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First record of the invasive green alga *Codium fragile* ssp. *fragile* (Chlorophyta, Bryopsidales) in Abruzzi waters, central Adriatic Sea

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*The authors report for the first time on the invasive green alga *Codium fragile* ssp. *fragile* (Suringar) Hariot from the Adriatic coast of the Abruzzi Region of Italy (central Adriatic Sea). Several thalli have been found stranded on the beach of Silvi Marina since November 2015. This species, native to East Asia, has widely invaded several locations of the Mediterranean where it has been probably introduced through boating or shellfish aquaculture.*

Key words: central Adriatic Sea, *Codium fragile* ssp. *fragile*, first record, introduced species

INTRODUCTION

The introduction and spread of invasive marine species into new environments, unintentional or deliberate, have become an increasing problem worldwide, with impacts on the biodiversity and ecosystem functioning and native communities (WILLIAMSON, 1996; GROSHOLZ, 2002). Nowadays, most biological invasions result from intensive human activities in the marine environment. In particular, aquaculture, fishing and interoceanic shipping have been widely accepted as causes and vectors of biological introductions (BOUDOURESQUE & VERLAQUE, 2002;

RIBERA SIGUAN, 2003). The introduction of alien marine species has stimulated renewed attention on environmental management policy in various international frameworks for monitoring marine biodiversity and ecosystems. The Descriptor 2: “Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems” of the EU Marine Strategy Framework Directive (2008/56/CE) is actually one of the eleven qualitative descriptors for achieving the ‘Good Environmental Status’ (GES) of all marine waters by 2020.

Codium fragile ssp. *fragile* (Suringar) Hariot is a coastal and estuarine species native to East

Asia (Japan and Korea). In general, *C. fragile* ssp. *fragile*, known commonly as dead man's fingers, is considered to have ten subspecies (GUIRY & GUIRY, 2017), three of which (including *C. fragile* ssp. *fragile*) are recognized as invasive in several parts of the globe (PROVAN *et al.*, 2008).

The species *C. fragile* ssp. *fragile*, hereafter referred to as *C. fragile*, is a cosmopolitan species widely distributed throughout all three major oceans (GUIRY & GUIRY, 2017). It was discovered along the Atlantic European coasts around 1900 (SILVA, 1955). Later, it has spread across Europe entering the Mediterranean Sea where it was recorded for the first time in France in 1946 (VERLAQUE, 1994) and in Italy in the Faro Lake (Sicily) in 1974 (FURNARI, 1974) as *C. fragile* ssp. *tomentosoides* (van Goor) P.C. Silva. The potential vectors of introduction and dispersal of *C. fragile* in the Mediterranean Sea have been recognized as fouling of ship hulls and importation of Asian shellfish (ZENETOS *et al.*, 2012). The successful invasion of *C. fragile* has been related to its wide physiological tolerance together with different establishment categories like pollutant tolerance, reproductive mode (sexual, parthenogenetic and vegetative), growth strategies and grazing defence mechanism (FALACE *et al.*, 2010). Considering that *C. fragile* can become a dominant canopy species in invaded habitats causing a nuisance to humans activities (CHERIF *et al.*, 2016), tracing its spreading may be useful to control and prevent potential adverse effects on local ecosystems. This note refers to the first record of *C. fragile* in Abruzzi waters, which represents the southernmost record on the Italian coasts of the Adriatic Sea. Specifically, a description of morphological thallus features and anatomical utricle characters is provided.

MATERIAL AND METHODS

On 3 November 2015, one of the authors (RC) found and photographed a thallus of the macroalga identified as *C. fragile* stranded on the beach of Silvi Marina (central Adriatic Sea, 42°33'54" N - 14°06'25" E, Fig. 1). The finding of this subspecies was confirmed again on the



Fig. 1. New location of *Codium fragile* ssp. *fragile* along the coast of Abruzzi (central Adriatic Sea)



Fig. 2. Specimen of *C. fragile* ssp. *fragile* stranded on the beach of Silvi Marina (Abruzzi) on August 2017 (scale bar: 2 cm). (Photo: R. Costantini)

same beach in April 2016, October 2016 and August 2017 (Fig. 2). The coastal zone facing the stranding area is a sandy bottom also featuring rocks at shallow depths and hosts the biocenosis of fine well-sorted sands (CASTRIOTA *et al.*, 2012). At depths ranging from 14 to 18 m, at about 5 km from the coast, submerged artificial reefs run parallel to the shoreline at few kilometres both north and south of the sampling area (GIANANTE *et al.*, 2010); breakwaters are also present both north and south of this area at a few hundred meters from the coast.

Collected samples were sealed in individual plastic bags and immediately preserved in 70% alcohol solution for subsequent identification. In the laboratory, thalli were cleaned with seawater to remove the maximum of epiphytes, and were observed using both an inverted microscope Leica DMI8 and a stereomicroscope Discovery.V20 (Zeiss). To determine the subspecies of *C. fragile*, the morphometric data were examined following the keys reported in the literature (SILVA, 1955; TROWBRIDGE, 1998; HUBBARD & GARBARY, 2002; CORMACI *et al.*, 2014). Voucher specimens were deposited in the personal herbarium of the first author at the Regional Agency for Environmental Protection of Sicily in Palermo (ARPA SICILIA - Unità Operativa Complessa ST3).

