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# Cryptic, alien and lost species: molecular diversity of *Ulva sensu lato* along the German coasts of the North and Baltic Seas

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**ABSTRACT**
DNA barcoding analysis, using *tuf*A, revealed considerable differences between the expected and observed species inventory of *Ulva sensu lato* in the Baltic and North Sea areas of the German state of Schleswig-Holstein. Of 20 observed genetic entities, at least four (*U. australis, U. californica, U. gigantea* and *Umbraulva dangeardii*) had been introduced recently, whereas three others (one *Ulva* sp. and two *Blidingia* spp.) could not be identified at the species level and could also represent recently introduced species. In addition, the observed distributions of *Kornmannia leptoderma* and *U. rigida* were much more extensive than indicated by historical records, whereas *Blidingia minima* and *Gayralia oxysperma* were absent or much less common than expected. Barcoding analysis also revealed that both *U. tenera* (type material) and *U. pseudocurvata* (historical vouchers) from Helgoland, an off-shore island in the North Sea, actually belong to *U. lactuca*, a species that appears to be restricted to this island. Furthermore, past morphological descriptions of *U. intestinalis* and *U. compressa* have apparently been too restrictive and have been responsible for numerous misidentifications. The same is true for *U. linza*, which, in northern Germany, clusters into two genetically closely related but morphologically indistinguishable entities. One of these entities is present on Helgoland, while the second is present on North Sea and Baltic Sea mainland coasts.

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## Introduction

Macroalgae of the orders Ulvales and Ulotrichales are ubiquitous inhabitants of fully marine and brackish coastal waters. Several macroalgal species have recently increased, owing to opportunistic lifestyles and the capacity to benefit from eutrophication and other anthropogenic impacts, and the ability to accurately identify such taxa has become much more important (Charlier *et al.*, 2007, 2008; Smetacek & Zingone, 2013). However, the identification of certain macroalgae, such as the genus *Ulva*, is notoriously difficult (Koeman & Van den Hoek, 1981, 1982*a*, 1982*b*, 1984; Hoeksema & Van den Hoek, 1983; Brodie *et al.*, 2007), with the morphological instability of specific *Ulva* species being attributed to variation in salinity (Reed & Russell, 1978; Steinhagen *et al.*, 2018*b*), nutrient concentrations (Blomster *et al.*, 2002; Steinhagen *et al.*, 2018*b*) and bacterial associations (Spoerner *et al.*, 2012; Wichard, 2015), as well as to an elevated tendency for mutagenesis (Wichard, 2015). As a consequence, morphological plasticity (i.e. multiple morphotypes within species) or cryptic speciation may hinder identification and lead to taxonomic confusion. Such identification problems have been confirmed by DNA barcoding studies (e.g. Blomster *et al.*, 1998, 2002; Tan *et al.*, 1999; Hayden & Waaland, 2002; Hayden *et al.*, 2003; Shimada *et al.*, 2003; Brodie *et al.*, 2007; Heesch *et al.*, 2009; Wolf *et al.*, 2012; Kirkendale *et al.*, 2013), which have reported that the historical separation of *Enteromorpha* (for tubular 'species') and *Ulva* (for sheet-like taxa) is artificial and does not reflect phylogenetic relationships, as predicted by Linnaeus (1753; Hayden *et al.*, 2003). The genera *Enteromorpha* and *Ulva* were consequently synonymized and the currently accepted genus *Ulva* includes tubular, sheet-like and mixed-morphology taxa. Thus, allegedly unique morphological characteristics that were indicated in past species descriptions, and subsequently used in identification keys, are often uninformative, whereas molecular methods allow for reliable species differentiation (Blomster *et al.*, 1998, 2002; Hayden *et al.*, 2003; Brodie *et al.*, 2007). In particular, *tuf*A has been reported as a useful marker for identifying green algae (Saunders & Kucera, 2010). However, DNA-based species identification remains ambiguous when reference sequences of type material are missing, as is the case for most of the Ulvales and Ulotrichales. The DNA quality of historical voucher specimens is often low, thereby hampering sequencing efforts (Staats *et al.*, 2011). Therefore, both molecular and morphological methods are still needed to link taxonomic concepts that were originally based on morphology with molecular traits (Hillis, 1987).

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The documentation of seaweeds in northern Germany has been conducted since the mid-19th century, and seaweeds of the small island of Helgoland, located in the SE North Sea, have received much attention from marine botanists and phycologists, making Helgoland among the best-studied seaweed habitats in Europe (Bartsch & Kuhlenkamp, 2000). The solid rock pedestal of Helgoland provides a natural substratum for a macrophytobenthos in a fully marine environment and comprises a unique habitat in Germany (Reinke, 1889; Bartsch & Kuhlenkamp, 2000). However, even the most recent comprehensive descriptions of Helgoland's macroalgae (Kornmann & Sahling, 1977, 1983, 1994) were exclusively based on morphological identification. Bartsch & Kuhlenkamp (2000) also included rare and doubtful species and summarized taxonomic changes. Furthermore, the understanding of macroalgal species diversity on Helgoland is only transferable to a limited extent to Germany's mainland coasts, which differ extensively in ecological conditions.

The tidal Wadden Sea is another fully marine ecosystem (salinity 30–33) within the North Sea, but it mainly consists of extended sand and mud flats, with relatively little hard substrate, and the German coast of the Baltic Sea is brackish, lacks tides, and is mainly composed of stones, gravel and sand (Rönnbäck *et al.*, 2007). Furthermore, except for general identification keys (Rothmaler, 1984; Pankow, 1990), information about the identity and abundance of macroalgae in the Wadden and Baltic Sea areas of Germany is relatively sparse. Based on a summary of literature records, Schories *et al.* (2009) described the distribution of macroalgae along the coast of Germany. However, the taxonomic concepts underlying historical records are often unclear and records based on molecular species identification are still sparse for the area.

Accordingly, the aim of the present study was to reassess the diversity of *Ulva sensu lato* at geographically separated areas along the coasts of the Baltic and North Seas in the German state of Schleswig-Holstein, as well as on Helgoland. The survey included both DNA barcoding and classical morphological identification approaches, and both field-collected and herbarium specimens were examined which allowed for the detection of several cryptic or newly introduced species and for the identification of several historical misinterpretations.

## Materials and methods

### Sample collection

Samples of *Ulva sensu lato* were collected from 127 sites throughout the state of Schleswig-Holstein, Germany (Fig. 1), including sites in the Wadden Sea ($n$ = 44), Baltic Sea ($n$ = 73) and on Helgoland ($n$ = 10). The sites represented a variety of habitats, such as estuaries, overflow basins and drainage channels, within each of the ecosystems. The sites were spread over 536 km along the coast of the Baltic Sea and over 466 km along the coast of the North Sea, with a maximum distance between sites of less than 25 km. Full data on the collection sites are available in Supplementary table S1. To ensure that seasonal species were sampled, collections were conducted during both summer (July–August 2014 and August–September 2015) and spring (April 2015 and March 2016). Single locations were also visited in 2017 and 2018, and only a limited number of sites were visited during winter (November 2014–early March 2015) owing to lower green algal growth. Sites along the coast of the North Sea (mainly groynes, bulwarks, rocks and mudflats) were sampled during low tide, whereas sites along the coast of the Baltic Sea were sampled when water levels were low using waders and an aquascope, which allowed for sampling to a depth of 1.2–1.5 m below mean sea level. Additional sampling ($n$ = 3) was undertaken by divers in August 2014. Representative specimens were collected for each morphotype that was observed at each sample site, and epiphytes were also collected from host specimens. The collected thalli were stored in a cool box (~10°C) and transported to the laboratory.

### Morphological analysis

Pre-identification was based on typical morphological characters (e.g. overall thallus morphology, cell form, cell arrangement, number of pyrenoids per cell, etc.) using identification keys (Koeman & Van den Hoek, 1981, 1982*a*, 1982*b*, 1984; Hoeksema & Van den Hoek, 1983), and morphological characters were recorded separately at basal, middle and apical-thallus parts using light microscopy. Lugol's solution (iodine-potassium iodide) was used to stain starch-containing compartments, such as pyrenoids. After morphological analysis, epiphyte-free pieces of remaining thallus tissue (1 cm$^2$) or complete smaller thalli were either frozen and lyophilized or dried in silica gel for future molecular analysis.

