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## NEW RECORDS OF NON-INDIGENOUS ALGAL SPECIES IN SLOVENIAN COASTAL WATERS

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### ABSTRACT

*New records of non-indigenous algal species in Slovenian coastal waters are presented. The red alga *Asparagopsis armata* Harvey (*Falkenbergia rufolanosa* phase) and the green alga *Codium fragile* subsp. *fragile* (*Suringar*) Hariot were collected in shallow waters in the period of the last five years. The author discusses the presence of other non-native algal species in the northern Adriatic and the importance of some vectors of introduction.*

**Key words:** non-indigenous algal species, Slovenian coastal waters, northern Adriatic Sea

## NUOVE SEGNALAZIONI DI SPECIE ALGALI NON-INDIGENE IN ACQUE COSTIERE SLOVENE

### SINTESI

*L'articolo riporta nuove segnalazioni di specie algali non-indigene in acque costiere slovene. L'alga rossa *Asparagopsis armata* Harvey (fase *Falkenbergia rufolanosa*) e l'alga verde *Codium fragile* subsp. *fragile* (*Suringar*) Hariot sono state raccolte in acque poco profonde negli ultimi cinque anni. L'autrice discute sulla presenza di altre specie alloctone nell'Adriatico settentrionale e l'importanza di alcuni vettori d'introduzione.*

**Parole chiave:** specie algali non-indigene, acque costiere slovene, Adriatico settentrionale

## INTRODUCTION

In the last three decades, at least 40 non-indigenous marine species have been recorded in the northern Adriatic Sea, among them 14 species of introduced macrophytes (reviews in Orlando-Bonaca, 2001 and Krnac, 2009; additional data in Curiel *et al.*, 2002). Different authors have documented the presence of four non-indigenous algal species in Slovenian waters.

In 1991, the tetrasporophyte (*Falkenbergia rufolana* phase) of the red alga *Asparagopsis armata* Harvey was recorded for the first time in Slovenian coastal waters and in the northern Adriatic (M. Richter, *pers. comm.*). Six years later, gametophyte plants were recorded in Croatian waters near Senj (M. Richter, *pers. comm.*). This species originates from Australia and/or New Zealand and it was introduced to the Mediterranean Sea unintentionally with oysters (Ribera & Boudouresque, 1995). The presence of the alga in Slovenian coastal waters was reported also by Battelli (2000).

In 1992, the presence of *Codium fragile* subsp. *fragile* (Suringar) Hariot (as *Codium fragile* subsp. *tomentosoides* (van Goor) P.C. Silva) was noticed for the first time by Munda (1992). The finding of the subspecies in Slovenian coastal waters was confirmed in the following years (Munda, 1993; Battelli & Vukovič 1995; Battelli, 1996, 2000). This green alga originates in the Pacific Ocean around Japan and it spread remotely either as an associated unintentional introduction attached to shellfish as oysters, attached to ships' hulls or as spores in ballast tanks. Ribera & Boudouresque (1995) reported that the presence of the subspecies in the Mediterranean Sea was firstly confirmed in French waters in 1950. Subsequently it appeared at both near and distant sites, with no apparent link to either the direction of the currents or the distance.

In 1995, the filamentous tetrasporophyte – *Trilliella* "pink cotton wool" phase of the red alga *Bonnemaisonia hamifera* Hariot was found in Slovenian coastal waters (M. Richter, *pers. comm.*). This species originates in the Pacific and was probably introduced with shellfish from Japan (Gollasch, 2006).

In 1998, the green alga *Ulva scandinavica* Bliding was recorded for the first time in Slovenian coastal waters and in the Adriatic Sea (Battelli & Tan, 1998). Before that, the species that originates from Sweden and Norway was recorded in the Mediterranean Sea only on the West and South coast of Italy (Battelli & Tan, 1998).

The aim of this paper is to provide new data about the presence of the introduced algae in Slovenian coastal waters. The current state of the non-indigenous algal species in the area is also discussed.

