde–seawater. The characteristics of the colonized area and different environmental parameters (temperature, salinity, dissolved O_2 and pH) were registered during the field study by using Yellow Springs Instruments (YSI) 6600 Multiparameter Water Quality Sonde. Secchi depth was also measured. The material was compared with a *Caulerpa taxifolia* strain kindly provided by an aquarium shop in Izmir, Turkey.

The following voucher specimens were deposited in the Herbarium Verlaque, Centre d'Océanologie de Marseille (COM), Marseille, France: H7741, *Caulerpa taxifolia* (Vahl) C. Agardh, leg. *C. Cevik*, Gulf of Iskenderun, Turkey, 15 June 2006, 11 m depth, silted sand; H7742, *C. taxifolia* (Vahl) C. Agardh, leg. MB Yokes, aquarium shop, Izmir, Turkey, 10 September 2006.

It was compared with the following dried specimens deposited in the Herbarium Verlaque: H5393, *Caulerpa taxifolia* (Vahl) C. Agardh, invasive aquarium strain, Cap Martin, France, 15 September 1992, 8 m depth; H5420, *C. taxifolia* (Vahl) C. Agardh, invasive aquarium strain, Porquerolles, France, September 1997, reared for 2 months in an aquarium in low light conditions; H5421, *C. taxifolia* (Vahl) C. Agardh, invasive aquarium strain, Cap Martin, France, September 2000, reared for 3 months in an aquarium, as well as a large set of introduced and native specimens of *Caulerpa* spp. Measurements were made on wet specimens.

2.2. DNA isolation, polymerase chain reaction amplification and sequencing

Fresh material was used for DNA extraction. Approximately 0.5 cm of fronds were rinsed with sterilized sea water and were directly added to 1 ml preheated (60 °C) 2% w/v CTAB buffer (with 2 µl β-mercaptoethanol) and incubated for 1 h at 60 °C. Repeated extractions with 0.5 ml chloroform iso-amyl alcohol (24:1 v/v) were performed until complete removal of the interphase was achieved. DNA was precipitated with 0.7 volumes of cold isopropanol for 1 h at 4 °C, pelleted by centrifugation at 10,000 × *g* for 20 min. The pellets were

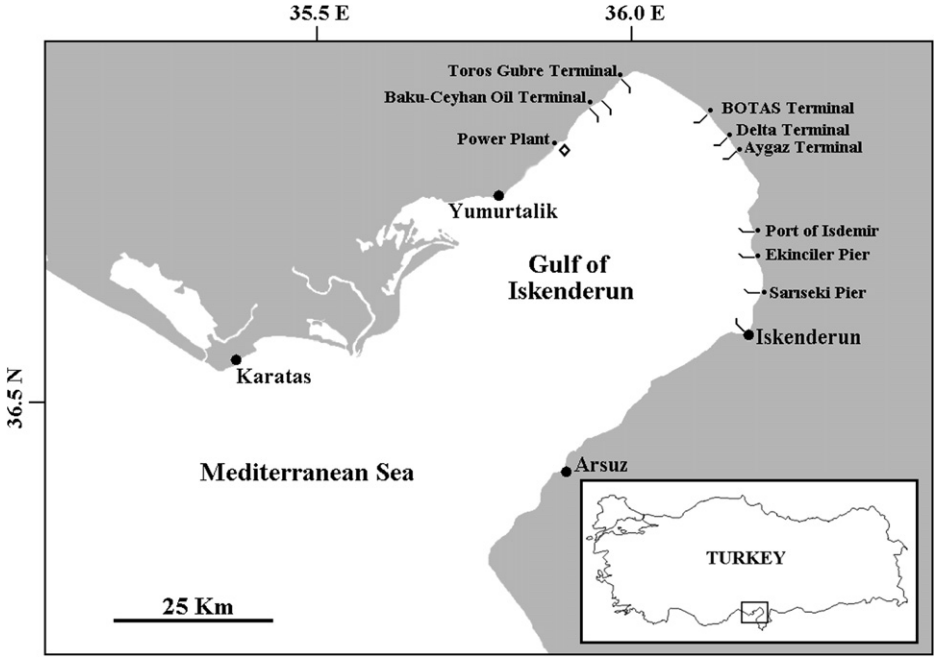

Fig. 1. Gulf of Iskenderun with the sampling locality (◇). The colonies of *Caulerpa taxifolia* were found on a transect line of 36° 49.409′ N, 35° 53.350′ E and 36° 50.049′ N, 35° 53.938′ E. The gulf is one of the major industrial regions of Turkey with intense ship traffic due to the presence of ports and terminals, especially the Baku–Ceyhan pipeline, and thermal power plant.