### Molecular analysis

Total DNA was extracted from lyophilized or silica-dried samples using the Invisorb Spin Plant Mini Kit (Stratec, Birkenfeld, Germany), according to the manufacturer's protocol, and the plastid-encoded DNA barcoding marker *tuf*A was PCR amplified using the primers tufGF4 (Saunders & Kucera, 2010) and tufAR (Famà *et al.*, 2002). The following conditions for amplification were used: initial denaturation at 94°C for 4 min; 38 cycles of 94°C for 1 min, 55°C for 30 s and 72°C for 1 min; then a final extension of 72°C for 7 min. Both strands of the

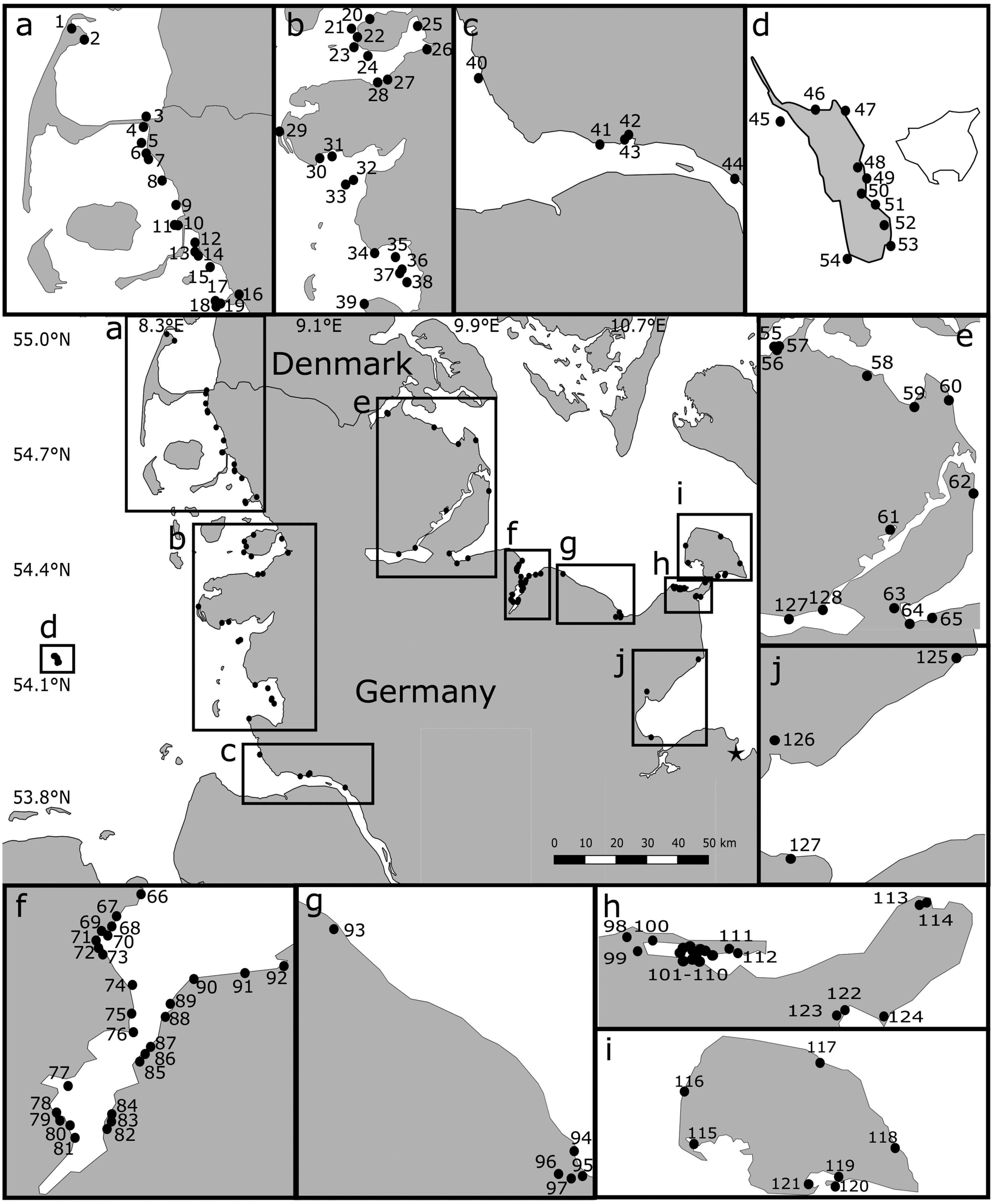



**Fig. 1.** Map of sampling sites in northern Germany. Insets a–j provide higher resolution. Numbers 1–126 cross-reference to Table 2 and Supplementary table S1, whereas numbers 127 and 128 indicate the sampling sites at Winning and Brodersby. The asterisk indicates a previously investigated site in Wohlenberg.

purified amplicons were directly sequenced by GATC Biotech (Konstanz, Germany) and both sequence alignment and reciprocal editing were performed using Sequencher (v. 4.1.4; Gene Codes Co., Ann Arbor, Michigan). The resulting sequences were uploaded to GenBank (Supplementary table 1). Sequence alignment was performed using MAFFT (Katoh *et al.*, 2002), whereas editing was done visually with Sequencher (v. 4.1.4, Gene Codes Corporation, Ann Arbor, Michigan). The alignment represented a 777 bp portion of the *tuf*A gene. An optimal substitution model was determined using MrModeltest software version v. 2.2. (Nylander, 2004) and found to be GTR+G+I. Subsequently, maximum likelihood analysis was performed using RAxML (v. 8; Stamatakis, 2014) with 1000 bootstrap iterations and the suggested substitution model, and Bayesian inference was performed using MrBayes (v. 3.2.2; Ronquist *et al*., 2012) with four simultaneously running Markov Chain Monte Carlo chains for $5 \times 10^6$ generations. The run was ended automatically when the standard deviation of split frequencies dropped below 0.01. Reference sequences from GenBank were also included in the analyses, with preference given to annotated sequences published in peer-reviewed articles. The trees were rooted by an outgroup that contained *Urospora penicilliformis* GenBank code HQ610440 and *Urospora wormskioldii* GenBank code HQ610441. Sequences used in the phylogenetic tree are listed in Table 1.

### *Comparison of recent species richness to historical findings*

To assess the potential misidentification of historical specimens, historical vouchers of Ulvales taxa from the study area and neighbouring regions were obtained from several macroalgae collections and herbaria (Herbarium of the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany (BRM), Herbarium of GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany (GEO); Herbarium of the Natural History Museum of Denmark, Copenhagen, Denmark (C)) and morphologically compared to specimens collected during the present study. The micro- and macromorphological characters of the vouchers were assessed using the above-mentioned criteria. When possible, small thallus pieces of the historical voucher specimens were sampled for molecular verification of species identity, as described in Steinhagen *et al.* (2018*a*).

## Results

A total of 370 *Ulva sensu lato* samples were processed genetically for species discrimination and identification, on the basis of *tuf*A sequence data, and the full dataset was subject to phylogenetic analyses (see Supplementary table S1). In addition, an analysis with selected representative sequences was also performed (Fig. 2). The ML and BI analyses yielded congruent consensus trees. The species observed during the present study are described here, with a few particularly conspicuous species discussed in detail, and the majority are discussed in more depth in the Supplementary Information.

The phylogenetic analyses separated the investigated specimens into 20 taxonomic entities, nearly all of which could be resolved on the basis of peer-reviewed reference sequences provided by GenBank. More specifically, the taxa were identified as members of *Ulva, Umbraulva, Percursaria, Blidingia, Kornmannia, Monostroma* and *Protomonostroma*. One major branch within the consensus tree included members of *Ulva, Umbraulva* and *Percursaria* (i.e. the Ulvaceae) and was split into two subgroups, with the larger one containing *Ulva* taxa exclusively and the smaller subgroup containing several *Ulva* taxa (*U. lactuca, U. australis, U. intestinalis* and *U. compressa*), *Umbraulva dangeardii* and *Percursaria percursa*. However, this topology was only observed when *P. percursa* sequences were included; when *P. percursa* sequences were omitted, *Umbraulva* clustered as a sister group to *Ulva* (Supplementary fig. S1). Most of the species clades obtained full bootstrap and posterior probability support.

All *U. gigantea* sequences were identical to a sequence from New Brunswick, Canada (Fig. 2, Table 2). The specimens of this species were always represented by distromatic blades and were only found in a limited area in the Wadden Sea, except for one specimen in the Baltic Sea (for details see Supplementary Information).

*Ulva rigida* was always distromatic, and attached specimens were found in all three investigated regions, whereas mats of drifting specimens were only observed in the Wadden Sea (for details see Supplementary Information). The cluster representing *U. rigida* in our phylogenetic tree (Fig. 2) contained reference sequences for *Ulva laetevirens* Areschoug 1854 from Connecticut (JQ048942) and New Brunswick (HQ610428), as well as for *U. rigida* from the Italian Adriatic Sea (HE600178). All sequences were nearly identical, exhibiting divergences from the references of 0–0.26% and were placed in a well-delimited cluster.

Specimens that clustered most closely to *U. shanxiensis* type sequences were genetically more diverse than other taxa, with sequence distances ranging from 0 to 2.8% (Fig. 2). Furthermore, the specimens of *Ulva* sp. sampled during the present study were quite divergent (2.4–2.8%) from the *U. shanxiensis* type sequence. Specimens that belonged to this cluster were observed at all three main study areas and were typically found in areas of intense anthropogenic impact. The specimens were generally tubular but, nonetheless, of variable morphology (for details see Supplementary Information).

