Plant Biosystems, Vol. 142, No. 1, March 2008, pp. 120 – 125

Taylor & Francis
Taylor & Francis Group

SHORT COMMUNICATION

The extensive development of the turf-forming red alga *Womersleyella setacea* (Hollenberg) R. E. Norris (Rhodophyta, Ceramiales) in the Bay of Boka Kotorska, Montenegro (southern Adriatic Sea)

CLAUDIO BATTELLI & FABIO RINDI

University of Primorska, Faculty of Education of Koper, Slovenia

Abstract

In August 2003, dense turfs formed by the filamentous red alga *Womersleyella setacea* (Hollenberg) R. E. Norris were found in the open part of the Bay of Boka Kotorska, on the shore of Montenegro (southern Adriatic Sea). The habitat and morphology of the alga are described and the impact of the massive development of this species on the structure of the algal communities is discussed.

Key words: *Macrobenthic algae, southern Adriatic Sea, sublittoral, turf-forming,* Womersleyella setacea

More than 90 taxa of macrophytes are known to have been introduced into the Mediterranean Sea through different routes (e.g. fouling on ship hulls and fishing nets), and at least 9 of them are considered invasive (Verlaque, 1994; Boudouresque & Verlaque, 2002). Some of the most invasive introductions are represented by species of filamentous turf-forming algae (Cinelli & Sartoni, 1969; Verlaque, 1989; Patzner, 1998). These have colonized the Mediterranean in the last decades, producing substantial changes in the structure of benthic algal communities (Airoldi et al., 1995; Piazzi & Cinelli, 2001). The expansive growth of turfs is considered an indicator of disturbance and is frequently associated with negative effects upon biodiversity (Barth & Fagan, 1990; Morand & Briand, 1996). The red alga *Womersleyella setacea* (Hollenberg) R.E. Norris, which was first recorded by Verlaque (1989) as *Polysiphonia setacea* in 1987, is one of the most invasive filamentous turf-forming algae of the Mediterranean Sea. To date, however, the origin and the time of its introduction are unknown. This species has been reported to produce thick turfs covering large portions of sublittoral bottoms in several regions of the Mediterranean (Airoldi et al., 1995; Athanasiadis, 1997; Piazzi & Cinelli, 2001). Compared to the rest of the basin, records of *W. setacea* for the Adriatic are relatively recent. Reports of the presence of this species are available for the eastern coast of the island of Cres and Oštro Cape (Rijeka Bay), for the Kvarner Gulf, Northern Adriatic (Sartoni & Rossi, 1998; Battelli & Arko-Pijevac, 2003, 2005) and at the Tremiti Islands, southern Adriatic (Furnari et al., 1999; Cormaci et al., 2000) (Figure 3).

The Bay of Boka Kotorska is situated on the coast of Montenegro, on the south-eastern Adriatic shore. The literature on the benthic algal flora and vegetation of this area is very limited. The information available consists of studies carried out in the 1940s on the distribution of *Fucus virsoides* (Linardić, 1940, 1949) and more recent investigations on the distribution and composition of the algal communities of different parts of the Bay (Karaman & Gamulin Brida, 1970; Solazzi, 1971; Stjepčević & Parenzan, 1980; Špan & Antolić, 1980; Antolić & Špan, 1992). *W. setacea* did not appear in the list of algal taxa collected from Boka Kotorska Bay in these studies and no mention of the development of filamentous algal turfs was made.

In this short communication, we present observations made during a survey of the algal flora of the open part of the Bay of Boka Kotorska in August 2003. The extensive development of filamentous turfs formed by *W. setacea* was noted. Since this

Correspondence: Claudio Battelli, University of Primorska, Faculty of Education of Koper, Cankarjeva 5, SI-6000 Koper, Slovenia. Tel.: +3865 6631264. Fax: +3865 6631268. E-mail: claudio.battelli@guest.arnes.si

ISSN 1126-3504 print/ISSN 1724-5575 online © 2008 Società Botanica Italiana
DOI: 10.1080/11263500701872747

species appeared in the Adriatic Sea only recently and the presence of dense turf communities dominated by this alga had not been reported for the southern Adriatic, this was an interesting observation, which revealed the aggressive expansion of *W. setacea* in this part of the Mediterranean. Details on the distribution and morphology of the alga are reported.

