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# DISAPPEARANCE OF *FUCUS VIRSOIDES* J. AGARDH FROM THE SLOVENIAN COAST (GULF OF TRIESTE, NORTHERN ADRIATIC)

*Claudio BATTELLI*
Ulica Sergeja Mašere 5, SI 6000 Koper, Slovenia
e-mail: claudio_battelli@t-2.net

## *ABSTRACT*

*At the end of 2010, a significant decline in populations of* Fucus virsoides *was observed in the Slovenian coast (Gulf of Trieste, northern Adriatic), which prompted the undertaking of a direct observation assessment of changes in the occurrence of these populations along the Slovenian coast over the period 2010–2015. The paper presents a comparison between historical and current data on the presence of* F. virsoides *along the Slovenian coast, gathered through in situ surveys and from literature, and proposes the possible causes that have led to the decline and disappearance of* F. virsoides *populations along the Slovenian coastline.*

**Key words:** *Fucus virsoides*, occurrence, disappearance, Slovenian coast, northern Adriatic

# SCOMPARSA DI *FUCUS VIRSOIDES* J. AGARDH DALLA COSTA SLOVENA (GOLFO DI TRIESTE, ALTO ADRIATICO)

## *SINTESI*

*Un importante declino dei popolamenti a* Fucus virsoides *è stato osservato verso la fine del 2010 lungo la costa della Slovenia (Golfo di Trieste, Alto Adriatico). Nella nota vengono riportati i risultati di uno studio sulla distribuzione di* F. virsoides *lungo la costa della Slovenia nel periodo 2010–2015, attraverso l'osservazione diretta. Si mettono inoltre a confronto i dati storici con quelli attuali sulla presenza di* F. virsoides *in quest'area attraverso uno studio in situ e su fonti bibliografiche. Vengono avanzate delle ipotesi sulle possibili cause che hanno portato al rapido declino e alla successiva scomparsa di questa specie lungo la costa della Slovenia.*

**Parole chiave:** *Fucus virsoides,* presenza, scomparsa, costa della Slovenia, Alto Adriatico

## INTRODUCTION

The brown alga *Fucus virsoides* J. Agardh is the only species of the genus *Fucus* that occurs in the Adriatic Sea (Ardissone, 1886; Schiffner & Vatova, 1938; Linardić, 1949; Pignatti, 1962; Giaccone & Pignatti, 1967; Munda, 1972). In the past, it was the only brown alga and the most conspicuous canopy-forming macrophyte to be found along the Slovenian coast, patchily distributed on the hard substrates of its midlittoral zone (Vukovič, 1980, 1982; Munda, 1993a; Battelli, 2002; Lipej *et al*., 2004; Rindi & Battelli, 2005; Battelli, 2013; Orlando-Bonaca *et al*. 2013). *F. virsoides* has been recorded along the Adriatic shores from Venice in Italy to Albania (*e.g*., Linardić, 1949; Kashta, 1995/96; Mačić, 2006). It is not clear which factors limit its occurrence. In addition to geomorphological characteristics, the key limiting factors are probably high salinity and high average annual temperatures (Vouk, 1938; Linardić, 1949). In recent years, particular attention has been paid to climate-related variables (Boero & Bonsdorff, 2007; Boero *et al*. 2008; Munda, 2008).

In studies carried out to date, the distribution pattern and abundance of *F. virsoides* have been related to substratum configuration, exposure to winds, wave direction (Lipizer *et al*., 1995; Orlando-Bonaca *et al*., 2013), low salinity of sea water (Vouk, 1938; Linardić, 1949; Giaccone & Pignatti, 1967; Munda, 1972), low concentration of pollutants (Vukovič, 1980, 1982; Munda & Kremer, 1977; Kremer & Munda, 1982; Munda, 1972, 1981, 1982, 1991, 1993a, 1993b), and type of substratum (Vukovič, 1982; Battelli, 2002; Rindi & Battelli, 2005; Battelli, 2013). Several authors revealed the midlittoral zone to be an extremely variable environment, characterized by periodic fluctuations of several ecophysiological parameters during the tidal cycles, such as light, temperature, hydrodynamics and grazing (Pignatti, 1962; Giaccone & Pignatti, 1967; Munda, 1972; Battelli, 2013).

The impact of anthropogenic disturbance on the structure, dynamics and composition of the macroalgal midlittoral assemblages of northern Adriatic was highlighted by several authors (Lipizer *et al*., 1995; Vukovič, 1980, 1982; Munda, 1993a, 1993b, 2000; Battelli, 2002; Rindi & Battelli, 2005; Lipej *et al*., 2004, 2006; Falace *et al*., 2010; Orlando-Bonaca *et al*., 2013).