The clades delimiting the species *U. flexuosa* and *U. californica* received low to medium support. Both species were observed at all three main study areas. The more fragile and relatively rare species, *U. flexuosa*, exhibited only tubular morphologies and was generally observed unattached. The sequences of specimens in this clade differed from reference sequences from Canada (HQ610296) and South Korea (JN029309) by 0–0.17%. In contrast, the more robust of the two species, *U. californica*, exhibited more variable morphology, ranging from tubular to lanceolate or amorphous forms, and preferentially settled on artificial substrates. The sequences of specimens in this clade differed from reference sequences

**Table 1.** List of green algal samples collected in 2014–2016 in northern Germany and used in the displayed phylogenetic tree.

| [a]Accession no. | Species | [b]Voucher no. | Collection date | Region | Location | [c]Site No. | Lat. | Long. |
|---|---|---|---|---|---|---|---|---|
| MH475471 | *Ulva australis* | TD_10 | 24-Jul-2014 | Wadden Sea | Norderfriedrichskoog | 28 | N 54,4136 | E 8,8789 |
| MH475472 | *Ulva australis* | TD_34 | 15-Aug-2014 | Wadden Sea | St. Peter-Ording | 30 | N 54,2857 | E 8,7032 |
| MH475473 | *Ulva australis* | TD_36 | 16-Aug-2014 | Wadden Sea | St. Peter-Ording | 29 | N 54,3267 | E 8,5851 |
| MH475450 | *Ulva californica* | S_106 | 30-Jul-2014 | Wadden Sea | Dagebuell | 11 | N 54,7301 | E 8,6892 |
| MH475454 | *Ulva californica* | S_791 | 23-Sep-2015 | Helgoland | Helgoland | 48 | N 54,1837 | E 7,8886 |
| MF979651 | *Ulva compressa* | S_672 | 21-Apr-2015 | Wadden Sea | Finkhaushallig | 27 | N 54,4156 | E 8,9036 |
| MF979652 | *Ulva compressa* | S_514_B | 19-Sep-2014 | Baltic Sea | Wulfen | 121 | N 54,4089 | E 11,1731 |
| MF979645 | *Ulva compressa* | S_14_B | 22-Jul-2014 | Helgoland | Helgoland | 46 | N 54,1882 | E 7,8742 |
| MH475451 | *Ulva flexuosa* | S_257 | 18-Aug-2014 | Baltic Sea | Kiel | 78 | N 54,3538 | E 10,1413 |
| MH475452 | *Ulva flexuosa* | S_769 | 16-Aug-2015 | Wadden Sea | Dagebuell | 11 | N 54,7301 | E 8,6892 |
| MH475453 | *Ulva flexuosa* | S_794 | 23-Sep-2015 | Helgoland | Helgoland | 51 | N 54,1780 | E 7,8887 |
| MH475474 | *Ulva gigantea* | S_775 | 16-Aug-2015 | Wadden Sea | Dagebuell | 10 | N 54,7304 | E 8,6939 |
| MH475475 | *Ulva gigantea* | S_564 | 9-Apr-2015 | Wadden Sea | Friedrich-Wilhelm-Luebke-Koog, Rhymschlot | 7 | N 54,8333 | E 8,6142 |
| MH475476 | *Ulva gigantea* | S_632 | 17-Apr-2015 | Wadden Sea | Dagebuell | 11 | N 54,7301 | E 8,6892 |
| MH475477 | *Ulva intestinalis* | S_72 | 24-Jul-2014 | Baltic Sea | Gluecksburg | 55 | N 54,8392 | E 9,5176 |
| MH475478 | *Ulva intestinalis* | S_133 | 31-Jul-2014 | Wadden Sea | Schluettsiel | 13 | N 54,6844 | E 8,7539 |
| MH475479 | *Ulva lactuca* | S_729 | 24-Apr-2015 | Helgoland | Helgoland | 47 | N 54,1882 | E 7,8801 |
| MH475480 | *Ulva lactuca* | S_696 | 23-Apr-2015 | Helgoland | Helgoland | 50 | N 54,1797 | E 7,8896 |
| MH475447 | *Ulva linza 1* | S_241_U. linza 1 | 18-Aug-2014 | Baltic Sea | Falckenstein | 76 | N 54,3904 | E 10,1922 |
| MH475448 | *Ulva linza 1* | S_504_U. linza_1 | 16-Sep-2014 | Wadden Sea | Hamburger Hallig | 18 | N 54,5990 | E 8,8122 |
| MH475449 | *Ulva linza 1* | S_64_U. linza_1 | 24-Jul-2014 | Baltic Sea | Gluecksburg | 55 | N54,8392 | E 9,5176 |
| MH475445 | *Ulva linza 2* | S_727_U. linza_2 | 24-Apr-2015 | Helgoland | Helgoland | 52 | N 54,1772 | E 7,8930 |
| MH475446 | *Ulva linza 2* | S_8_U. linza_2 | 22-Jul-2014 | Helgoland | Helgoland | 46 | N 54,1882 | E 7,8742 |
| MH475481 | *Ulva prolifera* | S_196 | 12-Aug-2014 | Baltic Sea | Falshoeft | 60 | N 54,7685 | E 9,9653 |
| MH475482 | *Ulva prolifera* | S_9 | 22-Jul-2014 | Helgoland | Helgoland | 46 | N 54,1882 | E 7,8742 |
| MH475483 | *Ulva prolifera* | S_466 | 10-Sep-2014 | Wadden Sea | Emmelsbuell | 8 | N 54,7949 | E 8,6581 |
| MH475484 | *Ulva rigida* | S_449 | 9-Sep-2014 | Wadden Sea | Friedrich-Wilhelm-Luebke-Koog, Rhymschlot | 7 | N 54,8333 | E 8,6142 |
| MH475485 | *Ulva rigida* | S_123 | 30-Jul-2014 | Wadden Sea | Dagebuell | 11 | N 54,7301 | E 8,6892 |
| MH475486 | *Ulva rigida* | S_111 | 30-Jul-2014 | Wadden Sea | Dagebuell | 11 | N 54,7301 | E 8,6892 |
| MH475487 | *Ulva shanxiensis* | S_228 | 13-Aug-2014 | Baltic Sea | Strande | 71 | N 54,4350 | E 10,1702 |
| MH475488 | *Ulva shanxiensis* | S_269 | 18-Aug-2014 | Baltic Sea | Moenkeberg | 82 | N 54,3465 | E 10,1742 |
| MH475489 | *Ulva shanxiensis* | S_256 | 18-Aug-2014 | Baltic Sea | Kiel | 78 | N 54,3538 | E 10,1413 |
| MH475490 | *Ulva shanxiensis* | S_2_A | 22-Jul-2014 | Helgoland | Helgoland | 53 | N 54,1698 | E 7,8894 |
| MH475491 | *Ulva shanxiensis* | S_317 | 22-Aug-2014 | Baltic Sea | Sehlendorfer lake | 95 | N 54,3088 | E 10,6886 |
| MH475492 | *Ulva shanxiensis* | S_221 | 13-Aug-2014 | Baltic Sea | Strande | 70 | N 54,4362 | E 10,1750 |
| MH475493 | *Ulva shanxiensis* | S_92 | 24-Jul-2014 | Baltic Sea | Aschau | 65 | N 54,4608 | E 9,9267 |
| MH475494 | *Ulva torta* | S_81 | 24-Jul-2014 | Baltic Sea | Wackerballig | 59 | N 54,7586 | E 9,8778 |
| MH475495 | *Ulva torta* | S_231 | 13-Aug-2014 | Baltic Sea | Schilksee | 72 | N 54,4313 | E 10,1693 |
| MH475496 | *Ulva torta* | S_350 | 25-Aug-2014 | Baltic Sea | Heiligenhafen | 99 | N 54,3787 | E 10,9555 |
| MH475497 | *Ulva torta* | S_73 | 24-Jul-2014 | Baltic Sea | Gluecksburg | 56 | N 54,8368 | E 9,5231 |
| MH475498 | *Umbraulva dangeardii* | R_1 | 8-Aug-2014 | Helgoland | Helgoland | 45 | N 54,1874 | E 7,8703 |
| MH475499 | *Umbraulva dangeardii* | R_2 | 8-Aug-2014 | Helgoland | Helgoland | 45 | N 54,1874 | E 7,8703 |
| MH475464 | *Blidingia marginata* | S_147_A | 31-Jul-2014 | Wadden Sea | Pellworm | 21 | N 54,4988 | E 8,8087 |
| MH475465 | *Blidingia marginata* | S_577 | 14-Apr-2015 | Wadden Sea | Brunsbuettel estuary | 41 | N 53,8890 | E 9,1011 |
| KT290281 | *Blidingia minima* | DA_12 | 18-Jul-2013 | Baltic Sea | Wohlenberg | * | N 53,9446 | E 11,2444 |
| MH475455 | *Blidingia* sp. 1 | S_828 | 24-Jul-2014 | Wadden Sea | Schobuell | 25 | N 54,5079 | E 8,9956 |
| MH475456 | *Blidingia* sp. 1 | S_818 | 24-Jul-2017 | Wadden Sea | Husum | 26 | N 54,4712 | E 9,0280 |
| MH475457 | *Blidingia* sp. 1 | S_815 | 24-Jul-2017 | Wadden Sea | Finkhaushallig | 27 | N 54,4156 | E 8,9036 |
| MH475458 | *Blidingia* sp. 1 | S_813 | 24-Jul-2017 | Wadden Sea | Friedrich-Wilhelm-Luebke-Koog | 6 | N 54,8374 | E 8,6122 |
| MH475459 | *Blidingia* sp. 1 | S_179 | 6-Aug-2014 | Wadden Sea | Brunsbuettel estuary | 41 | N 53,8890 | E 9,1011 |
| MH475460 | *Blidingia* sp. 2 | S_34 | 23-Jul-2014 | Helgoland | Helgoland | 53 | N 54,1720 | E 7,8993 |
| MH475461 | *Blidingia* sp. 2 | S_1 | 22-Jul-2014 | Helgoland | Helgoland | 48 | N 54,1837 | E 7,8886 |
| MH475462 | *Blidingia* sp. 2 | S_39 | 23-Jul-2014 | Helgoland | Helgoland | 49 | N 54,1825 | E 7,8906 |
| MH475463 | *Blidingia* sp. 2 | S_124 | 30-Jul-2014 | Wadden Sea | Dagebuell | 11 | N 54,7301 | E 8,6891 |
| MH475466 | *Kornmannia leptoderma* | S_154 | 5-Aug-2014 | Wadden Sea | Finkhaushallig | 27 | N 54,4156 | E 8,9036 |
| MH475467 | *Kornmannia leptoderma* | S_698 | 23-Apr-2015 | Helgoland | Helgoland | 50 | N 54,1797 | E 7,8896 |
| MH475468 | *Kornmannia leptoderma* | S_337 | 22-Aug-2014 | Baltic Sea | Heiligenhafen | 101 | N 54,3795 | E 10,9823 |