Materials and methods

Sampling was performed by SCUBA diving at three sites in the sublittoral zone along the outer coast of the Bay of Boka Kotorska: island Mamula (sites A and B) on 12 and 15 August, and Žanjice bay (site C) on 14 August 2003. Site A is located on the southern shore of Mamula island (42° 23′ 40″ N; 18° 33′ 80″ E), whereas site B is located on the northern shore of the island (42° 23′ 60″ N; 18° 33′ 80″ E). At both sites, the rocky bottom degrades quite steeply (with 40–45° angle) up to 35 m depth. At this depth, the bottom becomes horizontal and consists of a plateau in which numerous karst formations, filled by sediments, occur. Site C is situated in the northern part of Žanjice bay (42° 24′ 20″ N, 18° 34′ 20″ E), facing south. At this site, the bottom consists of rock with about 45° slope up to a depth of about 20 m, and subsequently of sand with an inclination of about 20°. At the three sites, the rocky bottom is formed by upper Cretaceous limestones and dolomites (Riđanović, 1993).

The average annual surface sea temperature is approximately 18°C. The lowest values occur in winter (about 10°C); in the spring, the temperature rises gradually to 18°C, and in summer it ranges from 20°C in June to 25–28°C in August and early September (Vesna Mačić, personal communication). The prevailing winds are bora (blowing from north–north east) in winter, sirocco (from south–south east) in spring and autumn, and landward breeze (sea breeze) in summer (Magaš, 2002).

Direction and average speed of currents vary at different times of the year. The average speed is about 0.25 m s^{-1}, but it may occasionally reach 2 m s^{-1}. Currents are generally strongest in spring and weakest in summer. In summer, the current normally flows from the open sea into the Bay, with north-westerly direction and a speed of approximately 0.4 m s^{-1}. At times of heavy rainfall, a strong current flows from the Bay to the open sea (direction south-east), with a speed of 1.3 m s^{-1} (Stjepčević, 1974).

Samples of turf were collected from hard and soft substrata at intervals of 5 m, from 5 to 25 m depth. The material collected was preserved in 4% buffered seawater–formaldehyde solution. Voucher specimens are deposited in the herbarium of the Faculty of Education of Koper, University of Primorska (Slovenia). Observations and measurements of the main morphometric characters were made using an OLYMPUS-BX51 microscope (DP-SOFT Imaging System DP70).

Algal nomenclature follows AlgaeBase (Guiry & Guiry, 2007).

Results and discussion

At the time of the survey, the bottom of the three sampling sites was colonized by macroalgal communities that appeared very poor in species number, and by patches of the seagrass *Posidonia oceanica* (Linnaeus) Delile. The most common macroalgae were the brown *Padina pavonica* (Linnaeus) J.V. Lamouroux, *Cystoseira* spp., *Dictyota* spp., the red *Laurencia* spp., *Osmundaria volubilis* (Linnaeus) R.E. Norris, *Peyssonnelia* spp. and the green *Halimeda tuna* (J. Ellis & Solander) J.V. Lamouroux and *Flabellia petiolata* (Turra) Nizamuddin. A dense red filamentous turf, 2–3 cm thick, was widespread at all sites examined, covering extensive portions of the sea bottom at depths between 12 and 25 m. The turf covered all substrata available: rocks, sand, and surface of the rhizomes of *P. oceanica*. The microscopic examination of the samples showed that the turf was mostly formed by *W. setacea*.

