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Fucus evanescens or *Fucus edentatus*? Taxonomic problems with a non-indigenous species, which arrived at the coast of Mecklenburg-Vorpommern.

Abstract

A fucoid species, which differs largely from the species known yet for this region, was found in the vicinity of Rostock harbour in 2015. Morphology and phenology, studied in 2016, result in difficulties to link it to a certain Fucus species irrespective of the fact that it is for certain the same taxon as Rice & Chapman (1985) treated as Fucus evanescens Agardh 1820. Here we describe morphology and phenology of the specimens studied and compare the characters observed with the different taxonomic opinions published so far.

Keywords: submerged macrophytes, Fucus evanescens, Baltic Sea, non-indigenous species

1 Introduction

The recent Checklist for German marine macroalgae (SCHORIES et al. 2009) lists three *Fucus* species for the German Baltic Sea coast: *Fucus evanescens* C. AGARDH 1820, *Fucus serratus* LINNAEUS 1753 and *Fucus vesiculosus* LINNAEUS 1753. For the entire Baltic Sea two more species, *Fucus spiralis* Linnaeus 1753 and *Fucus radicans* BERGSTRÖM & KAUTSKY, 2005, are listed in the recent HELCOM-checklist (MARTIN et. al. 2012).

Whereas the LINNEAEN species can be regarded as native ones and *F. radicans* is often regarded as an example of ongoing speciation, having evolved sympatrically from *F. vesiculosus* within less than thousand years in the Baltic Sea (PEREYRA et al. 2009), *F. evanescens* is seen as an invader, which established in the Baltic Sea during the last decades (e.g. SCHUELLER & PETERS 1994).

F. evanescens is described as a species preferring the niche close to the water surface (WENNBERG 1992) and profiting from the reduced grazing pressure in the southwestern Baltic Sea (WIKSTRÖM et al. 2006).

The species is still restricted to the higher saline areas of the Baltic Sea. Being recorded first in the Öresund area in the mid 1950ies, it reached Kiel Bight in the early 1990ies (SCHUELLER & PETERS 1994) and seems to expand eastwards since

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then. However, it has been shown by WIKSTRÖM et al. (2002) that sexual reproductive success declines sharply with decreasing salinity, which is thought to limit its spread into low-saline regions of the Baltic Sea. On the other hand, vegetative reproduction has been shown to be an important modus of colonization for, e.g. *F. radicans* (BERGSTRÖM et al. 2005; TATARENKOV et al. 2005), leading even to clonal populations as demonstrated by JOHANNESSON et al. (2011). Moreover, hybridization is a well-documented phenomenon in the genus *Fucus*, resulting in offspring with mixed traits (COYER et al. 2002, COYER et al. 2007) and fertilization rates of interspecific crossings may even exceed the rates obtained by intraspecific ones as demonstrated by FORSLUND & KAUTSKY (2012) for crossing between *F. radicans* and *F. vesiculosus*. So no definite conclusion about salinity limits of the newly arrived species can be drawn yet.

Therefore, the spread of the species along the Baltic Sea salinity gradient should be carefully observed, because it may give a chance to document an adaptation process potentially resulting in a speciation.

In this article, we are presenting the results of field work done during the last years, where phenology and morphological variability of *F. evanescens* was observed. In this context, we want to discuss taxonomic problems of the species in question in order to raise awareness for this taxon and to encourage field work along the German Baltic coast.

2 Material and methods

Field surveys in shallow water were conducted in 2015 and 2016 along the German Baltic Sea coastline by wading and Scuba-diving. *Fucus*-specimens completely lacking airbladders and exhibiting vegetative thalli which are narrow and unserrated with long, narrow receptacles (either compressed or only partially swollen) were found at several sites and could not be related to either *F. serratus* or *F. vesiculosus*. Monthly observations of the *Fucus* sp. stand at the site „Hohe Düne“ (54° 10‘ 47.2 N; 12° 6‘ 10.6 E) were carried out from February 2016 till January 2017 to get information about phenology. Pictures and videos were taken with an underwater camera directly in the field (Nicon Coolpix 130 Awi).

Herbar material was prepared from all sites, for determination several keys were compared with each other and the results of the comparison will be discussed.

3 Results

Field survey and description of the specimens

Fucus specimens with a morphology raising problems for identification (further called *Fucus* sp.) were first found in May 2015 as drift material washed ashore the beach between Markgrafenheide and Graal-Müritz. The features of these specimens differed from the species known for this area *(F. serratus* and *F. vesiculosus)* to an extent exceeding the range of morphological plasticity described for these species.