The use of historical data in marine ecology provides a valid instrument for detecting and understanding recent changes that may occur in marine ecosystems particularly due to human activities (Jackson *et al*., 2001). This approach is also important for designing appropriate policies for habitat management and conservation, so that the changes can be assessed through long-term analysis (*e.g*. Falace *et al*., 2010).

A significant decline in the abundance of populations of this species was observed at the end of autumn 2010 along the entire Slovenian coast (Gulf of Trieste, northern Adriatic). This appears to be the largest decline event ever recorded in the midlittoral assemblages of this area. To date, no explanation has been proposed about the cause(s) of this event.

In order to illustrate the decline of *F. virsoides* populations along the Slovenian coast, their historical distribution was compared to recent field observations. The aims of this study were: (a) to summarize the distribution of *F. virsoides* along the Slovenian coast based on literature information, and (b) to document the state of the populations of the species in this area during the period 2010–2015. Based on the current distribution, the possible causes of and the factors responsible for the observed disappearance of *F. virsoides* populations are proposed.

## MATERIAL AND METHODS

### Study area

The Slovenian coast is located in the southern part of the Gulf of Trieste and extends for approximately 46 km from Sv. Jernej's Bay (the cape Debeli rtič – the north side of the Koper Bay) to the Dragonja River (Piran Bay – near the Croatian border). Most of the shore is influenced by dominant winds blowing from North-North-East and from South-East. The sea surface temperature generally ranges between a minimum of 7 °C in February and a maximum of 28 °C in August; the salinity from 28 in spring and summer to 36–37 in winter. The vertical extent of the midlittoral zone (between Mean Higher High Water and Mean Lower Low Water) is approximately 90 cm (ARSO, 2015). The Slovenian coastal area is characterized by its two main bays: Koper Bay and Piran Bay. The rocky substrate consists mainly of Eocene flysch layers, with alternating solid sandstone and soft marl (Ogorelec *et al*., 1997); in the area of Izola (San Simon), the coast is formed of Alveoline-nummulitic limestone (Pavlovec, 1985). The morphology of the coastline varies from steep flysch cliffs to sloping beaches mainly composed of allochthonous substrata made of sandstone and marl gravel, and pebbles of different size. In the recent decades, the Slovenian coastal area has been subjected to many anthropogenic influences such as farming, mariculture, urbanization and large-scale tourism-related activities, with the result that nowadays only about 18% of the shore can be considered in its natural state (Turk *et al*., 2007).

### Historical information about the presence of *Fucus virsoides*

Long-term changes of the *F. virsoides* populations along the Slovenian coast were analysed and a comparison was made between historical data on the occurrence of these communities in the past and in the period 2010–2015. Only the collectors who gathered samples of *F. virsoides* from the Slovenian coast were cited. The first record dates back to 1856 – Pius Titius (1801–1884) collected the species along the coast of Piran under the name *Fucus sherardi* (specimens held in the Herbarium of the Slovenian Museum of Natural History, Ljubljana) (Alberti & Battelli, 2002). Giuseppe Accurti (1824–1907), in 1858, first mentioned the presence of this alga along the shores of Koper Bay. In 1858, he published the article "*Cenno sulle alghe di Capodistria*", in which he described in detail 195 species of algae collected in Koper Bay. Another important collector of marine organisms of this period was Antonio Zaratin (1846–1923). His herbarium contains nine samples of *F. virsoides*: two of them, collected in Koper Bay (one in September 1886 and the other in March 1910) and reported as *F. vesiculosus* Ag., are part of, respectively, the "*Herbarium Patavinum*" collection of the Botanical Museum of Padua, and the "*Flora marina Iustinopolitana*" collection of the Gian Rinaldo Carli Gymnasium, Koper. Five samples of *F. virsoides* were collected in Koper Bay as *F. Scherardi* Ag. in May 1886, September 1886, October 1909, January 1910 and May 1910, and they are all preserved in the above-mentioned "*Flora marina Iustinopolitana*". The oldest voucher samples of the Zaratin collection were collected in Piran Bay in August 1885 as *F. Sherardi* Ag., and are currently conserved at the Ruđer Bošković Institute Centar za istraživanje mora, Rovinj - Centre for Marine Research, Rovinj (Croatia) (Battelli & Alberti, 2003).

### Historical information about the distribution of *F. virsoides* populations

The past distribution of *F. virsoides* on the Slovenian coast was assessed using data obtained from a variety of sources, including all available published literature dealing with the presence of *F. virsoides* on the Slovenian coast (Accurti, 1858; Štirn, 1965; Matjašič & Štirn, 1975; Chiesa & Lorenzoni, 1980; Vukovič, 1980, 1982; Munda, 1991, 1993a, 1993b; Battelli, 1999, 2002; Alberti & Battelli, 2002; Battelli & Alberti, 2003; Lipej et al., 2004; Orlando-Bonaca *et al.*, 2013).