RESULTS AND DISCUSSION

Macroscopic and microscopic diagnostic characters of plants collected in this study matched with the descriptions of European specimens reported in the literature (see CHERIF *et al.*, 2016 and references therein). Macroscopically, our thalli of *C. fragile* were dark green in colour, ranging from 18 to 25 cm high, and composed of spongy and cylindrical fronds dichotomously branched, 0.5-1.0 cm in diameter, fixed by a spongy, basal holdfast (Fig. 3). Internal structure consisted of interwoven filaments ending in a layer of siphonous swellings, called utricles that were tightly compressed together. Microscopic details of thalli revealed that utricles were usually more or less cylindrical (190-230 μm wide and 680-790 μm long) with a distinct

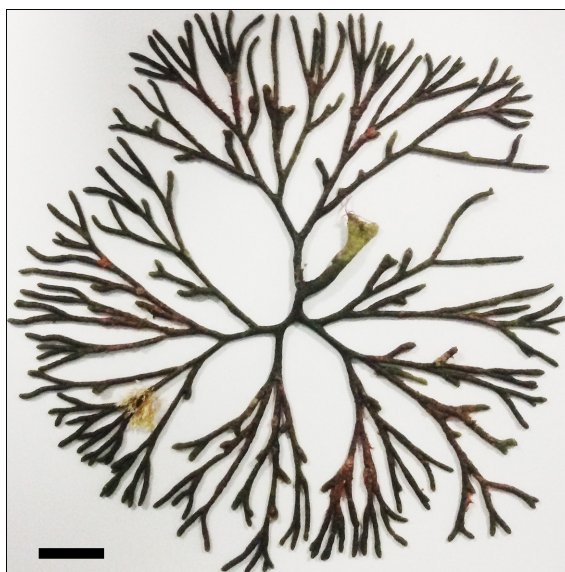


Fig. 3. Herbarium specimen of *C. fragile* ssp. *fragile* stored in the personal herbarium of G. Bellissimo at the Regional Agency for Environmental Protection of Sicily in Palermo (Unità Operativa Complessa ST3) (scale bar: 3 cm). (Photo: G. Bellissimo)

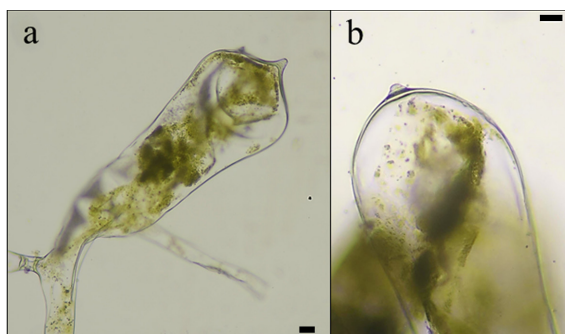


Fig. 4. Utricles of *C. fragile* ssp. *fragile*: a) pointed mucron; b) roundish mucron (scale bar: 50 μm). (Photo: F. Galfo)

constriction in the middle. The apex of the utricles was rounded and characterized by the presence of pointed and occasionally roundish mucrons (28.6-50.6 μm long), confirming the identification of this subspecies (Fig. 4). Oblong gametangia (75-85 μm wide and 240-290 μm long), one per fertile utricule, born laterally on the sub-apical parts of utricule, were found only in the specimens collected in October 2016 and in August 2017.

Codium fragile is one of the most important invasive marine algae becoming a dominant component of invaded habitats with dramatic ecological consequences on native understo-

rey assemblages (CARLTON & SCANLON, 1985; SCHEIBLING & ANTHONY, 2001). Recent studies indicated that the expansion and establishment of *C. fragile* have been likely favoured by the presence of hard coastal defence structures (e.g. breakwaters and seawalls), by providing novel and suitable habitats for its colonization and persistence (BULLERI & AIROLDI, 2005; BULLERI *et al.*, 2007). Along the north-east coast of the Adriatic Sea, where human-made structures have proliferated to control the erosion of sandy beaches, *C. fragile* is one of 14 macrophytes introduced in the last three decades (ORLANDO-BONACA, 2010), representing an important component of low intertidal assemblages of these habitats (BULLERI *et al.*, 2006). Although *C. fragile* was found only stranded on the beach, the high frequency of its findings recorded throughout the year let us think that it has settled on the nearby breakwaters occurring in the area. This leads to hypothesize it probably was carried from the surface currents of the north Adriatic Sea through vegetative propagation that plays a key role in long-distance dispersal (WATANABE *et al.*, 2009). However, this species was not previously reported among the components of

marine flora along the Abruzzi coast (FURNARI *et al.*, 2010), thus suggesting that the colonization on artificial habitats is recent and confirming its rapid spread.

CONCLUSIONS

The significance of invasive species in marine ecosystems worldwide has been discussed intensively in recent years from different ecological and economic points of view considering their complex and multilevel impacts on the introduced ecosystems. The knowledge of non-indigenous species status and their spreading in coastal areas is essential for an effective management of such habitats in order to plan appropriate strategies for protection and conservation of biodiversity.

Thus, additional studies have to be performed on this alien alga, integrating the existing information with a field survey in order to investigate about distribution, abundance, dynamics and impacts on marine environment and identify some of mechanisms underlying its successful establishment.

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**Prvi nalaz invazivne zelene alge *Codium fragile* ssp. *fragile*
(Chlorophyta, Bryopsidales) u vodama talijanske pokrajine Abruzzi,
srednji Jadran**

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SAŽETAK

Autori izvješćuju po prvi put o nalazu invazivne zelene alge *Codium fragile* ssp. *fragile* (Surin-gar) Hariot s jadranske obale talijanske pokrajine Abruzzo (središnji Jadran). Nekoliko talija je pro-nađeno na plaži u mjestu Silvi Marina u studenom 2015. godine. Ova vrsta, porijeklom iz istočne Azije, se rasprostranila na nekoliko Sredozemnih lokacija gdje je vjerojatno unesena plovilom ili akvakulturom školjkaša.

Ključne riječi: središnje Jadransko more, *Codium fragile* ssp. *fragile*, prvi nalaz, unesene vrste