(*Continued*)

**Table 1.** (Continued).

| [a]Accession no. | Species | [b]Voucher no. | Collection date | Region | Location | [c]Site No. | Lat. | Long. |
|---|---|---|---|---|---|---|---|---|
| MH475469 | *Monostroma grevillei* | S_548 | 8-Apr-2015 | Baltic Sea | Wulfen | 121 | N 54,4089 | E 11,1731 |
| MH475470 | *Monostroma grevillei* | S_617 | 16-Apr-2015 | Baltic Sea | Heiligenhafen | 101 | N 54,3795 | E 10,9824 |
| MH475500 | *Percursaria percursa* | S_360 | 25-Aug-2014 | Baltic Sea | Heiligenhafen | 101 | N 54,3795 | E 10,9824 |
| MH475501 | *Protomonostroma undulatum* | S_733 | 24-Apr-2015 | Helgoland | Helgoland | 49 | N 54,1825 | E 7,8907 |

A sequence of *Blidingia minima* (KT290281) from a former survey at an adjacent site in Mecklenburg-Vorpommern is included as reference. [a] Voucher no. = Accession no. = GenBank accession number for *tuf*A gene. [b] Identification number assigned to the voucher specimen by the GEOMAR Helmholtz Centre for Ocean Research herbarium, Kiel, Germany. [c] Site no. = Referring to number in Fig 1.

from California (KM255003) and Canada (HQ610279 and HQ610280) by 0–1.82% (Fig. 2, Table 2).

Specimens that exhibited the relatively characteristic morphology of *Ulva torta* (long, narrow, with entangled unbranched tubular thalli and a central lumen of only 3–11 µm) were infrequently observed in either the Baltic or Wadden Seas and were not observed on Helgoland (for details see Supplementary Information). The specimens were clustered with reference sequences from southern Australia (JN029340) and British Columbia, Canada (HQ610437), but with only moderate support (85/0.96; Fig. 2), even though the specimens exhibited relatively low genetic divergence from the reference sequences (0.12–0.3%).

Sequences of the *U. linza* specimens exhibited strong genetic divergence (Fig. 2) and clustered in two strongly supported subgroups, *U. linza* 1 (100/1) and *U. linza* 2 (95/1). The *U. linza* 1 specimens were abundant over the whole study area (except Helgoland), formed a cluster with a genotype from Tasmania (JN029337) and exhibited very low sequence divergence (0–0.0014%). In contrast, the *U. linza* 2 specimens were exclusively collected from Helgoland, formed a cluster with a reference sequence from the North-east Pacific (KM254997) and exhibited slightly greater sequence divergence (0–0.49%). A historical herbarium voucher, originally identified as *Enteromorpha ahlneriana* Bliding nom. illeg., could be genetically assigned to *Ulva linza* sp. 1 (Fig. 2, Table 2). However, the phylogenetic differentiation was not reflected morphologically, and both the *U. linza* 1 and *U. linza* 2 specimens exhibited a wide spectrum of tubular to lanceolate and partly distromatic morphologies (for details see Supplementary Information).

The *U. prolifera* reference sequences from Manitoba, Canada (HQ610395) and Labrador, Canada (HQ610394) clustered with specimens from all three main study areas. However, our samples were clearly more similar to one another (–/0.98; Fig. 2), even though their genetic divergence from the reference ranged from 0 to 1.23%. *Ulva prolifera* was always attached when observed, was relatively abundant, exhibited a variety of tubular morphologies and frequently, but not always, possessed a characteristically twisted stipe-like base (for details see Supplementary Information).

Specimens that formed strongly supported clusters (99/1) with *U. lactuca* reference specimens from New Brunswick (HQ610341, 0–0.31% divergence) and California (KM255044, 0.12–0.47% divergence) were collected exclusively from Helgoland (Fig. 2). Even though Hughey et al. 2019 have suggested that the oldest available name for the European '*U. lactuca' is U. fenestrata*, we will refer to the here mentioned genotype as *U. lactuca* for reasons of general understanding. They exhibited distromatic thalli of various shapes and were characterized by relatively strong attachment. The specimens were found abundantly within the intertidal zone and grew attached to hard substrata, such as naturally occurring rocks (Fig. 3), stones and mussel beds or artificial breakwaters and piers. Only a few drifting specimens were observed and such drifting thalli exhibited clear indications of recent ruptures in the rhizoidal zone, thereby suggesting that drifting is not tolerated for long time periods. Specimens of this clade were never found in rockpools that were subject to potential desiccation or influence by rainwater. All thalli were distromatic throughout, and their shape varied from rounded to lobed (Fig. 4) or laciniate morphologies that could be straight, petiolate-like (Figs 5, 6) but also strongly curved (Fig. 7). Filled disc-like rhizoidal zones (Fig. 8, 13) were frequently observed at the base of the blade. The margins of the thalli were never toothed (grazing traces were clearly distinguished) and were usually smooth, although the rounded individuals sometimes exhibited ruffled margins. Holes (2–6 mm diameter) were observed infrequently. The thalli reached lengths of 40 cm and widths of 35 cm, but smaller individuals (max. 5 cm length and 2 cm width) were also observed. Longitudinal ridges were observed in the basal regions of most of the investigated specimens but were often absent in young thalli. The thalli were attached by obconically shaped stipe-like structures that terminated in broad rhizoidal zones (Figs 8, 9). The cells of the middle and apical thalli were arranged in curved or short rows, whereas cells of the laciniate thalli were

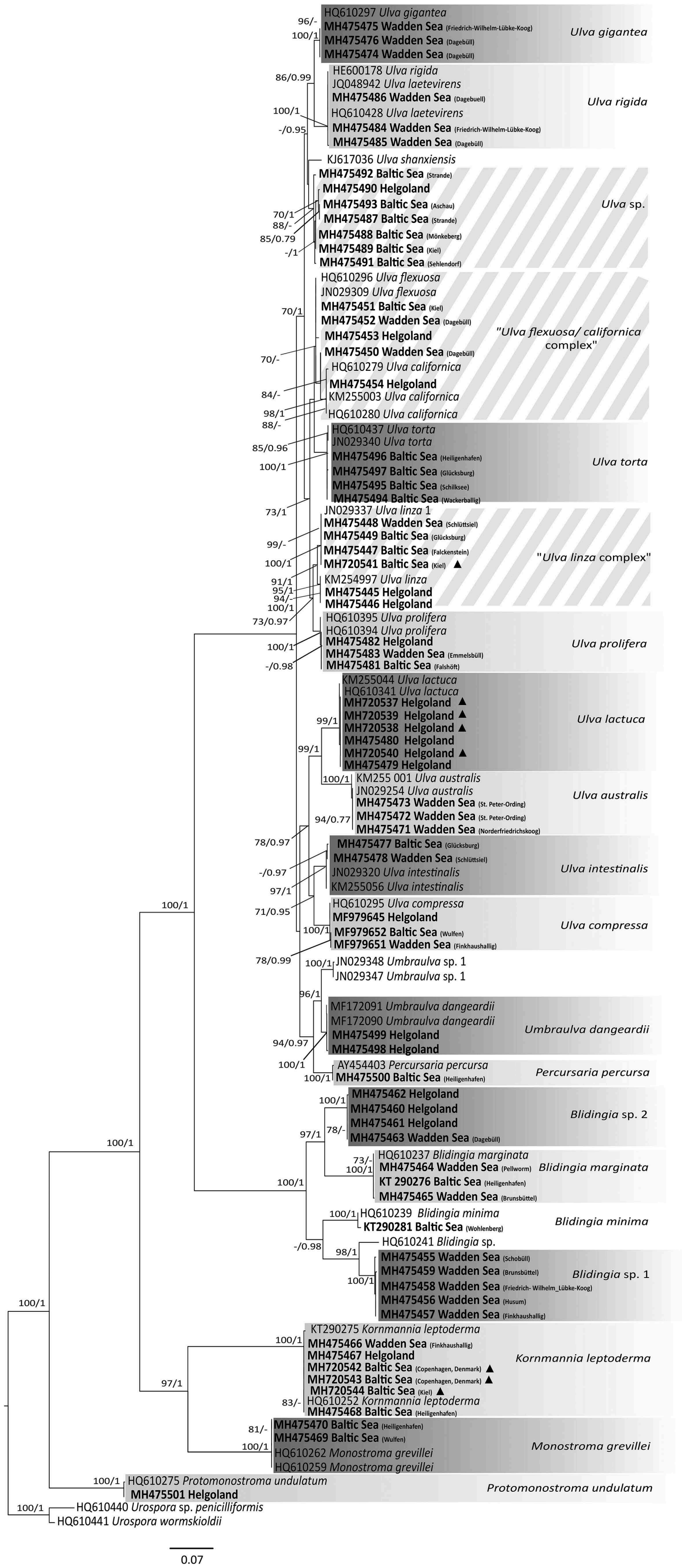



**Fig. 2.** Maximum likelihood phylogram of *tuf*A sequences from taxa of *Ulva sensu lato* from northern Germany. Solid triangles indicate herbarium vouchers (see also Table 2). The two shades of grey indicate clades that were present in the study area. Hatched boxes indicate species complexes and, thus, taxonomic entities that could not be clearly resolved phylogenetically. Numbers at nodes indicate bootstrap values (left) and Bayesian posterior probabilities (1000 replicates; right). Poorly supported nodes (< 70% bootstrap and < 0.70 Bayesian support) are not labelled. Branch lengths are proportional to sequence divergence.

