Estonian Journal of Ecology, 2012, **61**, 2, 135–147 doi: 10.3176/eco.2012.2.05

First findings of the benthic macroalgae *Vaucheria* cf. *dichotoma* (Xanthophyceae) and *Punctaria tenuissima* (Phaeophyceae) in Estonian coastal waters

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Received 19 December 2011, revised 7 March 2012, accepted 8 March 2012

Abstract. The north-eastern Baltic Sea is known to have relatively low species richness due to unfavourable salinity for many species. Here I report new records of two phytobenthic species for the Estonian marine flora: the yellow-green alga *Vaucheria* cf. *dichotoma* (L.) Martius and the epiphytic brown alga *Punctaria tenuissima* (C. Agardh) Greville. Besides, the former is the first observation of a species of the class Xanthophyceae in the Estonian coastal waters and is the first macrophytobenthic record of the class in the entire Gulf of Riga. The brown alga *P. tenuissima* was found for the first time in the entire Gulf of Finland. Morphological characteristics are shown for both species and possible reasons behind the new records are discussed.

Key words: yellow-green algae, brown algae, NE Baltic Sea, phytobenthos, distribution, wrack flora, epiphytes.

INTRODUCTION

The Baltic Sea is the world's largest brackish water body. It holds nearly 400 macroalgal species across the wide latitudinal salinity gradient, with a rapid decline in marine species richness from south to north (Middelboe et al., 1997; Larsen & Sand-Jensen, 2006). The lowest richness is predicted to be found at the horohalinicum salinity (5–8) and is reflected in relatively low macroalgal species in the NE Baltic Sea (Schubert et al., 2011).

In Estonian coastal waters, macroalgae have been recorded since the end of the 18th century (for a complete review see Martin et al., 2004). However, regular quantitative phytobenthic investigations started as late as in the 1960s (Trei, 1965), and continuous monitoring of phytobenthos started in 1995 (Martin et al., 2003). By today about 60 macroalgal taxa have been recorded in the Estonian coastal waters (according to the benthos database at the Estonian Marine Institute). Within these registered species, several algae have been found or rediscovered in the Estonian marine waters during recent decades (Martin & Kersen, 2011).

The genus *Vaucheria* de Candolle belongs to the class Xanthophyceae (yellow-green algae), and is one of the two benthic macroalgal genera within xanthophytes besides *Tribonema* (Christensen, 1987). They are mainly found on soft bottoms where they form felty growths on the mud (Snoeijs, 1999). Even though *Vaucheria* was long regarded as a green algae (Johnson & Merritt, 2002), molecular data show that Xanthophyceae are most closely related to Phaeophyceae (Lee, 2008).

Currently 73 species of the genus *Vaucheria* are known worldwide (Graham et al., 2009; Guiry & Guiry, 2011). In Europe, approximately 40 species are found, mainly in freshwater and terrestrial habitats (Rieth, 2009). In the Baltic Sea *Vaucheria* are mostly found sterile and therefore are difficult to identify to species level (Johnson & Merritt, 2002; Ott & Oldham-Ott, 2003; Rieth, 2009). According to the most recent macroalgal distribution index (HELCOM, 2012), 13 *Vaucheria* species have been recorded in the Baltic Sea, most of them found in the southern parts of the basin. Nevertheless, none of the Estonian marine phytobenthic studies have identified *Vaucheria* spp. previously (e.g. Trei 1983, 1986; Kukk, 1993, 1995). In the northern Baltic Sea, *Vaucheria* forms dense mats of loose macro-algae where it inhabits bays with soft sediment bottoms in the Baltic Proper, Gulf of Bothnia, and Gulf of Finland (Kautsky, 1992; Bergström & Bergström, 1999; Lehvo & Bäck, 2001).