The first map of the distribution of *F. virsoides* along the Slovenian coast was drawn by Štirn (1965). Among subsequent publications, some presented detailed maps of the area in its totality (Lipej *et al.*, 2004; Orlando-Bonaca *et al.*, 2013), others only in parts (Piran Bay by Vukovič, 1980, and Koper Bay by Vukovič, 1982).

### Environmental parameters

Data of several physical and chemical parameters of the sea surface, provided by the Environment Agency of the Republic of Slovenia (ARSO), were analysed. The selected parameters included: temperature (°C), salinity, nitrites (μmol $NO_2$/l), nitrates (μmol $NO_3$/l), ammonia (μmol $NH_4$), orthophosphates (μmol $PO_4$/l), total nitrogen (μmol N/l) and silicate (μmol $SiO_2$/l). The monthly means of these data were grouped into seasonal means for the period 2005–2014. The latter period was divided into two main periods, 2005–2010 and 2011–2014, since the onset of the decline of *F. virsoides* populations was observed in late 2010.

### Field work: observations in the period 2010–2015

The distribution of *F. virsoides* on the Slovenian coast in the years 2010–2015 was assessed through year-round field observation, grouping the data by season (i.e. winter comprised the data for January, February and March; spring comprised the data for April, May and June; summer comprised the data for July, August and September; autumn comprised the data for October, November and December). We inspected the whole Slovenian coastline at selected sites, as shown in Table 1, from Sv. Jernej's Bay (the cape Debeli rtič) to the Dragonja River (near the Croatian border), paying special attention to the sites sampled by previous researchers.

The occurrence of *F. virsoides* was assessed visually along the coast during low tide, as the latter provides the best conditions for direct observations. For this purpose, the semi-quantitative categories for the abundance of macroalgae, based on the work of Ballesteros *et al.* (2007) and tested by Orlando-Bonaca *et al.*, (2013), were used: F1= rare to scattered thalli, F2 = abundant patches, F3 = a continuous or almost continuous belt.

The vertical extent of the midlittoral surveyed zone was approximately 1 m and included sandstone and limestone boulders that are not moved by most waves, breakwaters composed of limestone, and sandstone boulders. Excluded from the survey were river mouths, inner parts of commercial harbours, sites to which access was forbidden (such as marinas, hotel beaches, etc.), areas composed of marl, and mobile substrates such as sand, mud, or pebbles, which are mobile in wave conditions, as they are all unsuitable for the development of *F. virsoides*.

### Sampling of *Patella caerulea*

During the period 2010–2015, an increase in the number of the main grazers of the midlittoral zone, *P. caerulea,* was observed (*pers. obs.*). Therefore, throughout April 2015, the density of *P. caerulea* in the rocky midlittoral zone was assessed in 20 sites distributed along the Slovenian coast (from Sv. Jernej's Bay – the cape Debeli rtič to the Sečovlje saltpans). The study examined the same sites as the previous researchers who studied the occurrence of *F. virsoides* populations. In order to estimate the density of *P. caerulea,* the individuals were counted in five randomly chosen 400 $cm^2$ (20 x 20 cm) quadrats at each selected site.

### Data analyses

To evaluate the differences between seasonal mean values of physical and chemical parameters of the sea