**Table 2.** List of genetically processed herbarium material.

| Region | Location | Collection date | [a]Herbar. ID | [b]Herbarium | Collector | [c]Accession no. | [d]Morphological identity | [e]Genetic identity *tufA* |
|---|---|---|---|---|---|---|---|---|
| Helgoland | Helgoland | 10.04.1991 | *BRM001700* | BRM | Kornmann and Sahling | MH720537 | *Ulva pseudocurvata* | *Ulva lactuca* |
| Helgoland | Helgoland | 10.04.1991 | *BRM001703* | BRM | Kornmann and Sahling | MH720538 | *Ulva pseudocurvata* | *Ulva lactuca* |
| Helgoland | Helgoland | 22.10.1988 | BRM007947 | BRM | Kornmann and Sahling | MH720539 | *Ulva pseudocurvata* | *Ulva lactuca* |
| Helgoland | Helgoland | 17.07.1978 | BRM007806 | BRM | Kornmann and Sahling | MH720540 | *Ulva tenera* | *Ulva lactuca* |
| Baltic Sea (Öresund) | Copenhagen | 27.11.2007 | 73544 | C | Ruth Nielsen and Peer Corfixen | MH720542 | *Gayralia oxysperma* | *Kornmannia leptoderma* |
| Baltic Sea (Öresund) | Copenhagen | 17.03.2004 | 40539 | C | Ruth Nielsen and Peer Corfixen | MH720543 | *Gayralia oxysperma* | *Kornmannia leptoderma* |
| Baltic Sea | Kiel, Friedrichsort | 19.09.1962 | | GEO | Elfriede Kaminski | MH720544 | *Gayralia oxysperma* | *Kornmannia leptoderma* |
| Baltic Sea | Kiel, Friedrichsort | 30.9.1976 | 95 | GEO | Elfriede Kaminski | MH720541 | *Enteromorpha ahlneriana* | *Ulva linza* |

[a] Herbar. ID = Barcode of respective Herbarium. [b] Herbarium = Abbreviation of the respective source herbaria (Herbarium of the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany (BRM); Herbarium of GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany (GEO); Herbarium of the Natural History Museum of Denmark, Copenhagen, Denmark (C)). [c] Accession no. = GenBank accession number for *tufA* gene. [d] Morphological identity = Name that was historically assigned to specimen using morphological characters. [e] Genetic identity = Genetic identity obtained using analysis of *tufA*.

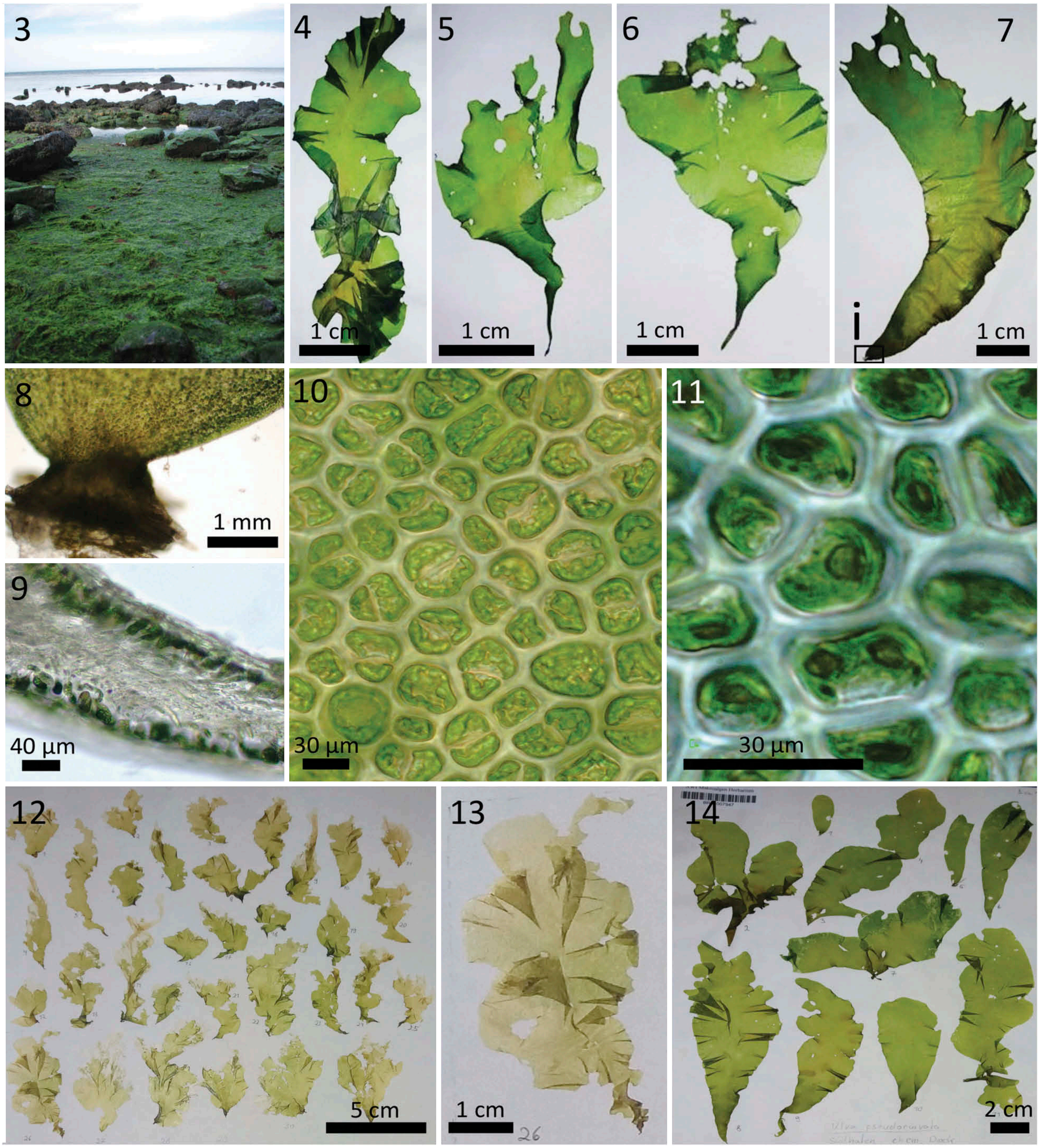
sometimes arranged in longitudinal rows. The cells were polygonal with rounded corners, 12–24 × 14–31 µm in surface view, and contained a parietal chloroplast (rarely filling the entire cell) and 1–2 (rarely up to 4) pyrenoids (Figs 10, 11). Cells of the rhizoidal zone contained up to seven pyrenoids, and both the stipe-like region and rhizoidal zone were filled by the elongated tails of the cell bodies, which became visible in microscopic transections. Thalli with these features were not only observed on Helgoland, but also along the mainland coasts, although they were always genetically assigned to *U. compressa*.

The sequence of one of over 100 syntypes of *U. tenera* Kornmann & Sahling – originating from Helgoland and stored at the BRM on Helgoland (voucher ID: BRM007806; Figs 12, 13, Table 2) – clearly clustered with *U. lactuca* (Fig. 2). Additionally, sequences from historical *U. pseudocurvata* vouchers (BRM001703 and BRM001700; Fig. 14), which provided the first evidence of the species' presence on Helgoland and were displayed in the publication of Kornmann & Sahling (1994), were also placed, with full bootstrap support, in the clade representing *U. lactuca* and were identical to the sequences of recently collected *U. lactuca* samples from Helgoland (Fig. 2).

A few specimens from the west coast of Helgoland and an area around the peninsula of Eiderstedt in the Wadden Sea (i.e. fully marine environments) were clustered with an *U. australis* reference sample from Australia (JN029254, genetic dissimilarity 0–0.33%, Fig. 2, Table 2). However, morphological comparison was impossible since only small thallus pieces conserved in silica gel could be obtained from our study area.

Sequences from the *U. intestinalis* specimens formed a fully supported clade (100/1) with reference specimens from Australia (JN029320) and California (KM255056; Fig. 2) but consistently exhibited slight divergence from both reference sequences (0.12–0.45%). The species was abundantly present at all three main study areas and in salinities that ranged from fresh water to fully marine. All of the specimens investigated exhibited tubular morphology, and most individuals were inflated and unbranched, corresponding to the typical morphology of *U. intestinalis*. Furthermore, specimens that exhibited branched and unbranched morphologies could not be distinguished genetically (for details see Supplementary Information).