The taxonomy of *Vaucheria* is based on sexual organs (oogonia and antheridia), which are observed in the field only sporadically. A widespread opinion is that *Vaucheria* spp. are difficult to identify to subgeneric levels (Nemjova & Kaufnerova, 2009; Schagerl & Kerschbauber, 2009). *Vaucheria dichotoma* (L.) Martius is a euryhaline species, preferably growing in brackish water, but it can also inhabit fresh waters (Christensen, 1988). It is believed to be of brackish or marine origin (Henschel et al., 1992) and is widespread along the European coasts, being distributed from the Black Sea to the Barents Sea (Guiry, 2010). In the Baltic Sea, *V. dichotoma* is the most dominant species of the genus and it occurs from the Blekinge Archipelago on the south coast of Sweden up to the northern Bothnian Bay (Snoeijs, 1999; J. Hansen, unpublished data), inhabiting also shallow bays of Finland (Holmström et al., 2007) and the southern part of the Baltic Sea (Nielsen et al., 1995).

The marine benthic alga *Punctaria tenuissima* (C. Agardh) Greville (= *Despotrichum undulatum* (J. Agardh) Reinke) is a member of the family Chordariaceae. It is characterized by an erect flattened blade arising from the discoid holdfast, having 'hairs' from the surface edge and surface cells that are quadrate or rectangular in rows (Fletcher, 1987). *Punctaria tenuissima* originates from the Atlantic region and has been found in the North Atlantic, the Mediterranean, the Black Sea, and even the Indian Ocean (Guiry & Guiry, 2011). This species has been reported as a non-indigenous benthic species in the Mediterranean (Ambrogi, 2000), where, due to its epiphytic life strategy, it was introduced probably by oyster culture (Boudouresque & Verlaque, 2010). In the Baltic Sea, *P. tenuissima* has been recorded from the Kattegat to the southern

Bothnian Sea (Nielsen et al., 1995), inhabiting a salinity gradient from 5 to 24 (Snoeijs, 1999). It is rare in the outer archipelago and is often found as an epiphyte on other algae, *Zostera marina* or *Ruppia maritima* (Tolstoy & Österlund, 2003). *Punctaria tenuissima* has been found also in littoral communities of the Finnish Archipelago Sea (Hällfors et al., 1975; Boström et al., 2004) up to the Gulf of Finland (Nielsen et al., 1995); however, it is absent from the Gulf of Finland nowadays (HELCOM, 2012).

The aim of this paper is (1) to report on the recent findings of *Vaucheria* and *Punctaria*, present the morphological characteristics of the collected material, and (2) to give a review of potential reasons why the algae have not been recorded previously in the Estonian marine flora.

MATERIAL AND METHODS

The study material includes data of a marine benthic habitat inventory (EU LIFE project: Marine Protected Areas in the Eastern Baltic Sea) in the Estonian coastal waters (Fig. 1) in 2005–2006, wrack monitoring in the Gulf of Riga (MARMONI