## MATERIAL AND METHODS

The Slovenian coastal sea covers the southern part of the Gulf of Trieste. It is a shallow semi-enclosed gulf with a maximum depth of ca. 33 m in waters off Piran. Its coastline is approximately 46.7 km long. The Slovenian coastal area is affected by freshwater inflows and local sources of pollution, mostly anthropogenic impacts such as intensive farming, sewage outfalls, and mariculture (Francé & Mozetič, 2006; Mozetič *et al.*, 2008; Grego *et al.*, 2009). Many activities such as urbanisation and massive tourism have modified the natural shoreline (Turk, 1999).

From 2006 to 2010, benthic macroalgae were sampled in the upper-infralittoral belt (depth range from 1 to 4 m) in at least 51 sites selected in order to assess the ecological status of macroalgal communities, as required by the European Water Framework Directive 2000/60/EC (WFD) (Orlando-Bonaca *et al.*, 2008; Orlando-Bonaca & Lipej, 2009). Additionally, macroalgae were sampled from the water surface down to 10 m of depth in order to characterize benthic habitat types (Lipej *et al.*, 2007, 2008). These studies were broadened in the last years, as required by the Marine Strategy Framework Directive 2008/56/ES (Orlando-Bonaca *et al.*, 2010a, 2010b).

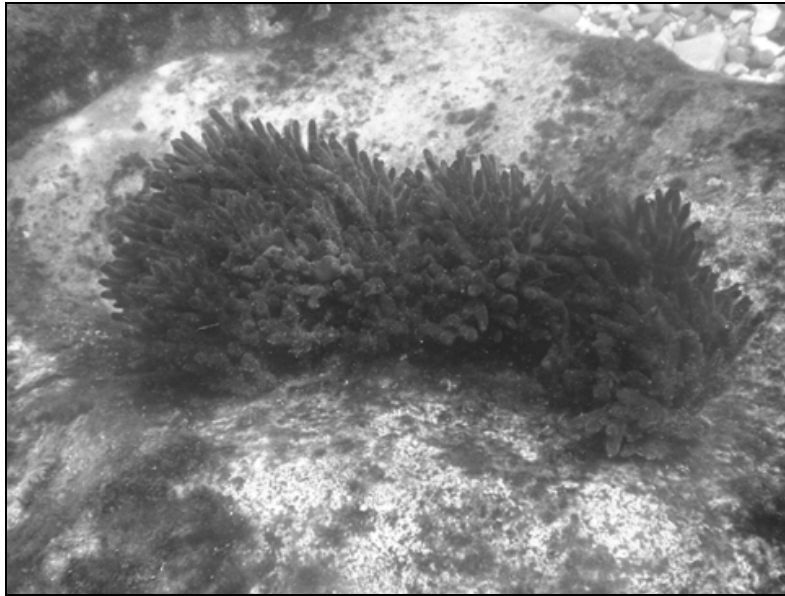
Collected samples were placed in plastic bags and the material was transported to the Marine Biology Station of the National Institute of Biology for analysis. Species identification of macroalgae was carried out in the laboratory in accordance with Ribera *et al.* (1992), Gallardo *et al.* (1993), Battelli (1996), Gomez Garreta *et al.* (2001), and Bressan & Babbini (2003).