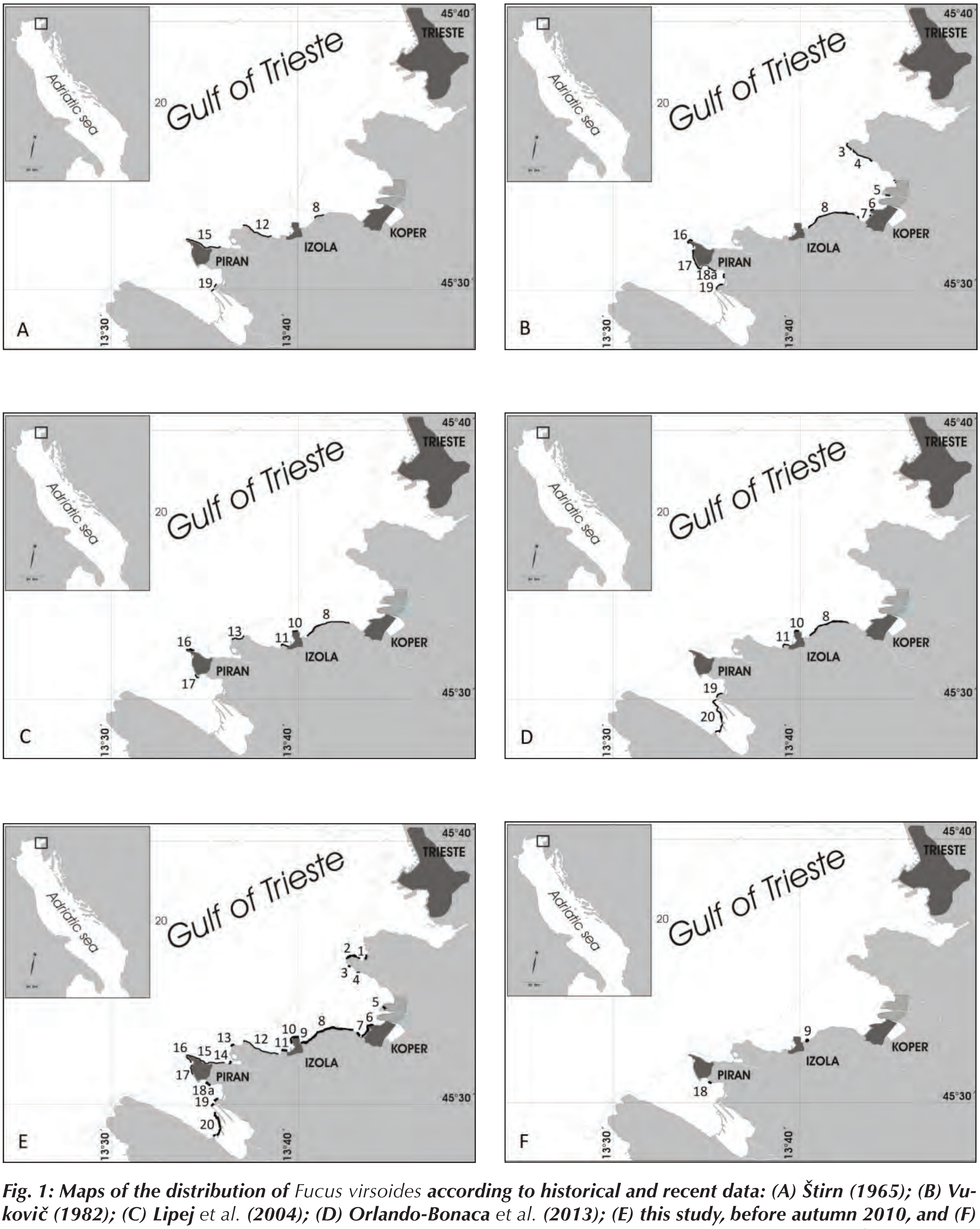


***Fig. 1: Maps of the distribution of*** *Fucus virsoides* ***according to historical and recent data: (A) Štirn (1965); (B) Vuković (1982); (C) Lipej*** *et al.* ***(2004); (D) Orlando-Bonaca*** *et al.* ***(2013); (E) this study, before autumn 2010, and (F) this study, during the period 2011–2015. The black bold lines with numbers indicate the presence of*** *F. virsoides.*
***Sl. 1: Zemljevid razširjenosti vrste*** *Fucus virsoides* ***glede na zgodovinske in novejše podatke: (A) Štirn (1965); (B) Vukovič (1982); (C) Lipej*** *et al.* ***(2004); (D) Orlando-Bonaca*** *et al.* ***(2013); (E) pričujoče delo; pred jesenjo 2010 in (F) pričujoče delo; v obdobju 2011–2015.*** **Črne črte s številkami označujejo pojavljanje vrste** *F. virsoides***.**

surface, the non-parametric Kruskal-Wallis test was used.

## RESULTS AND DISCUSSION

### Long-term distribution of *F. virsoides* populations

The historical and current distribution of the populations of *F. virsoides* along the Slovenian coastline is illustrated in Figure 1. Comparisons between the single distribution reports by Štirn (1965), Vukovič (1982), Lipej *et al*. (2004), Orlando-Bonaca *et al*. (2013) and the present study, for the period before autumn 2010, show an increase in the distribution of this species all along the Slovenian coast. To date, no explanation about the cause(s) of this event has been proposed.

A comparison between the distribution of *F. virsoides* before autumn 2010 (Fig. 1A, 1B, 1C, 1D, 1E) and the findings of the present study covering the period 2011–2015 (Fig. 1F) reveal a drastic decline that began after autumn 2010.