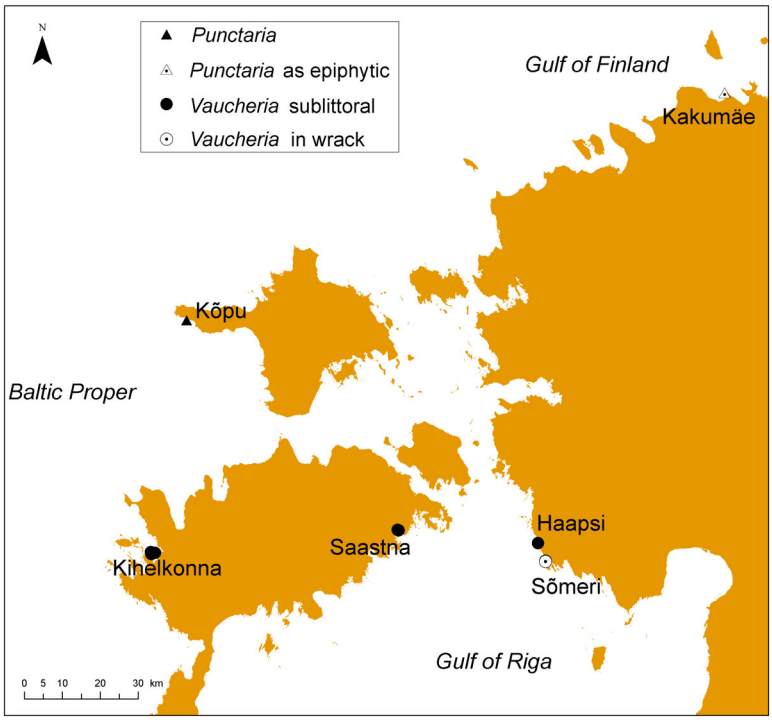

Fig. 1. Study area indicating where new algal species were registered in the Estonian coastal waters.

project 'Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea'), and *Fucus*/*Furcellaria* epiphyte sampling during 2011. Therefore, specimens have been collected by different methods and devices – bottom grab, SCUBA diving, frame sampler, and underwater videography.

Benthos sampling was performed in summer. Three replicated quantitative samples were collected by an Ekman-type bottom grab (0.02 m^2), a plant frame (0.04 m^2), or by thallus removal (Kersen et al., 2011). Sediment samples were sieved in the field and proportions of different sediment types were determined (i.e. silt, sand, gravel, shingle, stone, and decay). Algal material was stored in a deep freezer at –20 °C until analysing. Simplified Wave Model (SWM) method was used to calculate the wave exposure for mean wind conditions represented by the ten-year period from 1 January 1997 to 31 December 2006 (Isæus, 2004). SWM exposure metric (m^2 s^{-1}) indicates the following exposure classes: from 4000 to 10 000 – very sheltered, from 10 000 to 100 000 – sheltered, and from 100 000 to 500 000 – moderately exposed. These exposure levels follow the EUNIS classification modified for the Baltic conditions (e.g. HELCOM, 2008; Nikolopoulos & Isæus, 2008).

Wrack samples (*sensu* Orr et al., 2005) were collected from three transects, all located parallel to the shoreline (e.g. Kersen & Martin, 2007). Transect lengths were 5 m and samples were collected with a 20 cm × 20 cm frame at each metre.

Species identification was done after Christensen (1987) and Fletcher (1987) by means of compound microscope (magnification ×40–100) with independent opinions of Swedish algologists used for confirmation (J. Hansen and L. Kautsky, pers. comm.). Measurements of cells and other structure were made using a micrometre eyepiece. Thereafter algae were weighed (dry weight, 60 °C for a week) or visual abundance of *Vaucheria* was estimated (from wrack samples) as the ratio to total wrack biomass.

RESULTS AND DISCUSSION

Vaucheria

Morphological description

The *Vaucheria* specimen collected from Sõmeri can be characterized as follows: macroscopic thallus of siphonous (i.e. without cell walls) cylindrical filaments were 90–110 μm wide, branched in a few cases, forming green felt-like patches (Fig. 2). In the cytoplasm numerous elliptical chloroplasts were found. No pyrenoids were observed in the specimen separately from the chloroplast due to the limitations of light microscopy.

(a) (b)