## RESULTS AND DISCUSSION

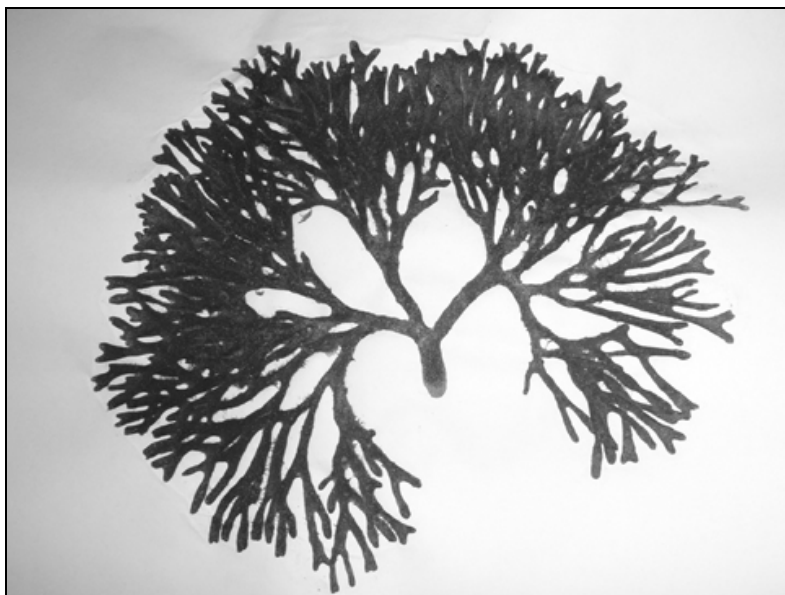
Two non-indigenous algal species were collected in Slovenian coastal waters in the past five years. Samples of *C. fragile* subsp. *fragile* were collected twice (Tab. 1). In summer 2006, a single thallus was found at 3 m of depth at the Cape of the Piran peninsula, during regular monitoring sampling (Orlando-Bonaca *et al.*, 2008). In 2007, 2008 and 2009, the alga was not present in any sample. In August 2010, the subspecies was found to be much more abundant (average density 4 thalli m<sup>-2</sup>) in the same site, along a coastal segment 50 m long, in a depth range from 1 to 1.5 m. Various unidentified red filamentous algae were growing epiphytically on thalli (Figs. 1, 2). The subspecies could be considered as established in this area; however, it is too early to evaluate its potentially damaging impact on the native algal associations.

**Tab. 1: Records of non-indigenous algal species in Slovenian coastal waters from the period of the last 5 years.**  
**Tab. 1: Podatki o tujerodnih vrstah alg v slovenskih obalnih vodah iz obdobja zadnjih 5 let.**

Species	Sampling site	Date	Depth (m)	Average density (thalli m <sup>-2</sup> )
<i>Codium fragile</i> subsp. <i>fragile</i>	Cape Piran	24.07.2006	3.0	a single thallus
	Cape Piran	25.08.2010	1.5	4
<i>Asparagopsis armata</i>	Marina Izola	26.06.2008	1.0	3
	Cape Ronek	02.09.2008	1.0	2



**Fig. 1: *Codium fragile* subsp. *fragile* in the summer 2010 at the Cape of the Piran peninsula. (Photo: L. Lipej)**  
**Sl. 1: *Codium fragile* subsp. *fragile* poleti 2010 na rtu Piranskega polotoka. (Foto: L. Lipej)**



**Fig. 2: Herbarium specimen of *C. fragile* subsp. *fragile* collected in the summer 2010. (Photo: M. Orlando-Bonaca)**  
**Sl. 2: Herbarijski primerek *C. fragile* subsp. *fragile*, nabran poleti 2010. (Foto: M. Orlando-Bonaca)**

In the Italian part of the Gulf of Trieste, *C. fragile* subsp. *fragile* was firstly reported by Godini & Avanzini (1988). Nowadays, the subspecies is commonly found in the northern area of the Gulf (Duino-Sistiana sampling sites) as reported in Falace (2000) and Ceschia *et al.* (2007). Scheibling and Gagnon (2006) provide clear evidence that competitive interactions with large, canopy-forming brown algae can limit the growth of *C. fragile* subsp. *fragile* on the Atlantic coast of Nova Scotia (Canada) but, once established, *Codium* meadows inhibit the re-establishment of native canopy-forming species. Molecular genetics analyses of widely distributed populations of subsp. *fragile* and of herbarium samples suggest that this is the only invasive form among the recognized subspecies of *C. fragile* (Provan *et al.*, 2008).