In the period from the winter to summer 2010, *F. virsoides* was present along the Slovenian coastline from Sv. Jernej's Bay (Debeli rtič – near Italian border) to the Sečovlje saltpans (near the Croatian border) (Fig. 1E) with an abundance that ranged between rare to scattered thalli (F1) and a continuous or almost continuous belt (F3) according to the substrates favourable for the development of this species. In Koper Bay, *F. virsoides* was sparsely distributed from Debeli rtič to Sv. Katarina's Bay, Ankaran (sites 1–5), with an abundance of rare to scattered (F1) because of the presence

***Tab. 1: Occurrence and abundance (semi-quantitative) of* Fucus virsoides *in investigated sites, during different seasons. Legend: Sp – spring, Su – summer, A – autumn, W – winter, F1=rare to scattered thalli; F2=abundant patches; F3=a continuous or almost continuous belt.***

***Tab. 1: Prikaz raziskanih mest pojavljanja bračiča (*Fucus virsoides*) in njegove abundance (semi-kvantitativne), v različnih časovnih obdobjih. Legenda: Sp – pomlad, Su- poletje, A- jesen, W – zima, F1=redke do razpršene steljke; F2=gručasta razporeditev; F3=skoraj sklenjen do sklenjen pas.***

| No site | Site | Period | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2010 (W, Sp, Su) | 2010 A | 2011 (W, Sp, Su, A) | 2013 (W, Sp, Su, A) | 2014 (W, Sp, Su, A) | 2015 (W, Sp, Su, A) |
| 1 | Sv. Jernej Bay | F1 | - | - | - | - | - |
| 2 | Cape Debeli rtič | F1 | - | - | - | - | - |
| 3 | Port - Cape Debeli rtič | F1 | - | - | - | - | - |
| 4 | Valdoltra | F1 | - | - | - | - | - |
| 5 | Sv. Katarina | F1 | - | - | - | - | - |
| 6 | Porporela harbor, Koper | F2 | - | - | - | - | - |
| 7 | Koper - Semedela | F2 | - | - | - | - | - |
| 8 | Koper - Izola | F2 | - | - | - | - | - |
| 9 | Viližan bay | F2 | F1 | F1 | F1 | - | - |
| 10 | Izola | F3 | - | - | - | - | - |
| 11 | San. Simon | F3 | - | - | - | - | - |
| 12 | Cape Kane Strunjan | F1 | - | - | - | - | - |
| 13 | Cape Strunjan | F1 | - | - | - | - | - |
| 14 | Strunjan saltpans | F1 | - | - | - | - | - |
| 15 | Fiesa–Madona - Piran | F1 | - | - | - | - | - |
| 16 | Cape Madona Piran | F2 | - | - | - | - | - |
| 17 | Bernardin | F1 | - | - | - | - | - |
| 18 | »Pirat« Bernardin | F1 | F1 | F1 | F1 | F1 | - |
| 18a | Fizine | F1 | - | - | - | - | - |
| 19 | Cape Seča | F1 | - | - | - | - | - |
| 20 | Sečovlje saltpans | F1 | - | - | - | - | - |

of mobile substrata composed mainly of sand or marl and sandstone mobile pebbles in wave conditions. In the southern part of Koper Bay (along the coast between Koper and Izola in sites 7–9), *F. virsoides* populations were dominant on breakwaters with an abundance ranging from scattered thalli (F1) to abundant patches (F2). In the vicinity of ports and main urban areas (Koper, Izola and Piran; sites 6, 10, 16), where the coast is completely artificialized, only a few patches were preserved (F2). In the inner parts of the ports, *F. virsoides* was present as isolated individuals (F1) or in small patches (F2). The largest populations in abundant patches (F2) and in a continuous or almost continuous belt (F3) were observed on the limestone rocky coast all around Izola and Korbat Cape in San Simon near Izola (sites 10 and 11). Along the natural coast (sites 12, 13, 14, 15) extending from San Simon to the Cape of Strunjan, populations of *F. virsoides* were more fragmented with an abundance ranging from rare to scattered (F1) due to the presence of substrata unsuitable for the development of this alga, i.e. substrata composed mainly of sand, mud or marl and of sandstone pebbles that are mobile in wave conditions. A similar situation was observed on the coast stretching from Piran to Forma viva (sites 17–19), near Lucija, and on the breakwaters along the external part of the Sečovlje saltpans (site 20).

### Decline of *Fucus virsoides* populations

During the period from autumn 2010 to autumn 2015, the situation of *F. virsoides* populations turned critical. One of the most striking observations was that no attached *F. virsoides* and not even one individual thallus was observed during field observation in this period, except for sites 9 and 18. At Viližan Bay (site 9), near Izola, and in the inner part of the Sailing Club Pirat near Bernardin (Piran Bay, site 18) (Fig. 1F; Tab. 1), *F. virsoides* were scattered or present with only rare thalli (F1).

Up to 2013, a few small individuals (F1) were observed growing on small natural sandstone pebbles at Viližan Bay, while at Bernardin a very small, patchily distributed population (F2) was observed on an artificial concrete surface of about 6 $m^2$, but unfortunately only up until autumn 2014 (Tab. 1).