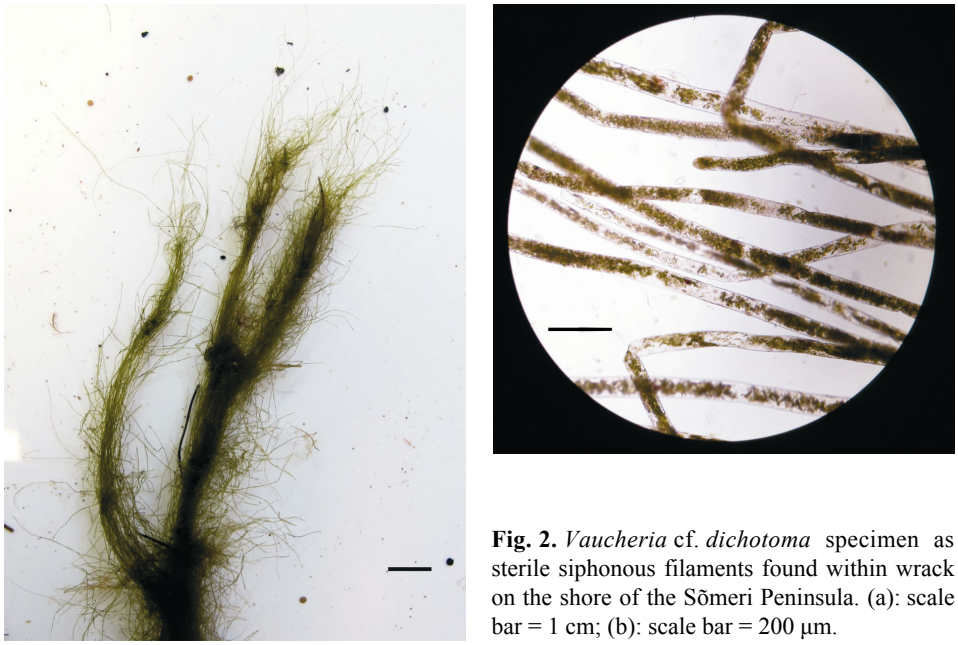

Fig. 2. *Vaucheria* cf. *dichotoma* specimen as sterile siphonous filaments found within wrack on the shore of the Sõmeri Peninsula. (a): scale bar = 1 cm; (b): scale bar = 200 µm.

Records

Although I did not find sexual organs of this specimen (on which the taxonomy of the genera is mostly based), I concluded that it was most likely *Vaucheria* cf. *dichotoma* (L.) Martius. This conclusion was made by following an authoritative identification key of Xanthophyceae (Christensen, 1987) and also considering the environmental tolerance (mainly salinity preference, e.g. Christensen, 1988; Henschel et al., 1992) and distribution records around the Baltic Sea. This was the first find of *Vaucheria* cf. *dichotoma* in Estonian marine waters. The species was found within a wrack community on the shore of the Sõmeri Peninsula, in the Gulf of Riga, on 19 May 2011. It was found at a moderately exposed site on a moraine/sandy shore (Fig. 1) where it formed up to 22% of the total wrack biomass (DW g^{-2}). A month later we found the species again at that site, but its abundance had decreased to 2% of the total wrack biomass (Table 1).

Occurrence of *Vaucheria* in wrack is due to its siphonous thallus structure, which enables to effectively overcome the water transport problem and enables the alga to grow outside truly aquatic habitats (Christensen, 1987). I suspect that the species had started to grow inside the wrack instead of having been snatched by storm waves and landed on the shore because we could not find any sublittoral *Vaucheria* in May–June. *Vaucheria* is also known to be ecologically important as a substrate stabilizer if strong currents occur (Stevenson, 1996; Calvo & Barbara, 2004). Therefore it is very likely that *Vaucheria* can enhance the diversity and abundance of soft bottom macrophytes and macrofauna in the coastal area

Table 1. New records of *Vaucheria* cf. *dichotoma* in Estonian marine waters with basic environmental characteristics. Sediment % indicates the proportion of bottom coverage

Sublittoral survey

Site	Sampler	Date	Depth, m	Station	Lat (WGS-84)	Lon (WGS-84)	Wave exposure, $m^2\ s^{-1}$	Biomass, DWg m^{-2}	Silt, %	Sand, %	Gravel, %	Shingle, %	Decay, %	Stone, %
Saastna	Birge grab	5.08.2005	0.75	SLSAAST4	58.42577	23.07843	3 400	0.6345	60	16			24	
Saastna	Birge grab	5.08.2005	0.5	SL33	58.42477	23.08277	5 600	3.3229	60	0		40		
Kihelkonna	Diving	1.08.2006	1.5	LF409	58.35869	21.98711	33 600		5	80	10	5		
Kihelkonna	Video	1.09.2010	2.1	VILH471	58.35582	21.97116	26 000			95	5			
Kihelkonna	Video	1.09.2010	1.1	VILH472	58.36015	21.96862	28 000			95	5			
Haapsi	Plant frame	5.08.2011	1.0	Marmoni 4	58.39705	23.71138	307 000	281.515		60		30		10