The morphology of *W. setacea* was in agreement with descriptions of this species from other parts of the Mediterranean. The alga was brown-red to reddish in colour and consisted of an extensive system of prostrate axes, from which poorly ramified erect axes arose. Filaments of *W. setacea* were formed by a central axis surrounded by 4 pericentral cells devoid of cortication; the diameter of the prostrate filaments ranged between 66 and 106 μm (average = 80.22 μm; standard deviation = 9.42 μm; $n = 16$). The diameter of the pericentral cells was 35–45 μm (average = 37.95 μm; standard deviation = 3.11 μm; $n = 12$) and the length was 11–184 μm (average = 125.00 μm; standard deviation 43.39 μm; $n = 12$). The cells contained numerous discoid, irregularly distributed plastids; in the erect axes, the pericentral cells were frequently arranged in slightly oblique longitudinal rows. The diameter of the segments of the erect axes ranged between 38 and 76 μm (average 57.18 μm; standard deviation = 11.75 μm; $n = 16$) and the length was 50–100 μm (average = 80.20 μm; standard deviation = 13.94 μm; $n = 16$). The prostrate axes were attached to the substratum by short multicellular rhizoids, 31–137 μm long (average = 65.62 μm; standard deviation 44.07 μm; $n = 8$), cut off as separate cells from the pericentral cell and producing distally a multicellular pad. Trichoblasts occurred at the top of the filaments, with 1–3 (4) dichotomies.

(Figure 1a–f; Figure 2a–f). No reproductive structures were observed in any sample.

The presence of *W. setacea* in the Adriatic has been reported relatively recently. In general, the information available on this species for the Adriatic is much more limited than for the rest of the Mediterranean. The present study represents the first record of the invasive behaviour of *W. setacea* in the southern Adriatic and our observations suggest that the aggressive development of *W. setacea* represents the most serious invasive event in this area. The massive cover of this alga on sublittoral bottoms of the Bay of Boka Kotorska is in agreement with the fast and aggressive propagation reported for the western Mediterranean Sea (Verlaque, 1989, 1994; Airoldi et al., 1995; Athanasiadis, 1997; Rindi et al., 1999; Piazzi & Cinelli, 2001; Boudouresque & Verlaque, 2002). Turf communities in which this species was a quantitatively important component were also recorded in the northern Adriatic, at several sites in the Bay of Rjieka (Battelli & Arko-Pijevac, 2003, 2005; Jaklin & Arko-Pijevac, 1997). At the time of this survey, large-sized erect algae, such as *Cystoseira* and *Sargassum*, appeared generally rare. Furthermore, the leaves of many plants of the seagrass *P. oceanica* appeared to be reduced in number (only 2–3 per rhizome). The general impression is that the extensive