*Ulva compressa* was abundant in all three main study areas, although only tubular, usually branched individuals were observed on Helgoland, whereas only distromatic sheet-like specimens were found along the Baltic coast. Both morphologies were encountered along the Wadden coast, sometimes even at the same location. Furthermore, individuals exhibiting transition forms between the two




**Figs 3–14.** Morphology of *Ulva lactuca* specimens from Helgoland, Germany. **Fig. 3.** *U. lactuca* population growing on the northeast rocky tidal flats. **Fig. 4.** Typical lobular morphotype. **Figs 5, 6.** Petiolate-like morphotype. **Fig. 7.** Strongly curved morphotype, with (**Fig. 8**) a disk-like rhizoidal zone (cross section) and (**Fig. 9**) elongated club-shaped cells that extend to the centre of the rhizoidal disc. **Fig. 10.** Cells of the apical and middle thallus parts, with a hood-shaped chloroplast and one (sometimes two) central or marginal pyrenoids. **Fig. 11.** Marginal pyrenoid. **Fig. 12.** *U. tenera* syntypes collected from Helgoland in 1978 (Herbarium of the Alfred Wegener Institute, Bremerhaven; ID BRM007806). (I) However, by sequencing one individual (see also Table 2 and Fig. 2), its genetic affiliation to *U. lactuca* was confirmed. **Fig. 14.** *U. pseudocurvata* specimens collected from Helgoland in 1988 (Herbarium of the Alfred Wegener Institute, Bremerhaven; ID BRM007947); arrowhead indicates specimen that was genetically identified as *U. lactuca* (see also Table 2 and Fig. 2).

morphologies were only rarely observed (for details see Supplementary Information). However, the morphotypes were not separated during the phylogenetic analyses and remained clustered with a *U. compressa* reference sample from Canada, New Brunswick (HQ610295, genetic dissimilarity 0–0.77%).

Sequences that were identical to those of *Umbraulva dangeardii* reference sequences from southern Italy (MF172090 and MF172091, genetic dissimilarity: 0–0.13%) were only recovered from specimens collected at Helgoland at a depth of 8 m. The specimens were distromatic sheets with a conspicuous dark olive colour and thin, soft texture, which corresponds to descriptions of specimens from the British Isles (Maggs *et al.*, 2007*a*).

*Percursaria percursa* was only encountered once in a macroscopically visible state at Heiligenhafen (Baltic Sea), where it grew unattached in dense mats in the supralittoral zone. Microscopic examination confirmed the typical morphology of unbranched biseriate filaments (Maggs & Kelly, 2007) and our sequence was placed in a fully supported cluster with a *P. percursa* reference sequence (AY454403, genetic dissimilarity: 0.13%).

A well-delimited cluster that included *Blidingia marginata, B. minima* and *Blidingia* sp. reference sequences formed a sister clade to that including the *Ulva, Umbraulva* and *Percursaria* sequences and included four genetic entities (Fig. 2). Two of the four subgroups could not be resolved, since they did not match any references in GenBank, but were putatively identified as *Blidingia* specimens based on sequence similarity, overall morphology and growth habit.

Specimens that exhibited low genetic variability and clustered with a *B. marginata* reference sequence from New Brunswick, Canada (HQ610237, genetic dissimilarity: 0–0.28%) were abundant in all three main study areas. The specimens formed dense populations of variable tubular morphology in the upper intertidal and supralittoral zones and were often encountered as the only macroalgal settlers in microhabitats that are influenced by fresh water and that may fall dry for longer periods (for details see Supplementary Information).

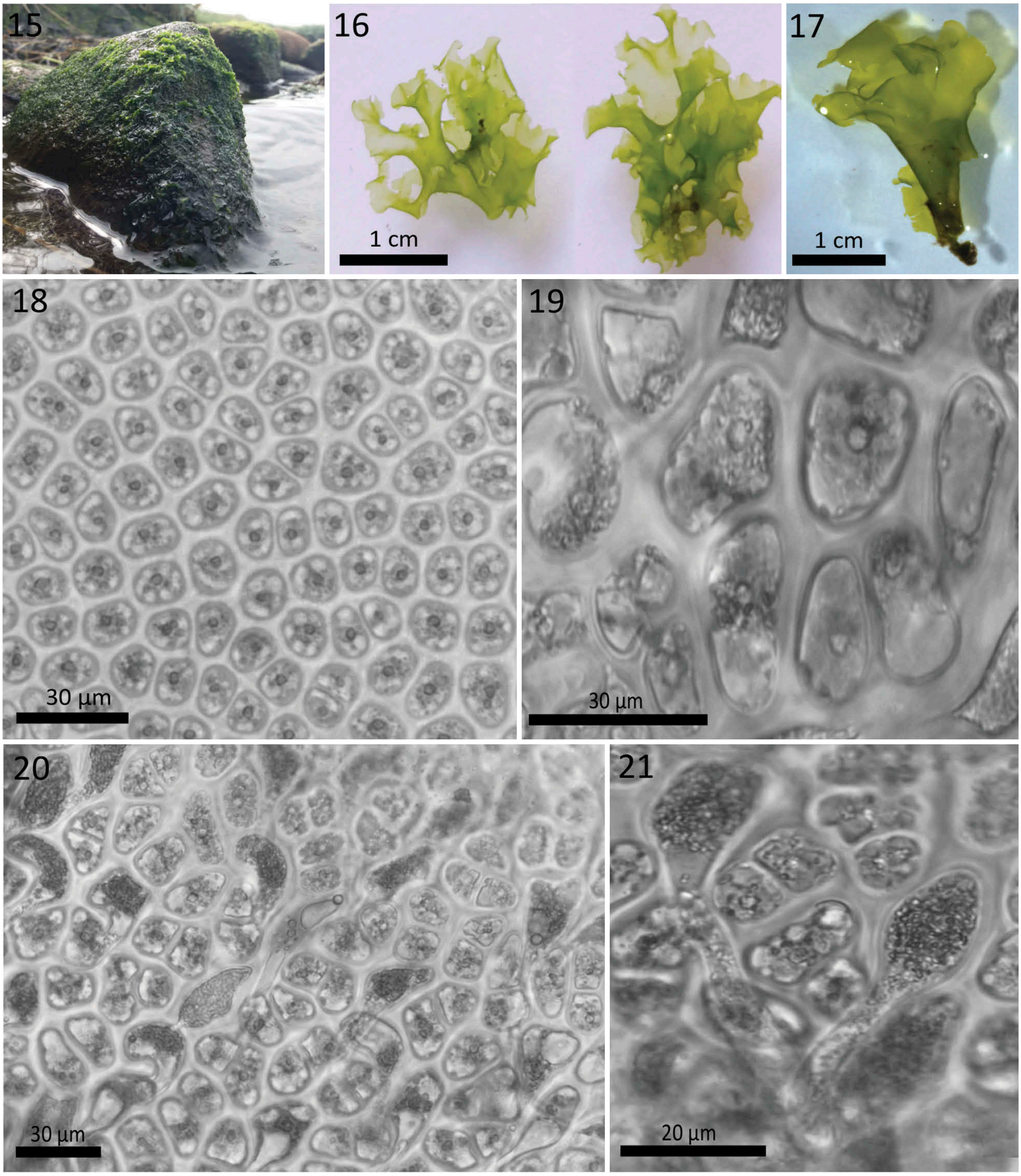
Specimens that belonged to the unresolved entity *Blidingia* sp. 2 were morphologically indistinguishable from *B. marginata* but formed a separate and fully supported cluster with 8–8.2% divergence from the *B. marginata* reference sequence (HQ610237). These specimens were collected from Helgoland and one site in the Wadden Sea (Dagebüll).

Molecular analysis failed to confirm the presence of *B. minima*. However, in a previous project *B. minima* was found at Wohlenberg (Fig. 1, site marked by an asterisk in general map), a site only 30 km to the East in the neighbouring German state of Mecklenburg-Vorpommern. A sample from the previously reported population was included in the phylogenetic tree (KT290281, Fig. 2) and formed a fully supported clade with a *B. minima* reference sequence from Canada (HQ610239).

Specimens that belonged to the unresolved entity *Blidingia* sp. 1 formed a fully supported cluster that was clearly delimited from other *Blidingia* species and genetically dissimilar (4.5–4.8%) from the *B. minima* reference sample (HQ610239). Specimens that belonged to this cluster had a broad distribution and were observed in all three main study areas, at remote and protected sites as well as in highly trafficked waters (see also Steinhagen *et al.*, 2018*b*). The specimens grew as mats on various substrata in the supralittoral zone and were often found in the close vicinity of freshwater inflows, such as drainage pipes. The *Blidingia* sp. 1 specimens were relatively minute and they often exhibited a characteristic antler-like branched tubular morphology. However, macroscopically visible branches were rarely observed and appeared as spiralled or inflated.