Wrack survey

Site	Sampler	Date	Depth	Section	Lat (WGS-84)	Lon (WGS-84)	Wave exposure, $m^2\ s^{-1}$	Occurrence in samples	Biomass proportion, %
Sõmeri	Frame	19.05.2011	n.a.	1	58.35483	23.7463	200 000	1 sample of 5	<1
Sõmeri	Frame	19.05.2011	n.a.	3	58.35373	23.7462	200 000	4 samples of 5	12
Sõmeri	Frame	14.06.2011	n.a.	2	58.35437	23.74642	200 000	2 samples of 5	2

n.a., not applicable.

(Bolam & Fernandes, 2002). The genus is found also in Atlantic salt marshes, where species of *Vaucheria* are pioneers, settling over the bare mud and facilitating decomposition of silt (Calvo et al., 1999).

Two months later *Vaucheria* was found for the first time in sublittoral habitats near Haapsi in the Gulf of Riga (Fig. 1). *Vaucheria* was the dominant phyto-benthic species on the soft bottom, which was covered also with *Cladophora glomerata*, *Chara aspera*, *Zannichellia palustris*, and *Fucus vesiculosus*. This was the first time to observe Xanthophyceae directly in the Estonian marine waters.

This study is the first to report a yellow-green alga of macroscopic form in the Gulf of Riga (after Nielsen et al., 1995; HELCOM, 2012). *Vaucheria* was previously registered in phytoplankton samples in Pärnu Bay (Tenson, 1995), where it probably occurred as zoospores. I am only aware of one previous record adjacent to Estonia, namely Skuja (1924) described occurrence of *Vaucheria* in the southern Gulf of Riga on a sandy bottom (cited in Kukk, 1993, 1995). We probably registered *Vaucheria* sp. quantitatively on sublittoral soft bottoms in Saaremaa bays as early as in 2005 and 2006 and again in 2010 by video observation (Table 1), but without reference specimen identification.

I argue that it is possible to find *Vaucheria* in many sheltered semi-enclosed bays with river inflows. *Vaucheria* is the most frequent macroalga together with *Cladophora* and *Ulothrix* in Estonian running waters (Trei, 2001; Trei & Paal, 2004). Growing together with higher plants, *Vaucheria* has been observed even in oxidation ponds in Estonia (Viik, 1999) and presumably it belongs to the lacustrine macroflora in Estonia (*see* Leppik, 1922; Mölder, 1944).

Punctaria

Morphological description

The *P. tenuissima* specimen collected from Kakumäe can be characterized as follows: spirally twisted erect blades, dimensions 0.8 mm × 40 mm, numerous plurilocular sporangia with several hairs from the edge of the thallus (Fig. 3). In surface view the cells are quadrate or rectangular, regularly ordered, 20 μm in diameter, each containing discoid chloroplasts.

Records

The brown alga *Punctaria tenuissima* (C. Agardh) Greville was found for the first time in marine waters of Estonia close to the Kõpu Peninsula, Hiiumaa Island, on 5 June 2011. It was found at a moderately exposed site (Fig. 1) at a depth of 4.2 m on a hard substrate with a high vegetation coverage (100%). The algal community at the site was dominated by *Cladophora glomerata*, *Polysiphonia fucoides*, *Chorda filum*, *Stictyosiphon foeniculaceus*, *Ceramium tenuicorne*, and *Furcellaria lumbricalis*. The new species was found in a frame sample with a low biomass (Table 2). It is most likely the first record of