Searching for the source of this drift material, in June 2015 a population of *Fucus* sp. was found on the blocks of the outer side of the south mole of Warnemünde (Hohe Düne) between 0.3-1.0 m depth. In May 2016 the entire harbour area was sampled, but the above location was the only location where *Fucus* sp. settled.

The specimens of *Fucus* sp. from this site are shown in Figure 1. They are characterised by an entire (unserrated) thallus with a broad flat, in some cases even rudimentary, midrib. The midrib occasionally raises above the frond and is well visible along the fronds, including their distal parts. However, in no case a sharp difference between thallus and midrib, as typical for *F. vesiculosus*, was observed; the colour of the darker vegetative thallus becomes just brighter orange towards the middle of the frond. The midrib usually continues until the receptacles, but becomes thinner and less prominent. The fronds are fan-like and appear flat. The margins of vegetative fronds are entire, but sometimes part of the fronds exhibit some teeth. However, interpreting this feature as a kind of irregular serrating is hard to follow because the teeths are sparse and separated from each other. Young vegetative apices in summer and autumn are very thin, acute and with hardly visible midribs. In winter, vegetative apices are getting broader and stout, midribs are becoming more prominent.

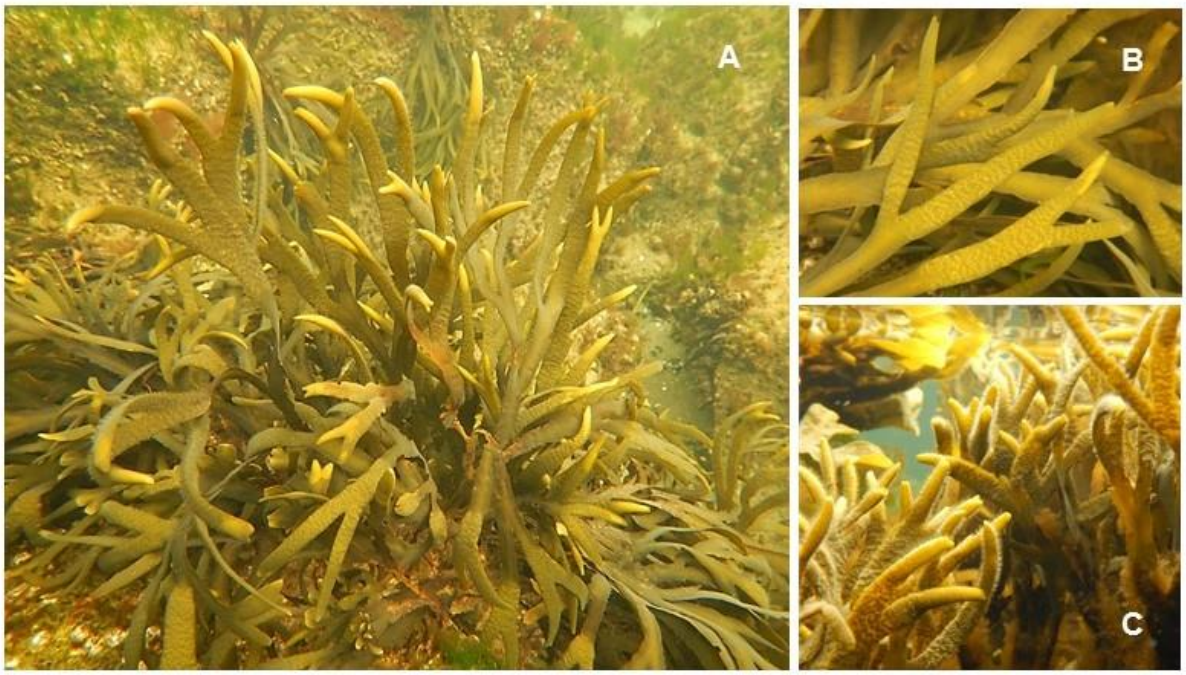

Fig. 1: *Fucus* sp. from Hohe Düne (Warnemünde). A individual with receptacles becoming swollen at the apex, already able to uplift the thallus; B detail showing flat, bifurcated receptacles and midrib continuing until receptacles; C mature receptacles.

Receptacles are lanceolate (young ones may appear slightly oval), at the base as wide as the the fronds they are appearing from, getting gradually narrower to the apex. At the margin to the frond receptacles are flat, becoming swollen apically, with a length of (1.0) 5.0 – 10.0 (15.0) cm.