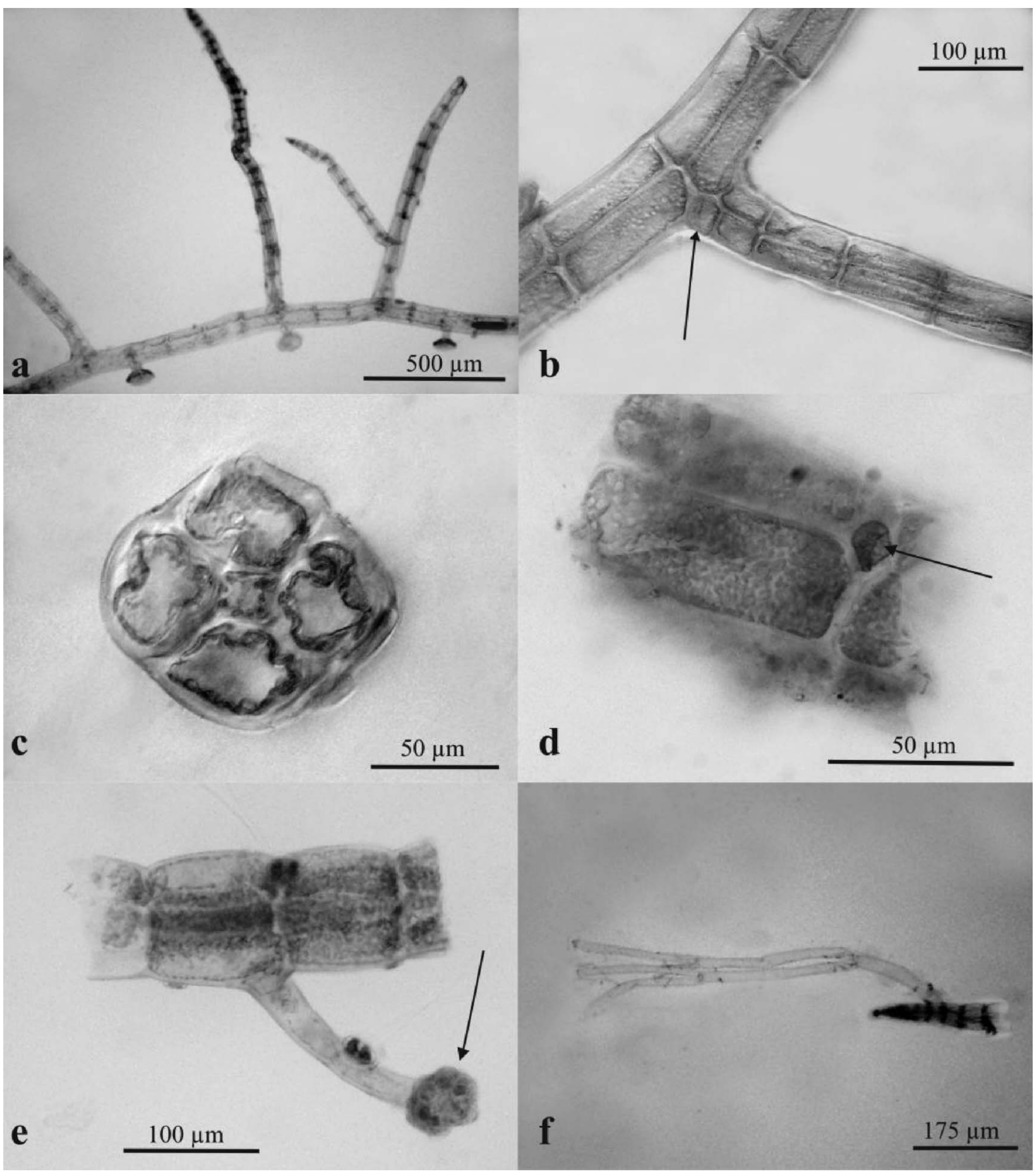

Figure 1. *Womersleyella setacea* from the open part of the Boka Kotorska Bay, Montenegro, Southern Adriatic, August 2003. (a) General aspect (habit). (b) Detail of a main prostrate part of thallus with lateral development of new young erect axes from scar cells (arrow). (c) Transverse section of axis with 4 pericentral cells. (d) Discoid chromatophores and a scar cell (arrow). (e) Multicellular rhizoid, cutting off as a separate cell from the distal end of a pericentral cell, with multicellular tips (arrow). (f) Apical portion of an erect branch bearing trichoblasts.