The remaining three clades (Fig. 2) only included specimens with monostromatic blades and formed fully supported clusters with reference sequences of *Kornmannia leptoderma, Monostroma grevillei* and *Protomonostroma undulatum. Kornmannia leptoderma* specimens from all three study areas clustered with reference sequences from Canada (HQ610252, dissimilarity: 0–0.38%) and northern Germany (KT290275) and exhibited little to no genetic diversity. Specimens that belonged to this cluster were found in the middle and lower intertidal zones and were typically attached to substrata. The specimens appeared to avoid exposure to direct sunlight and were frequently found on the shaded sides of stones (Fig. 15) or jetties, or under piers. The 1–5 cm (rarely up to 8 cm) long thalli of the *K. leptoderma* specimens were nearly unrecognizable when the substrate became dry during low tide. The membranous and very soft thalli appeared funnel-shaped (Fig. 17), lanceolate or rosette-like (Fig. 16). Older thalli that had sporulated were amorphous in shape and deeply cut. The rhizoidal zone was not defined by a disc-like structure, and cells proceeded without tapering in a stipe-like region. Cells in the apical and middle thallus parts differed in shape from those in the basal thallus parts. The cells of the upper and middle thallus regions were either polygonal to round or with sharp and clearly defined angular edges, 9–15 × 11–16 µm in surface view, with a single centrally located pyrenoid and a chloroplast that was either marginal or filling the entire cell (Figs 18, 19). Meanwhile, the cells of the apical and middle thallus regions were thick-walled (Fig. 19), although progressively thinner and larger toward the basal region, and with 1–3 (rarely 4) pyrenoids per cell. In the lower mid-thallus parts, the cells were 11–21 × 11–27 (32) µm in surface view and sometimes appeared grainy, whereas others already resembled rhizoidal cells with long drawn-out tips (Figs 20, 21). Cells of the rhizoidal zone were up to 50 µm long, always grainy, with rhizoidal tips extending from the main body, and typically with 1–3 pyrenoids (rarely more; Fig. 21).

All the *M. grevillei* specimens formed a cluster and were often identical to reference sequences from Maine, USA (HQ610262, dissimilarity: 0–0.51%) and New Brunswick, Canada (HQ610259, dissimilarity: 0–0.39%). The species was abundant in the Baltic Sea and




**Figs 15–21.** Morphology of *Kornmannia leptoderma* specimens from northern Germany. **Fig. 15.** Typical sampling site along the coast of the Baltic Sea (Aschau lagoon), with *K. leptoderma* growing on the shaded side of a rock. **Fig. 16.** Rosette-shaped specimens from the Baltic Sea (Aschau lagoon). **Fig. 17.** Funnel-shaped specimen from the Baltic Sea (coastal inlet, Schlei, Lindaunis). **Fig. 18.** Cells in apical and middle thallus regions, in rows or pairs. **Fig. 19.** Marginal chloroplasts and central pyrenoids (one or rarely two). **Figs 20, 21.** Club-shaped cells of the rhizoidal zone.

also occurred on Helgoland. However, the species was only observed during spring (March to May), and in late spring drifting mats of *M. grevillei* frequently developed in sheltered bays, harbours and lagoons. The cells of the *M. grevillei* specimens were arranged in more distinct rows than those of the *K. leptoderma* specimens.

The only specimen that clustered with the *P. undulatum* reference sequence (dissimilarity: 0.13%) was found in the lower intertidal zone of Helgoland. As in *M. grevillei*, the cells were often arranged in rows. However, instead of a smooth transition from basal cells to rhizoidal cells, abrupt changes in cell shape were observed, and the rhizoidal cells were longer than those of the *K. leptoderma* specimens (60–90 µm, up to 110 µm; Supplementary fig. S2; for details see Supplementary Information).

An additional taxon that might represent *Gayralia oxysperma* was not detected at any of the study sites, even though Kützing (1843) originally described its basionym, *Ulva oxysperma*, on the basis of material collected in Schleswig-Holstein at Winning (located at the inner Schlei, a narrow inlet of the Baltic Sea, site 127 in Fig. 1). Unfortunately, the type material of *U. oxysperma* appears to be lost. However, historical *G. oxysperma* vouchers from Friedrichsort, Kiel, Germany, that were sampled in 1962 (MH720544) and from Copenhagen, Denmark, that were sampled in 2004 and 2007 (MH720542 and MH720543) were available for sequencing. Notably, all three voucher sequences clustered with *K. leptoderma* (Fig. 2, Table 2). During subsequent visits (i.e. additional collections in 2017 and 2018), thalli exhibiting the described morphology of *G. oxysperma* were not detected at Winning (site 127 in Fig. 1, salinity 1) but were collected at the inner Schlei at Brodersby (site 128 in Fig. 1, salinity 7), which is 10 km from Winning, and at Lindaunis (site 61 in Fig. 1, Supplementary table S1), which is 30 km from Winning. However, sequences from these *G. oxysperma*-like specimens were also placed in the *K. leptoderma* cluster (MH720545–MH720547; Supplementary table S1).

## Discussion

The 20 taxa of green algae that were detected in the present study (Fig. 2) can be identified with variable degrees of certainty. Only one taxon could be assigned to a clade that included a reference sequence from type material, namely for *Ulva tenera* (Kornmann & Sahling, 1994). However, *U. tenera* was described relatively recently, and the corresponding cluster in our phylogenetic analysis also encompassed several reference sequences from specimens that were recognized elsewhere as *U. lactuca* L. Even though only one of the more than 100 *U. tenera* syntypes was examined, and given that the current concept of *U. lactuca* has been challenged (Butler, 2007), the phylogenetic analysis presented here strongly suggests that *U. tenera* is a synonym of *U. lactuca*. This view is further supported by the observation that young *U. lactuca* specimens from Helgoland exhibit the described morphology of *U. tenera* (Kornmann & Sahling, 1994). Other described characteristics of *U. tenera* are its restriction to the uppermost eulittoral and its exclusively vegetative propagation (i.e. with biflagellate spores; Kornmann & Sahling, 1994); apparently, the authors observed dwarfish forms of *U. lactuca* that were adapted to extended air exposure. Therefore, *U. tenera* is here reduced to synonymy with *U. lactuca*. Other homotypic synonyms of *U. lactuca* cited below are according to Guiry & Guiry (2018).

### *Ulva lactuca*

Linnaeus, C. 1753. Species plantarum, exhibentes plantas rite cognitas, ad gen era relatas, cum differentiis specificis, nominibus trivialibus, synonymis selectis, locis natalibus, secundum systema sexuale digestas. Vol. 2 pp. [i], 561–1200, [1–30, index], [i, err.]. Holmiae [Stockholm]: Impensis Laurentii Salvii.

Homotypic synonyms:
*Phyllona lactuca* (Linnaeus) F.H.Wiggers 1780
*Monostroma lactuca* (Linnaeus) J.Agardh 1883
*Ulva tenera* Kornmann & Sahling 1994

The genetic-based species identities of several other taxa corresponded to characteristic morphological traits. Indeed, this was the case for *U. torta*, which usually formed massively intertwined tubular thalli of small diameter; *U. prolifera*, which mostly exhibited characteristically twisted stipes; and *Umbraulva dangeardii*, which is characterized by its olive green pigmentation. Meanwhile, the genetic-based species identities of the three monostromatic taxa corresponded to known phenotypic traits. For example, *M. grevillei* was only observed during spring, which was not the case for any other entity; *K. leptoderma* exhibited a characteristic heteromorphic life cycle, as reported elsewhere (Weinberger *et al.*, 2018); and *P. undulatum*, despite only being observed once, exhibited a typical morphology (see Supplementary Information). Furthermore, specimens that clustered with *Ulva intestinalis* mostly exhibited the tubular and unbranched morphology considered characteristic of the species (Kornmann & Sahling, 1977; Rothmaler, 1984; Pankow, 1990), but branched specimens were occasionally observed, as reported previously (Reed & Russell, 1978; Blomster *et al.*, 1998), probably promoted by low salinity (Steinhagen *et al.*, 2018*b*).

However, for most cases, genetic-based species identities failed to correspond to characteristic morphological traits. For example, specimens that exhibited the characteristic lanceolate and partly distromatic type morphology of *U. linza* (Kornmann & Sahling, 1977; Rothmaler, 1984; Pankow, 1990) clustered with *U. linza* reference sequences, but also with sequences from specimens that exhibited tubular and branched morphologies corresponding to descriptions of *U. procera* and *U. ahlneriana* (Kornmann & Sahling, 1977; Rothmaler, 1984; Pankow, 1990) and a sequence from a historical voucher of *U. ahlneriana* (Fig. 2). This observation supports the previous suggestions that *U. procera* (Maggs *et al.*, 2007*b*) and *U. ahlneriana*(Guiry & Guiry, 2018) are synonyms of *U. linza*. It was interesting that the cluster representing *U. linza* in our phylogenetic tree included two lineages which were morphologically indistinct. One of the lineages was only detected on Helgoland, whereas the second was only detected on mainland coasts. However, more information is needed to determine whether the groups represent distinct species or simply unique genotypes that developed in response to geographic separation.

Meanwhile, the *U. compressa* specimens also exhibited multiple gross morphologies. One morphotype was only observed on North Sea coasts and corresponded to the morphology of the tubular and branched type material (Linnaeus, 1753). However, as already discussed elsewhere (Steinhagen *et al.*, 2018*a*), genetically indistinguishable specimens from the Baltic and Wadden Seas exhibited a completely different morphology that was consistently distromatic and sheet-like. Evidently, the distromatic morphology of *U. compressa* strongly overlaps with the allegedly unique morphology of *U. lactuca*, thereby causing a considerable amount of historical taxonomic confusion (Steinhagen *et al.*, 2018*a*). Based on the results of the present study, *U. lactuca* in northern Germany is only present on Helgoland (Table 2, Supplementary table 2), whereas historical records from the Baltic Sea (Schories *et al.*, 2009) are misidentified *U. compressa* specimens (Steinhagen *et al.*, 2018*a*). Notably, historical vouchers from Helgoland (Kornmann & Sahling, 1994) that exhibited the curved morphology of *U. pseudocurvata* (Hoeksema & Van den Hoek, 1983) yielded sequences that clustered with *U. lactuca* sequences, whereas specimens that were recently collected from mainland coasts of northern Germany (Steinhagen *et al.*, 2018*a*) and elsewhere (Tan *et al.*, 1999; Hayden & Waaland, 2004) exhibiting the same morphology yielded sequences that clustered with *U. compressa* sequences. This clearly challenges the validity of *U. pseudocurvata* as a taxonomic entity, because its description is based on morphological traits that are clearly not specific, and it also confirms the strong morphological plasticity of *U. lactuca* on Helgoland and *U. compressa*, in its distromatic form, on the mainland coasts of northern Germany.