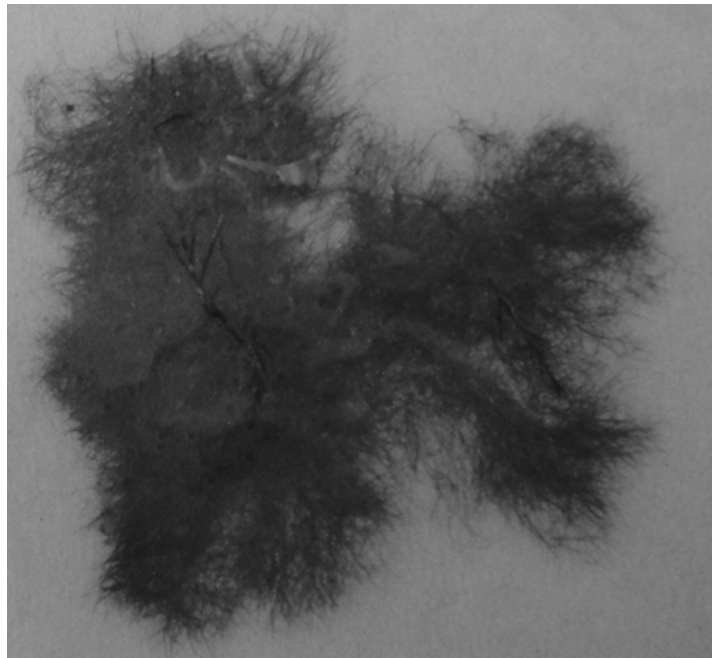
The tetrasporophyte of *A. armata* was collected in summer 2008 on limestone breakwater boulders of the Marina Izola (Tab. 1, Fig. 3). The alga was present along a coastal segment 20 m long. In the same year, some more thalli of the species were found at Cape Ronek on a sandstone terrace. The alga was not found during the last two years.

In 1978, *A. armata* was firstly reported for the Gulf of Trieste (Giaccone, 1978). Nowadays, the tetrasporophyte of the species is reported to be commonly found in Italian waters of the Gulf of Trieste (mostly in Miramare, Barcola and Aurisina sites) (Falace, 2000). However, the CIESM Atlas of Exotic Macrophytes in the Mediterranean Sea (2009) defines the species as "infrequent" for the Adriatic Sea.

*B. hamifera* has never been found in any macroalgal sample collected by the Marine Biology Station. Falace (*pers. comm.*) has not found the species in the Italian part of the Gulf of Trieste. Anyhow, the CIESM Atlas of Exotic Macrophytes (2009) reports on one local record of the species in the Italian part of the Gulf (which is also the only record for the Adriatic Sea), but the bibliography is currently not available. It is therefore impossible to confirm the presence of this red alga in Slovenian waters.

The presence of *U. scandinavica* was not reconfirmed for Slovenian coastal waters. Moreover, it has never again been reported for the Mediterranean Sea after the publication of Battelli & Tan (1998). Some authors reported its presence on the Atlantic coasts of France, Portugal and Spain (Diaz-Tapia & Bárbara, 2005; Dizerbo & Herpe 2007; Araujo *et al.*, 2009). But according to AlgaeBase (Guiry & Guiry, 2010) and WoRMS (Appeltans *et al.*, 2010) registers, this name is currently regarded as a taxonomic synonym of *Ulva rigida* C. Agardh.

Although just two non-indigenous algal species appear nowadays to be established in Slovenian coastal waters, it is reasonable to expect the list to expand in the near future. Other non-indigenous algal species were found to be well established in the northern Adriatic, and they could easily reach the Slovenian Sea, both from Italian and Croatian waters. In the years from 1992 to 1994, three invasive algae, *Undaria pinnatifida* (Harvey) Suringar, *Sargassum muticum* (Yendo) Fensholt, and



**Fig. 3: Herbarium specimen of *Asparagopsis armata* collected in the summer 2008. (Photo: M. Orlando-Bonaca)**  
**Sl. 3: Herbarijski primerek *Asparagopsis armata*, nabran poleti 2008. (Foto: M. Orlando-Bonaca)**

*Antithamnion pectinatum* (Montagne) J. Brauner were recorded in the Venetian Lagoon (Curiel *et al.*, 1994, 1995, 1996, 1998). These seaweeds were introduced into European waters along with *Crassostrea gigas*, in the late 1960s (Critchley *et al.*, 1983; Rueness, 1989). They quickly colonized the hard substrata in the Venetian Lagoon, competing very well with indigenous species, due to their efficient reproduction mechanisms (Curiel *et al.*, 1998). In 1996, a brown alga from the genus *Sorocarpus* was first recorded in the Mediterranean Sea, again in the Venetian Lagoon (Curiel *et al.*, 1999). Some years later, Curiel *et al.* (2002) reported the finding of *Polysiphonia morrowii* Harvey, and *Desmarestia willii* Reinch (as *Desmarestia confervoides* (Bory de Saint-Vincent) M. E. Ramírez & A. F. Peters) in the same area. Moreover, in 2000 *Lomentaria hakodatensis* Yendo, known from China, Japan and Korea, was found in the Venetian Lagoon (Curiel *et al.*, 2006). The last record concerns *Acrothamnion preissii* (Sonder) E.M. Wollaston, originating from Western Australia, that was collected in July 2007 in the Marano and Grado Lagoon (Falace *et al.*, 2009).