Thalli with receptacles can be found all year round. In January 2016 about 60% of all adult fronds developed receptacles. From February till May this percentage increased to 95-100%. During maturation receptacles become swollen, the process always starting at the apex and continuing downwards, changing colour from olive-orange to orange. Thalli with vegetative apices or flat receptacles lay down, once the receptacles are getting swollen they lift the algae into an upright position.

Old receptacles became covered with epiphytes in April-May. In May about half of the fronds lost their old receptacles. Some individuals beared both, old swollen orange receptacles as well as developing, flat olive-coloured receptacles. After loss of receptacles fronds continued to grow, sometimes also above remainders of old receptacles. These new fronds developed in June a second generation of olive-coloured, immature receptacles (5.0-6.0 cm) at about 10% of their apices. This second generation continued to grow during summer, developing to a length of 10.0-15.0 cm in August-November. At this time of the year, at about 1-5% of all apices observed receptacles were found.

Similar specimens were reported from Börgerende, a site close to Warnemünde, where it has been found during Scuba-diving in 2-3 m depth (pers. comm. S. Breyer, IfAÖ, February and April 2016). However, searching for specimens in February 2017 remained unsuccessful.

The same applies for a search eastwards from Hohe Düne, where no fucoids at all were found on the wavebreakers in front of Wustrow and Ahrenshoop.

In Strelasund, the easternmost locality *F. evanescens* has been reported in the Baltic yet (Lackschewitz et al., 2013), but only *F. vesiculosus* was found in depths until 0.8 m along the shoreline from Altefähr till Grahlerfähre in March 2016.

Identification

Fucus sp., as described above, resembles *F. evanescens*, *F. distichus*, *F. edentatus*, not to speak about hybrids as, e.g. *F. evanescens* x *F. serratus*, making a determination of the specimens found problematic. Identification as *F. evanescens* just by the fact that this species is known to be introduced and established in the neighbouring Western Baltic Sea is somewhat unsatisfying, because the key presented by RICE & CHAPMAN (1985) uses quantitative characters (size) which did not fit well to the specimens found. Qualitative characters used in the description fit far better, but not completely as, e.g. midribs of our specimens did not disappear and mature receptacles were clearly swollen (compare with RICE & CHAPMAN, 1985).

Therefore the original description by AGARDH (1820) was taken as a basis and compared with the opinions of later authors (table 1). It seems that at least two different morphotypes can be distinguished by means of the shape of the receptacles. The specimens found in our survey, clearly fit best to the ones described for Kiel Bight and Öresund; however, they differ in some details often used as discriminative characters as, e.g. apical disapparance of the midrib and presence / absence of subterminal receptacles. Metric characters used as, e.g. plant size can be regarded as less valuable because of the different salinities the plants were taken from.

Tab. 1: Comparison of important species features of *Fucus evanescens*.

Reference	**AGARDH, 1820**	**KÜTZING, 1860**	**ZINOVA, 1953**	**POWELL, 1957**	**RICE & CHAPMAN, 1985**	**SCHUELLER & PETERS, 1994**	***this survey***
Midrib	distinct, somewhat rudimentary, disappearing in front of all apices	disappearing in front of all apices	distinct, disappear in front of all apices	indisctinct in apical parts	principal branches with slightly raised midrib, occasianally indistinct (5 %)	rudimentary, flat, indistinct in upper parts	broad flat, or slightly raised, **not** disapearing in front of all apices
Form of receptacles	short, compressed, not inflated	short, oval	round-oval-triangular, compressed	short, broad, not markedly elongated, rather flattened	long, lanceolate, compressed, occasionally swollen 50-150 mm	long, lanceolate, 60-85 mm	long, lanceolate, compressed, becoming inflated upon maturation, 30-100 mm
Position of receptacles	terminal	terminal	terminal	terminal	terminal	terminal, subterminal	terminal, subterminal

4 Discussion

After being found in the Öresund area already in the mid-1950ies, a morphotype of *Fucus* very distinct from *F. spiralis*, *F. serratus* and *F. vesiculosus*, which are the *Fucus* species known for this region at that time, reached Kiel Bight in the early 1990ies (SCHUELLER & PETERS 1994), regarded as *F. evanescens* AGARDH (1920).

The taxonomic level of this entity is a matter of an ongoing debate for several reasons. ATHANASIADIS (1996) raised principal doubts about the use of the name for North Atlantic specimens, not only for nomenclatural reasons. Moreover, the rank of the name is matter of a continous debate since POWELL (1957) concluded that *F. evanescens*, *F. edentatus*, *F. anceps* and *F. distichus* all belong on a subspecies level to the species complex *Fucus distichus* L. emend POWELL (1957). However, irrespective of its thorough analysis, this view was not accepted generally.