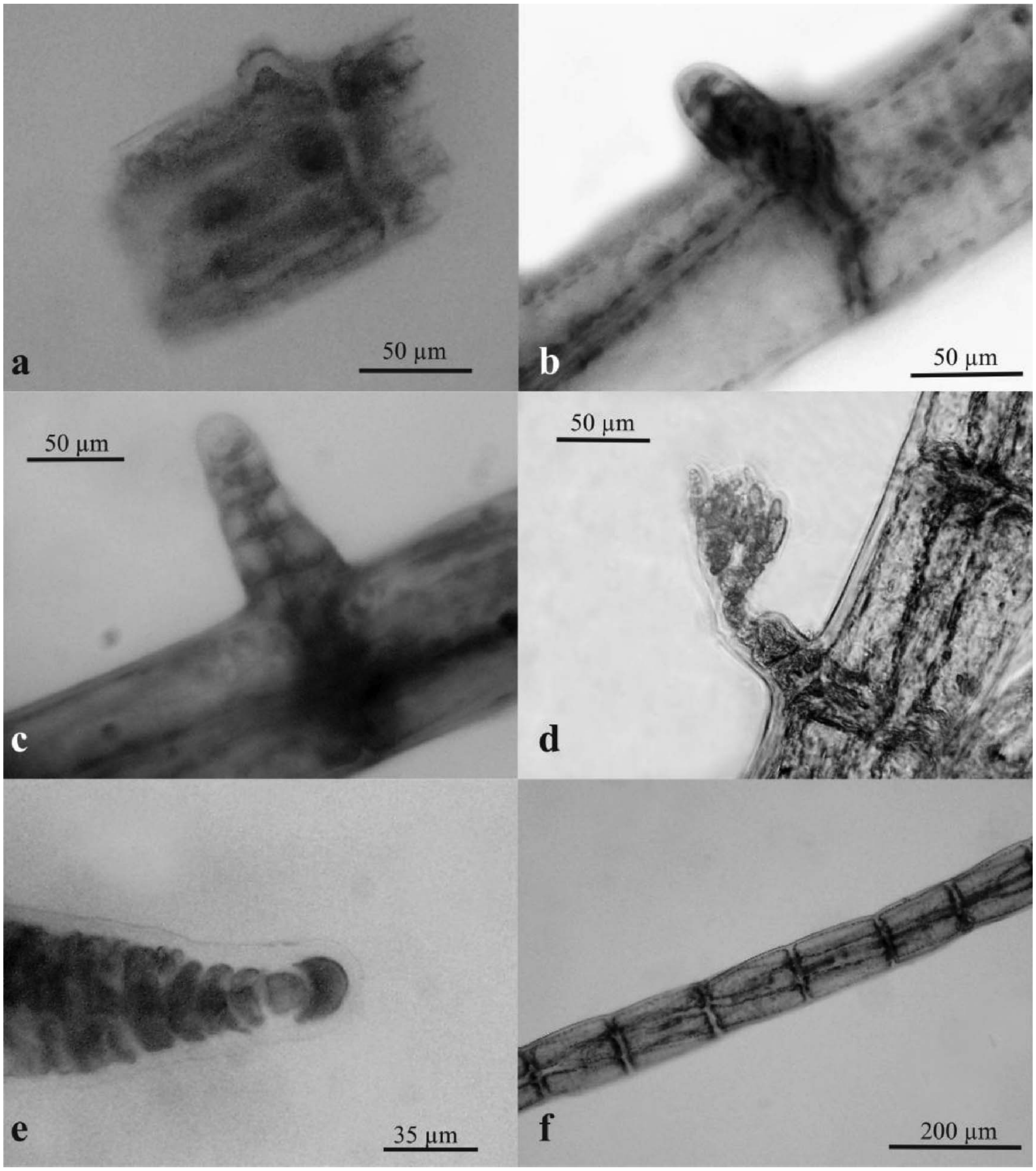

Figure 2. *Womersleyella setacea* from the open part of the Boka Kotorska Bay, Montenegro, Southern Adriatic, August 2003. (a) (b) (c) Development of new young erect axes from pericentral cell. (d) Development of new young erect axes with trichoblast. (e) Young axis with apical cell. (f) Detail of an erect branch showing cells rows obliquely arranged.

turf of *W. setacea* negatively affected the development of several erect algae and of *P. oceanica*. The monopolization of the substratum by turf-forming filamentous algae can prevent the development of other macroalgae by overgrowth and accumulation of sediment, which makes the settlement of spores and the survival of juvenile stages impossible, thus reducing species diversity and equitability (Airoldi et al., 1995; Airoldi & Virgilio, 1998; Morand & Briand, 1996; Piazzi & Cinelli, 2001).

The population of *W. setacea* of the Bay of Boka Kotorska seems to reproduce only vegetatively, since no tetrasporangia or gametangia were observed. This is also in agreement with observations available for other Mediterranean regions; specialized reproductive structures have never been recorded, not even in very detailed field investigations (Airoldi et al., 1995) and intensive culture studies (Rindi et al., 1999). This trait is in contrast with the triphasic life history typical of most red algae, which is assumed to take place in the native Hawaiian population of *W. setacea*; Hollenberg (1968) reported the presence of tetrasporangia in the original collections on which the description of the species was based. The causes of this phenomenon are unknown. Comparative molecular investigations on the phylogeny and biogeography of Mediterranean and extra-Mediterranean populations of *W. setacea*, as well as other closely