Other three invasive algal species are considered to be established in the Croatian part of the northern Adriatic Sea. The tropical alga *Caulerpa taxifolia* (M. Vahl) C. Agardh, accidentally introduced from the Oceanographic Museum in Monaco into the natural environment (Meinesz & Hesse, 1991), was found in the Adriatic Sea in Stari Grad Bay (Hvar Island, Croatia) and in Malinska (Krk Island) in 1994, and in the Barbat Channel (Dolin Island) in 1996 (Žuljević & Antolić, 1998). The alga was only partially eradicated from Malinska (Žuljević & Antolić, 1998). *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque, originating from South-western Australia, is currently considered more dangerous for natural habitats of the northern Adriatic. The first record of the species in the Adriatic dates from 2000 at the Pakleni Islands (Žuljević *et al.*, 2003). Nowadays, more than 60 affected locations (also in the northern Adriatic) were recorded, with the species changing native macroalgal populations (Despalatović *et al.*, 2008). The third invasive species present in Croatian North Adriatic waters is the red filamentous alga *Womersleyella setacea* (Hollenberg) R.E. Norris.

The seaweed has Indo-Pacific-Caribbean origin and was recorded for the first time in the Rijeka Bay in 1997 (Battelli & Arko Pijevac, 2005). Since then, the species has frequently been found in at least 50 Adriatic locations, where its dense monospecific turfs on rocky bottoms are covering native algal assemblages (Despalatović *et al.*, 2008).

Nowadays it is well known that marine non-indigenous species are mostly transported intentionally and/or unintentionally for aquaculture purposes, or unintentionally with marine traffic (transport of organisms in ballast waters, sediments in ballast tanks and hull fouling) (Gollasch & Leppäkoski, 1999). Krmac (2009) reported that ballast waters that are released in the Port of Koper mostly originate from Porto Marghera (Venetian Lagoon) where vessels unload the cargo and introduce ballast waters. Subsequently, water from their ballast tanks is released into the Koper Bay when they reload. The possibility of new non-native species introduction into Slovenian waters is therefore still high, since the Venetian Lagoon is considered to be rich in invasive species. From studies concerning the tracking of the invasive species spread, underlying the accurate identification of cryptic taxa, it is evident that the number of taxonomic units involved in bio-invasion is currently underestimated (Provan *et al.*, 2008). As the future of the introduced species is unpredictable, it would be very useful to enforce the international collaboration in the Adriatic, and to constantly update the global data bank on introduced species and receptive habitats.

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This paper is dedicated to the memory of our wonderful colleague and friend Žiga Dobrajc, who recently tragically passed away.

## NOVI ZAPISI O TUJERODNIH VRSTAH ALG V SLOVENSKIH OBALNIH VODAH

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## POVZETEK

Avtorica podaja pregled novih podatkov o tujerodnih vrstah alg v slovenskih obalnih vodah. Rdeča alga *Asparagopsis armata* Harvey (faza *Falkenbergia rufolanosa*) in zelena alga *Codium fragile* subsp. *fragile* (Suringar) Hariot sta bili v zadnjih petih letih opaženi in nabrani v plitvem morju. Za zdaj sta to edini tujerodni algi, ki sta ustaljeni v slovenskem morju. Avtorica nadalje razpravlja o navzočnosti drugih vrst tujerodnih alg v Severnem Jadranu in o načinih vnosa. Tujerodne vrste bi lahko v slovensko morje prispele iz Beneške lagune, kjer so doslej potrdili navzočnost vsaj 8 vrst tujerodnih alg. Prav tako so 3 druge vrste alg že prisotne ob hrvaški obali v Severnem Jadranu in jih lahko zato upravičeno pričakujemo tudi v slovenskem delu Jadrana.

**Ključne besede:** tujerodne vrste alg, slovenske obalne vode, Severni Jadran

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