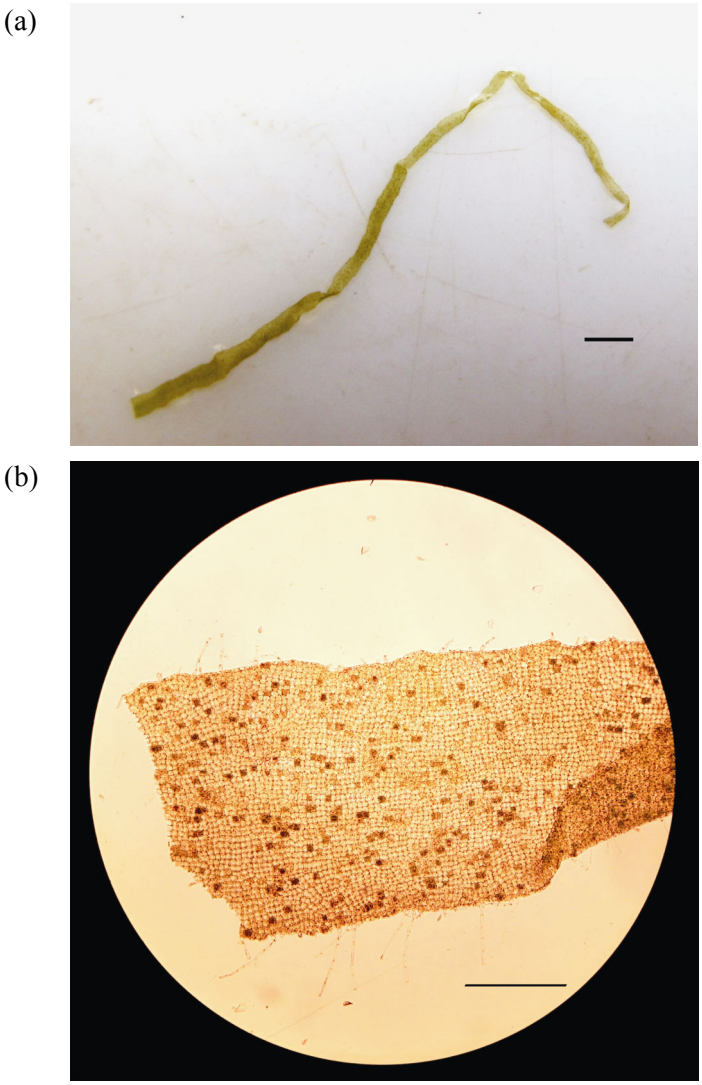

Fig. 3. *Punctaria tenuissima* specimen found in Kakumäe Bay as an epiphyte on sublittoral macroalgae. (a): scale bar = 1 cm; (b): scale bar = 200 µm.

P. tenuissima in Estonian marine waters, although Nielsen et al. (1995) mentioned that the species was reported in coastal waters of western Estonia before 1970. However, we are not aware of any reliable original records yet. In June 2011, *P. tenuissima* was found epiphytically in Kakumäe Bay, the Gulf of Finland (Fig. 1). It was found in low biomass growing on *Furcellaria* and *Fucus* at depths from 1 to 4.1 m in a sheltered site (Table 2). According to a recent check-list of HELCOM (2012), this is also the first time *P. tenuissima* was found in the entire Gulf of Finland.