### Environmental parameters

From the comparisons of sea surface chemical parameters for the Slovenian coastal sea (MOP, ARSO, 2015), shown in Figure 2, it is evident that the differences in the mean values of single chemical parameters during the periods 2005–2010 (before the decline of *F. virsoides* populations) and 2011–2014, barring a few exceptions, are not that remarkable.

For instance, compared to the period 2005–2010, before the decline of the *F. virsoides* populations, the concentrations of nitrates in the period 2011–2014 were in general slightly lower in all seasons, but the difference was statistically non-significant. A very similar situation was found for total nitrogen, while in silicates, during the summer period, the differences in concentration were statistically significant ($P < 0.001$). For nitrites the concentration was higher—but not statistically significant—in winter and summer during the period 2011–2014. An increase in the concentration of orthophosphate was observed for almost all seasons in the period 2011–2014, especially in spring, when the difference was statistically significant ($P < 0.01$), and autumn, whereas in summer a slight but statistically non-significant decrease would occur. The concentration of ammonia was higher in winter, spring and summer in the period 2011–2014, but with statistical significance only in spring ($P < 0.05$) and summer ($P < 0.01$). The salinity was higher in all seasons except for summer, but not statistically significant. We noticed that the trend and the values of sea temperature remained very similar and statistically non-significant in all seasons in both periods (Fig. 2).

Two decades ago it was found that the trophic conditions in the Gulf of Trieste do not exert a significant impact on the distribution of *F. virsoides* (Lipizer *et al.*, 1995). During our observation many populations of *F. virsoides* were found growing inside small harbours or along boatyards, where fluctuations in salinity and nutrient concentrations are frequent, which is consistent with Lipizer *et al.* (1995) and Orlando-Bonaca *et al.* (2013). Although *F. virsoides* is able to tolerate a wide range of salinity and temperature, our opinion is that it is necessary to confirm this with experimental data, because at the present we do not know the limits of survival of this species in relation to salinity and temperature. According to several authors (e.g., Vouk, 1938; Linardić, 1949; Giaccone & Pignatti, 1967; Munda, 1972; Mačić, 2006), the limiting factors for the presence of *F. virsoides* seem to be extreme salinity and temperatures.

*F. virsoides* is considered an alga with a great tolerance to high pollution levels and variation in many environmental factors such as temperature, salinity, wave exposure, etc. (Lipizer *et al.*, 1995; Orlando-Bonaca *et al.*, 2013). At present we do not know what factor(s) should be considered the potential reason(s) for this drastic event.

### The presence and abundance of grazers

During autumn 2010 (when the first decline of *F. virsoides* was noticed) a substantial increase in the individuals of *P. caerulea* distributed among and immediately above the *F. virsoides* populations was observed, but not evaluated.

The hypothesized increased densities of grazers can lead to the loss of dominant habitat forming species, such as *F. virsoides*. The main grazer that is involved in