MUNDA (2004) came to the conclusion that the four subspecies of *F. distichus* L. emend. POWELL are forming distinct associations, which can be distinguished by physiognomy, their position in the tidal gradient and accompanying species but, because of e.g. being geographically separated, she recommended to keep POWELL's (1957) concept irrespective of numerical analysis (RICE & CHAPMAN 1985, RICE et al. 1985) which separated POWELL's (1957) subspecies (except for *F. anceps*, which was not included in the study) by means of multifactorial analysis. Later authors, performing genetic studies, identified genetic differences between these taxa, but kept them as "ecotypes" MCLACHLAN et al. (1971), MCLACHLAN (1974), SIDEMAN & MATHIESON (1983a, b, 1985).

In a very recent publication, JUETERBOCK et al. (2016), generally supporting POWELL's concept, came to the conclusion that at least *F. distichus* subsp. *anceps* (HARVEY ET WARD EX CARRUTHERS) POWELL 1957 should be treated as a separate genetic entity and should be excluded from the *F. distichus*-species complex. This opinion was based mainly on the data published by COYER et al. (2011), which could clearly separate *F. anceps* within the rather scattered *F. distichus* L. emend. POWELL – species complex. With respect to the three subspecies *F. distichus* subsp. *distichus* (LINNAEUS) POWELL 1957; *F. distichus* subsp. *edentatus* (DE LA PYLAIE) POWELL 1957; and *F. distichus* subsp. *evanescens* (C. AGARDH) POWELL 1957 he followed the point of LAUGHINHOUSE et al. (2015), who concluded that these morphotypes may interbreed and distinction between them is not supported by any species concept applied.

Interbreeding often occurs in the genus *Fucus* and results in morphological intermediate forms. By means of microsattelitte markers, BILLARD et al. (2005), ENGEL et al. (2005) and WALLACE et al. (2004) identified many hybrids between *F. spiralis* and *F. vesiculosus*, for *F. evanescens* crossings with *F. serratus* were described by COYER et al. (2002, 2007).

However, this point of view is not followed by algaebase yet, GUIRY (2017) still lists *F. edentatus*, *F. distichus* and *F. evanescens* as accepted taxonomic names.

Therefore, the *Fucus* morphotype found along the German Baltic coast should be related to one of the above species it is resembling.

As shown here, shape of receptacles, but also general appearance of the thallus, being very narrow and with a midrib until the edge of the receptacles, do not match with the original description for *F. evanescens*, the species these morphotypes

were linked to before. On the other hand, *F. evanescens* is regarded as the most variable subspecies in the *F. distichus* L. emend. POWELL (1957) – species complex. But still the "principal features" of the original description, as listed by POWELL (1957) and clearly visible from AGARDH's illustration (AGARDH, 1821) should be taken into account: plants large, fronds broad, midrib indistinct in the apical part of the plant – from these vegetative characters the frond width of the specimens found here do not apply at all and with respect to the midrib some doubts are left, because the midrib becomes indistinct just below the receptacles. With respect to receptacles, POWELL (1957), referring to the original description, identifies as general features: receptacles flattened, not markedly elongated, relatively broad (c.f. POWELL, 1957) – features which are in contrast to the specimens described here.

Comparing with *F. distichus*, the alae of the morphotype found are much too broad and also form of receptacles, which should be cylindrical to fusiform and always inflated for *F. distichus*, do not match at all.

Moreover, one of the striking characters of the specimens found here, vegetative growth above receptacles, has never been described for *F. distichus* or *F. evanescens*, but for *F. edentatus* it is mentioned already by POWELL (1957).

F. edentatus is, in accordance with the specimens found here, described as a large and sturdy plant, and the general description given by POWELL (1957), mentioning "well developed, but comparable narrow alae, midrib becoming indistinct immediately below receptacles" fit rather well. Just the form of receptacles, which are described to be elongated, swollen and cylindrical to "somewhat flattened" do not fit completely – receptacles of the morphotype described here became swollen cylindrical during maturation, but were compressed when immature. On the other hand vegetative growth above the receptacles is a character only reported for *F. edentatus* and has been found in our specimens as well.

As a conclusion we propose that the morphotype found is to be placed into the taxon *F. edentatus* rather than *F. evanescens*.

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