Table 2. New records of the *Punctaria tenuissima* in Estonian marine waters with basic environmental characteristics. Sediment % indicates the proportion of bottom coverage

***Punctaria* in epiphytic survey**

Host alga	Depth, m	Lat (WGS-84)	Lon (WGS-84)	Date	Location	Wave exposure, $m^2 s^{-1}$	*Punctaria*, DWg on host	Host alga, DWg	Epiphytic load, %
Furcellaria lumbricalis	4.1	59.45805	24.56707	22.06.2011	Kakumäe	70 000	0.0001	4.6672	0.002
Furcellaria lumbricalis	4.1	59.45805	24.56707	22.06.2011	Kakumäe	70 000	0.0001	2.9183	0.003
Furcellaria lumbricalis	4.1	59.45805	24.56707	22.06.2011	Kakumäe	70 000	0.0001	3.7622	0.003
Fucus vesiculosus	1	59.45833	24.56894	22.06.2011	Kakumäe	70 000	0.0002	26.663	0.001
Fucus vesiculosus	2.4	59.45833	24.56844	22.06.2011	Kakumäe	70 000	0.0001	12.4422	0.001
Fucus vesiculosus	2.4	59.45833	24.56844	22.06.2011	Kakumäe	70 000	0.0001	7.3967	0.001
Fucus vesiculosus	2.4	59.45833	24.56844	22.06.2011	Kakumäe	70 000	0.0004	22.9225	0.002

***Punctaria* in habitat mapping survey**

Station	Depth, m	Lat (WGS-84)	Lon (WGS-84)	Date	Location	Wave exposure, $m^2 s^{-1}$	Biomass, DWg m^{-2}	Shingle, %	Boulder, %
KOPU130	4.2	58.90903	22.1001	5.06.2011	Kõpu	427 000	0.0025	60	40

One of the reasons why the brown alga *P. tenuissima* has not been found in the Estonian waters before is obviously its complex life history. The alga grows both microthalli and macrothalli. The different morphological phases of the thallus are mainly modified by temperature (Rietema & van den Hoek, 1981) and pluriseriate ribbon-like thalli form under lower water temperatures (4–16°C). Even then, the alga appears with low coverage (Eriksson et al., 2002). Moreover, according to Parente et al. (2010), comparison of the life histories of *P. tenuissima* and *P. latifolia* suggests that they are conspecific.

Another reason behind this distribution pattern of *P. tenuissima* is the lack of a regular seasonal monitoring of phytobenthos to register also epiphytic flora on the macroalgae. This is an important shortcoming since the species is known as a spring–summer annual in the boreal Atlantic, and if epiphytic then it grows mainly on overwintering leaves of *Zostera marina* (Novaczek, 1987; Boström et al., 2004). This kind of methodological problem was also noted for the British Isles (Hardy & Guiry, 2003) and the Mediterranean (Bellemo et al., 1999).

ACKNOWLEDGEMENTS

I am very grateful to Joakim Hansen, Gustav Johansson, and Lena Kautsky for helping to identify algal specimens. I thank Anastasiia Kovtun-Kante, Agnes Siiber, Liis Rostin, and Remi Treier for analysing algal samples. This study was financed by the Estonian Science Foundation under grant ETF8775, EU Life+ project MARMONI, EU Interreg IVA project HISPARES, and Estonian target financed project SF0180013s08.

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Bentiliste makrovetikate *Vaucheria* cf. *dichotoma* ja *Punctaria tenuissima* esmaleiud Eesti rannikumeres

Priit Kersen

Läänemere kirdeosa tuntakse soolsusest tingitud madala bentilise liigirikkusega merealana. Eesti mereala põhjataimestikust on leitud kaks uut vetikaliiki: mõikja ehitustüübiga nuivetikas *Vaucheria* cf. *dichotoma* (Xanthophyceae) ja epifüütne pruunvetikas *Punctaria tenuissima* (Phaeophyceae). Ühtlasi on *Vaucheria* cf. *dichotoma* näol tegemist esimese eriviburvetikate leiuga Eesti rannikumere põhjaelustikus ja seda liiki on esmakordselt leitud ka Liivi lahest. Pruunvetikas *P. tenuissima* leid on esmakordne kogu Soome lahes. Lisaks on toodud leidude ajalugu, levik ja mõlema liigi morfoloogilised tunnused. On välja toodud ka võimalikud põhjused, miks neid liike pole varem Eesti rannikumerest leitud.