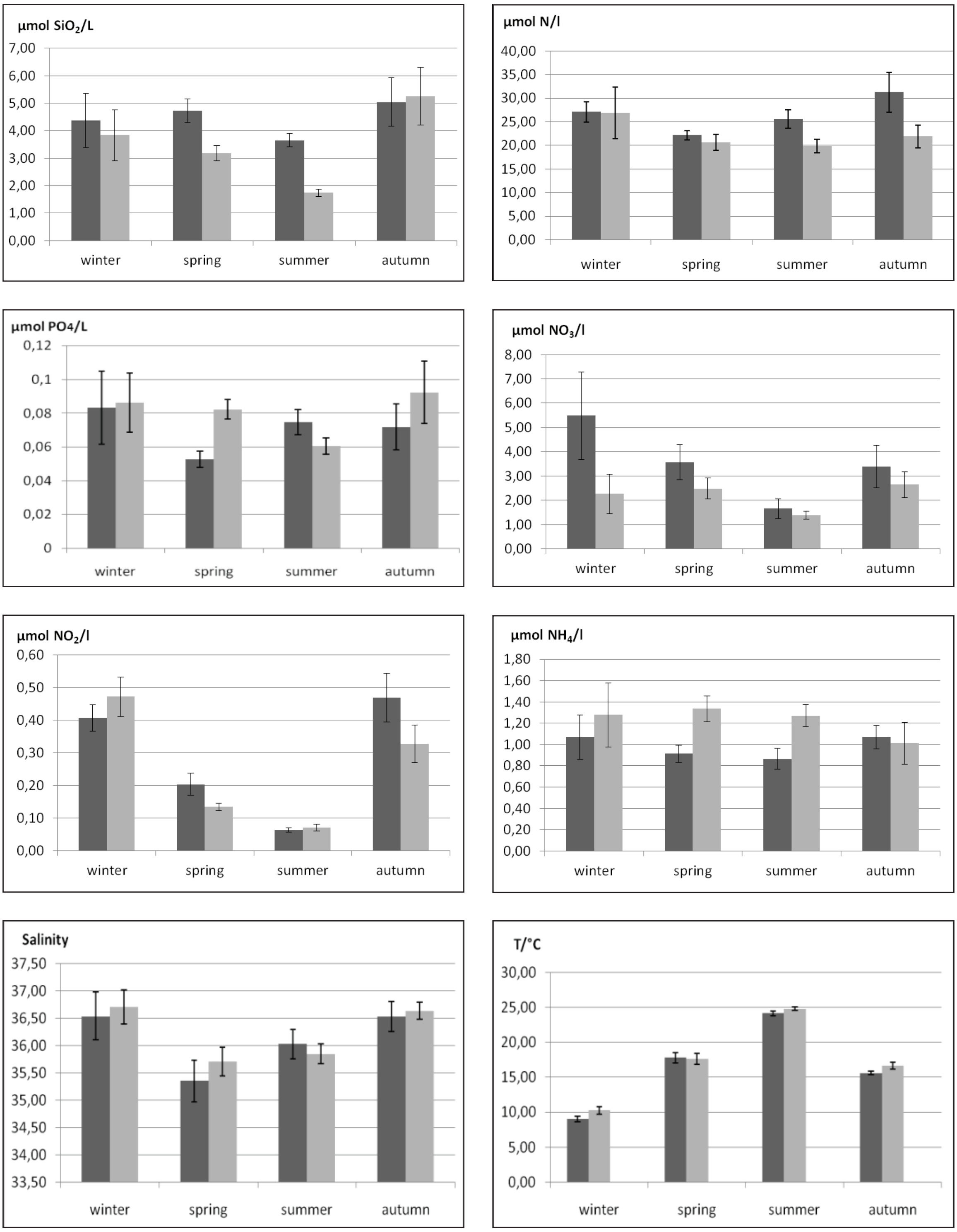


***Fig. 2: Seasonal values (mean ± SE) of sea surface chemical parameters (silicate, nitrogen, orthophosphate, nitrate, nitrite, ammonia and salinity) and physical parameters (temperature) during the periods 2005–2010 (black columns) and 2011–2014 (grey columns) for the Slovenian coastal sea (Source of data: MOP, ARSO, 2015 - http://www.arso.gov.si/en/).***

***Sl. 2: Sezonske vrednosti (povprečje ± SN) kemijskih (silikati, dušik, ortofosfati, nitrati, nitriti, amonijak in slanost) in fizikalnih (temperatura) parametrov v obdobjih 2005–2010 (črni stolpci) in 2011–2014 (sivi stolpci) v površinskem sloju slovenskega morja (Vir podatkov: MOP, ARSO, 2015 - http://www.arso.gov.si/en/).***

this process along the Slovenian coast is *P. caerulea* (De Min & Vio, 1997). Population densities of this species in different study sites are shown in Table 2. The densities occurring at the sites situated along the coastline between Koper and Izola and at Bernardin (both 11/400 $cm^2$) were higher than the average of limpets at selected sites along the Slovenian coastline. The minimum density was observed at site KP Semedela (3/400 $cm^2$).

The massive presence of *P. caerulea* along the Slovenian coastline leads us to consider the possibility that this might be one of the factors explaining the decline of *F. virsoides* populations. Our field observations are supported by several previous studies that considered limpets, such as *P. caerulea,* as important structuring agents of midlittoral communities, controlling the distribution of algae (Arrontes *et al*., 2004). It is well documented that the composition and dynamics of midlittoral communities in rocky shores are strongly influenced by the activity of grazers (Hawkins *et al*., 1992; Jenkins *et al*., 1999; Arrontes *et al*., 2004). It is obvious that not all species in the grazer assemblage have the same effect on algae (Underwood & Jernakoff, 1981). Other gastropods (Cervin & Åberg, 1997, Viejo *et al*., 1999), chitons (Dethier & Duggins, 1984) or crustaceans may play relevant roles, but limpets are very often the key grazers in midlittoral zone (Hawkins *et al*., 1992; Johnson *et al*., 1997, 1998; Jonsson *et al*., 2006).