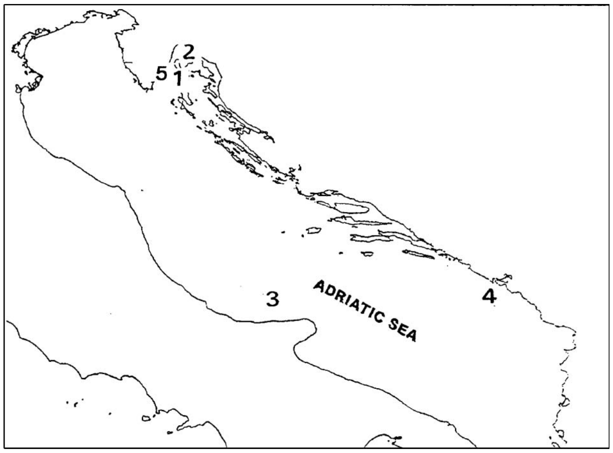

Figure 3. Chronological records of Womersleyella setacea in the Adriatic Sea. (1) 1997 July August. Cres, Kvarner Gulf, Croatia, Northern Adriatic (Sartoni & Rossi, 1998). (2) 1997 May October. Tremiti Island (Cormaci et al., 2000). (3) 1997 Oštro Cape, Kvarner Gulf, Croatia, Northern Adriatic (Battelli & Arko-Pijevac, 2003, Battelli & Arko-Pijevac, 2005,). (4) 2003 August. Boka Kotorska Bay, Montenegro, Southern Adriatic, record presented in this paper, (5) 2004 August. Rabac, Kvarner Gulf, Croatia, Northern Adriatic, the last record (personal comm.).

related species, would be helpful to clarify the relationships of the invasive strain. It is interesting to observe, however, that rapid spread by vegetative fragmentation is a typical trait of many invasive seaweeds, associated with some of the most harmful algal introductions that have taken place in the last decades in the Mediterranean.

The present observations are limited to three sites and a single sampling date; it is therefore obvious that further investigations, repeated in time and extended to larger geographical areas, will be necessary to understand how widespread and persistent the dominance of *W. setacea* is. On the basis of information available for other parts of the Mediterranean, it is reasonable to expect that the structure of the benthic algal communities of the Adriatic Sea will be negatively influenced by the development of *W. setacea* and other introduced species. Excessive growth of turf-forming algae can be expected to produce effects similar to those observed for the western Mediterranean (Barth & Fagan, 1990; Morand & Briand, 1996). Further detailed investigations on the distribution of these forms (in particular *W. setacea*) and their interaction with native species should be therefore carried out in the future.

Acknowledgements

We wish to thank Dr Valentina Turk and Tihomir Makovec from the Marine Biology Station of Piran, who kindly helped us during the observation and measurements of morphometric characters of the samples.

References

Airoldi L, Rindi F, Cinelli F. 1995. Structure, seasonal dynamics and reproductive phenology of a filamentous turf assemblage on a sediment influenced, rocky subtidal shore. Bot Mar 38:227–237.

Airoldi L, Virgilio M. 1998. Responses of turf-forming algae to spatial variations in the deposition of sediments. Mar Ecol Prog Ser 165:271–282.

Antolić B, Špan A. 1992. The inventory of benthic flora of the Bay Boka Kotorska (southern Adriatic). Acta Adriat 33(1/2):75–84.

Athanasiadis A. 1997. North Aegean marine algae IV. *Womersleyella setacea* (Hollenberg) R. E. Norris (Rhodophyta, Ceramiales). Bot Mar 40:473–476.

Barth H, Fagan L. 1990. Eutrophication-related phenomena in the Adriatic Sea and in other Mediterranean coastal zones. Commission of the European Communities water Pollution Research Report. 16 p.

Battelli C, Arko-Pijevac M. 2003. Structure and seasonal variations of a subtidal turf-dominated assemblage of the Oštro Cape (Rijeka Bay, Nothern Adriatic Sea). In: 38th European Marine Biology Symposium: EMBS 38, Marine biodiversity, Aveiro, Portugal, 8–12 September 2003. Abstract book, programme. Aveiro: Universidade de Aveiro. 173 p.

Battelli C, Arko-Pijevac M. 2005. Development of the invasive turf-forming red algae *Womersleyella setacea* (Hollenberg) R. E. Norris on subtidal shores of Rijeka Bay (nothern Adriatic Sea). Annales Ser Hist Nat 15(2):215–222.