***Tab 2. Average density (number of specimens/400 cm²) of*** *Patella caerulea* ***at selected sites along the Slovenian coast during April 2015.***
***Tab. 2: Povprečna gostota (št. osebkov/400 cm²) vrste*** *Patella caerulea* ***na izbranih postajah vzdolž slovenske obale v aprilu 2015.***

| No site | Site | Density (individuals/ 400 cm²) | stdev |
|---|---|---|---|
| 1 | Sv. Jernej's Bay | 5.00 | 0.71 |
| 2 | Cape Debeli rtič | 5.20 | 0.84 |
| 3 | Port - Cape Debeli rtič | 8.80 | 3.35 |
| 4 | Valdoltra | 5.25 | 0.45 |
| 5 | Sv. Katarina's Bay | 5.00 | 1.00 |
| 6 | Porporela harbor, Koper | 8.80 | 4.15 |
| 7 | Koper - Semedela | 3.00 | 0.71 |
| 8 | Koper - Izola | 11.00 | 3.65 |
| 9 | Viližan Bay | 5.80 | 0.84 |
| 10 | Izola | 4.80 | 0.45 |
| 11 | San Simon | 7.40 | 2.30 |
| 12 | Cape Kane Strunjan | 9.40 | 3.05 |
| 13 | Cape Strunjan | 7.60 | 1.14 |
| 14 | Strunjan saltpans | 5.80 | 2.49 |
| 15 | Fiesa–Madona - Piran | 7.80 | 2.17 |
| 16 | Cape Madona Piran | 7.40 | 2.30 |
| 17 | Bernardin | 11.00 | 6.08 |
| 18 | »Pirat« Bernardin | 4.80 | 1.30 |
| 18a | Fizine | 8.50 | 1.92 |
| 19 | Cape Seča | 8.00 | 2.51 |
| 20 | Sečovlje saltpans | 3.60 | 1.14 |
| | Total of averages | 5.96 | 2.99 |

## CONCLUSIONS

There are probably several reasons for the observed decline of *F. virsoides* populations. Many factors have been suggested as possible causes of this occurrence, including urbanization and eutrophication (Gessner, 1969; Gessner & Hammer, 1971; Munda, 1981, 1982; Kremer & Munda, 1982, Vukovič, 1982; Munda, 1993a, 1993b; Munda & Veber, 1996), as well as climate change (Munda, 2008). Some authors (*e.g.*, Munda, 1981; Kremer & Munda, 1982; Vukovič, 1982; Munda, 1997) suspect that an excess of nitrates may be responsible for the disappearance of *F. virsoides* populations from polluted sites, although Lipizer *et al*. (1995) considers *F. virsoides* to have a great tolerance to high pollution levels. The comparison of seasonal variation of nitrates during the period before the disappearance of this species with the values after its decline indicates a slight decrease in these values. Therefore, we are inclined to consider this parameter as insufficient to trigger this event. Describing the benthic vegetation in the midlittoral zone of Koper Bay, Vukovič (1982) highlights the presence of *F. virsoides* populations on solid substrates (natural sandstone and jetties) along the entire coastline from the cape Debeli rtič to Izola with preference for limestone, which is in accordance with our observations.

Based on our 2010–2015 field observations, the *F. virsoides* populations along the Slovenian coast can be considered highly endangered, and the high density of limpets, present all along the Slovenian coast, might be one of the factors explaining the decline of *F. virsoides* populations and, consequently, their disappearance.

More environmental data is needed to be able to establish precisely the causes leading to the decline of *F. virsoides* populations in the Slovenian coast. Experimental data is also needed on the effects of organic and chemical pollution on this species. The role of grazers, such as *P. caerulea,* highlighted in this study, deserves further attention, too. Therefore, we strongly believe that further research and monitoring programmes of biological, physical and chemical parameters are necessary to evaluate the level of their impact on *F. virsoides* populations.

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# IZGINOTJE BRAČIČA (*FUCUS VIRSOIDES* J. Agardh) IZ OBALE SLOVENIJE (TRŽAŠKI ZALIV, SEVERNI JADRAN)

*Claudio BATTELLI*
Ulica Sergeja Mašere 5, SI 6000 Koper, Slovenia
e-mail: claudio_battelli@t-2.net

*POVZETEK*

*V članku avtor poroča o izrazitem upadanju bračiča* (Fucus virsoides) *vzdolž obale Slovenije (Tržaški zaliv, severni Jadran), ki se je začelo proti koncu leta 2010. Podaja rezultate o razširjenosti bračiča v Sloveniji v obdobju 2010-2015, ki jih je avtor pridobil na podlagi opazovanja na terenu* (in situ). *Avtor primerja zgodovinske podatke o pojavljanju* bračiča *na tem območju s sedanjimi na temelju raziskav na terenu in bibliografskih virov. Podaja tudi nekatere predpostavke o morebitnih vzrokih, ki so povzročili hitri upad in posledično izginotje te vrste vzdolž obale Slovenije.*

**Ključne besede:** *Fucus virsoides,* pojavljanje, izginotje, obala Slovenije, severni Jadran

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