Boudouresque CF, Verlaque M. 2002. Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. Mar Poll Bull 44:32–38.

Cinelli F, Sartoni G. 1969. *Acrothamnion* J. Ag. (Rhodophyta, Ceramiaceae): genere algale nuovo per il mare Mediterraneo. Pubbl Staz Zool Napoli 37:567–574.

Cormaci M, Furnari G, Alongi G, Catra M, Serio D. 2000. The benthic algal flora on rocky substrata of the Tremiti Islands (Adriatic Sea). Plant Biosyst 134:133–152.

Furnari G, Cormaci M, Serio D. 1999. Catalogue of the benthic marine macroalge of the Italian coast of the Adriatic Sea. Bocconea 12:5–214.

Guiry MD, Guiry GM. 2007. AlgaeBase version 4.2. World-wide electronic publication, National University of Ireland, Galway. Available: http://www.algaebase.org (accessed 14 February 2007).

Hollenberg GJ. 1968. An account of the species of *Polysiphonia* of the central and western tropical Pacific. Pacific Sci 22:56–98.

Jaklin A, Arko Pijevac M. 1997. Benthic biocoenoses of the Sv. Marko Islet (Rijeka Bay). Period Biol 99:219–228.

Karaman G, Gamulin Brida H. 1970. Contributionaux recherches des biocoenoses benthiques du golfe de Boka Kotorska. Studia marina 4:3–42.

Linardić J. 1940. Prilog poznavanju geografskog jadranskog fukusa-*Fucus virsoides* (Don) J. Agardh. God. Oceanogr Inst Split 2:115–122.

Linardić J. 1949. Studije o jadranskom fukusu (*Fucus virsoides*). Acta botan. Univ. Zagreb 12/13:7–131.

Magaš D. 2002. Natural-geographic characteristics of the Boka kotorska area as the basis of development. Geoadria 7/1:51–81.

Morand P, Briand X. 1996. Excessive growth of macroalgae: A symptom of environmental disturbance. Bot Mar 39:491–516.

Patzner RA. 1998. The invasion of *Lophocladia* (Rhodomelaceae, Lophotalieae) at the northern coast of Ibiza (western Mediterranean Sea). Boll Soc Hist Nat Balears 41:75–80.

Piazzi L, Cinelli F. 2001. Distribution and dominance of two introduced turf-forming macroalgae on the coast of Tuscany, Italy, northwestern Mediterranean Sea in relation to different habitats and sedimentation. Bot Mar 44:509–520.

Riđanović J. 1993 Die Bucht von Kotor und Meeresspiegelanstieg im Holozän, W.G.A., 87, Würzburg, 305 – 312.

Rindi F, Guiry MD, Cinelli F. 1999. Morphology and reproduction of the adventive Mediterranean rhodophyte *Polysiphonia setacea*. Hydrobiologia 398/399:91 – 100.

Sartoni G, Rossi S. 1998. New records for the benthic algal flora of the Northern Adriatic Sea. Fl Medit 8:9 – 15.

Solazzi A. 1971. Reperti algologici delle Bocche di Cattaro. Thal Salentiana 5:3 – 18.

Stjepčević J. 1974. Ekologija dagnje (*Mitylus galloprovincialis* Lam.) i kamenice (*Ostrea edulis* L.) u gajiliatima Bokokotarskog zaliva. Studia marina 7:1 – 164.

Stjepčević J, Parenzan P. 1980. Il golfo delle Bocche di Cattaro—condizioni generali e biocenosi bentoniche con carta delle sue due baie interne: di Cattaro e di Risano. Studia Marina 9–10:3 – 145.

Špan A, Antolić B. 1983. Prilog poznavanju fitobentosa Crnogorskog primorja (Južni Jadran). Studia Marina 13 – 14:87 – 110.

Verlaque M. 1989. Contribution à la flore des algues de Méditerranée: Espéces rare ou nouvelles pour les côtes Françaises. Bot Mar 32:101 – 113.

Verlaque M. 1994. Inventaire des plantes introduites en Méditerranée: Origines et répercussions sur l'environnement et les activités humaines. Océanol Acta 17:1 – 23.