In addition to *U. lactuca* and the distromatic form of *U. compressa*, three additional entities with consistently distromatic blades were also observed in the present study. These specimens clustered with *U. gigantea, U. australis, U. rigida* and *U. laetevirens* reference specimens (Fig. 2). In these cases, the observed morphologies generally paralleled the corresponding type morphologies. However, based on morphological observations the taxa were not reliably distinguishable from one another, *U. lactuca*, or the distromatic form of *U. compressa*. Furthermore, as recently demonstrated by ITS and *rbc*L analysis (Horta *et al.*, 2018), *U. rigida* and *U. laetevirens* could not be distinguished using *tuf*A gene sequences. Therefore, *U. laetevirens* Areschoug 1854 should be considered a synonym of *U. rigida* C. Agardh 1823.

Some clades with tubular morphologies could not be clearly resolved. As reported previously (Heesch *et al.*, 2009; Kraft *et al.*, 2010; Saunders & Kucera, 2010; Kirkendale *et al.*, 2013), there was no clear species boundary between *U. flexuosa* and *U. californica* (Fig. 2). However, despite this observation, Hiraoka *et al.* (2017) used hybridization experiments to confirm the biological separation of *U. flexuosa* and *U. californica* from Japan. Because cross-breeding experiments were not included in the present study, we have chosen to indicate the species' lack of genetic resolution using the term '*Ulva flexuosa/californica* complex'.

A reference sequence for type material of the tubular species *U. shanxiensis*, which was recently described from a freshwater stream in northern China (Chen *et al.*, 2015), was placed basal to a clade of tubular specimens in the phylogenetic analysis of the present study (Fig. 2). However, the clade encompassing *U. shanxiensis* and the tubular specimens was poorly supported, indicating relatively high sequence divergence (Fig. 2, note branch length). Therefore, the tubular specimens are unlikely to belong to *U. shanxiensis*, and the identity of the clade remains unidentified as a result.

Identities could also not be determined for two genetic entities in the genus *Blidingia* (*Blidingia* sp. 1 and *Blidingia* sp. 2), since they did not match any available reference sequences. Specimens of the *Blidingia* sp. 2 clade exhibited strong morphological overlap with a second clade encompassing a reference sequence of *Blidingia marginata* and could only be distinguished molecularly. The morphology of both clades was consistent with that of *B. marginata* but, perhaps, also with that of *B. ramifera* (Garbary & Barkhouse, 1987), a species that has not yet been reported from the area and which is, for formal reasons, invalid (Cormaci *et al.*, 2014) and currently regarded as a synonym of *B. marginata* (Guiry & Guiry, 2018). In contrast, specimens of the relatively abundant *Blidingia* sp. 1 exhibited unique genetic and morphological traits that clearly distinguished them from other *Blidingia* taxa in northern Germany. In addition to *B. marginata* and *B. minima*, two other *Blidingia* species (*B. chadefaudii* and *B. subsalsa*) have also been reported from the German coasts of the North Sea (Kornmann & Sahling, 1978; Bartsch & Kuhlenkamp, 2000; Schories *et al.*, 2009). However, no molecular reference data were available for *B. chadefaudii* and *B. subsalsa*, and morphological identification criteria for the species remain ambiguous and overlapping. Therefore, in order to identify *Blidingia* sp. 1 and *Blidingia* sp. 2 and to confirm the identities of *B. marginata* and *B. minima*, type material of different *Blidingia* species should be analysed by molecular markers and species life cycles should be documented using cultivated material. The same strategy might also facilitate the identification of ambiguous *Ulva* specimens in the future.

Notably, our phylogenetic analyses did not support the monophyly of the genus *Ulva* (Fig. 2). In our study the inclusion of *U. lactuca*, *U. australis*, *U. intestinalis* and *U. compressa* as a sister clade of *Umbraulva* species and *Percursaria percursa* was revealed (Fig. 2), in contrast to previous studies which used other marker genes (Hayden *et al.*, 2003; Heesch *et al.*, 2009; Kirkendale *et al.*, 2013). This topology was not observed when *P. percursa* was excluded from the analysis (Supplementary fig. S1). However, the inclusion of more, rather than fewer, taxa is more likely to yield true phylogenetic relationships.

The species inventory of *Ulva sensu lato* of the present study diverged considerably from the expected inventory (Schories *et al.*, 2009). Four species (*U. australis, U. californica, U. gigantea* and *Umbraulva dangeardii*) were observed in the area for the first time (Fig. 22). *Ulva australis* was first introduced to southern France and very recently reported from the Dutch Oosterschelde estuary (Fort *et al.*, 2019). Now, the species is also present in the North Friesian Wadden Sea. The same is true for *U. gigantea*, which, in Europe, had only been reported from Britain and other westerly locations (Maggs *et al.*, 2007*b*). Single individuals of *U. californica* were first observed in Germany in 2008 on the Wadden Sea island of Wangerooge in Lower Saxony (Lackschewitz *et al.*, 2015) and, over the next six years, eventually reached the SW Baltic Sea. In the present study, *Umbraulva dangeardii* was only observed at one site on Helgoland (Table 2, Supplementary table S1). It is interesting that even though Helgoland is a phycological hotspot in Germany, *U. dangeardii* has never before been included in inventories (Kornmann & Sahling, 1977, 1983, 1994; Bartsch & Kuhlenkamp, 2000), suggesting recent introduction. Yet, the presence of *U. dangeardii* in Germany may have been ignored for some time, due to the preference of the species for subtidal habitats. In addition to the above-mentioned newly introduced species, three (*Blidingia* sp. 1, *Blidingia* sp. 2, *Ulva* sp.) or even four (if one of the two genetic entities within *U. linza* is included) additional taxa that were observed in our study probably represent cryptic and perhaps undescribed species that have so far not been recognized.

Despite these new records, the morphology-based species inventories of all three main study areas were expected to be larger than the genetically validated ones (Fig. 22). Altogether, 14 of the species (members of *Ulva, Blidingia, Monostroma, Gayralia* and *Ulvaria*) that were listed by Schories *et al.* (2009) and are currently accepted taxonomically (Guiry & Guiry, 2018) were not encountered genetically in the present study. This lack of detection could indicate their absence but might also be attributed to other factors, such as low abundance or lack of molecular reference material. Indeed, no *tufA* reference sequences are available for 11 of the 14 missing species, and the numerous historical records from the area may be the result of misidentification and taxonomic confusion.

As discussed above, records of *Ulva pseudocurvata* from northern Germany are often, and perhaps always, due to the misidentification of either *U. compressa* or *U. lactuca*. Also, the only record of *U. splitiana* from our area (as *Enteromorpha jugoslavica*; Kaminski, 1980) was due to the misidentification of *U. linza*, as demonstrated through sequencing of the ITS marker gene from the corresponding herbarium voucher (Gesche Bock, pers. comm.). Furthermore, analysis of historical *Gayralia oxysperma* vouchers from northern Germany and adjacent areas indicated that all the vouchers were genetically identical to *Kornmannia leptoderma*, which had until now been considered a relatively rare species that was only present on Helgoland (Kornmann & Sahling, 1983) and, therefore, has not been included in identification keys for other parts of Germany (Rothmaler, 1984; Pankow, 1990) or adjacent areas (Brodie *et al.*, 2007). However, *K. leptoderma* was present in all three main areas of the present study (see also Weinberger *et al.*, 2018). In striking contrast, *G. oxysperma* was not observed, even at the type locality of its basionym *U. oxysperma* Kützing (see the Supplementary Information for a description of the relatively complicated nomenclatural history of *G. oxysperma*). For further details see Doty (1947), Gayral (1965) and Womersley (1984). This apparent absence or rarity of *G. oxysperma* is surprising because the species should be present across the entire Baltic Sea (Schories *et al.*, 2009). Descriptions of *G. oxysperma* (Rothmaler, 1984; Pankow, 1990) are in complete agreement with the morphology of *K. leptoderma* in our area (Figs 15–21, see also Weinberger *et al.*, 2018). The two species have very different life cycles (Vinogradova, 1969), but ontogenetic observations are time consuming, and for this reason most historical records of *G. oxysperma* are probably based on the morphological traits of field-collected material. As a consequence, it is likely that most records of *G. oxysperma* are due to the misidentification of *K. leptoderma*. Similarly, the molecular analysis of *G. oxysperma*-like specimens from the North-west Atlantic yielded two clusters attributed to

| Species | Baltic Sea | | Wadden Sea | | Helgoland | |
|---|---|---|---|---|---|---|
| | 2019 | 2009 | 2019 | 2009 | 2019 | 2009 |
| *Blidingia marginata* (J.Agardh) P.J.L.Dangeard ex Bliding 1963 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Blidingia minima* (Nägeli ex Kützing) Kylin 1947 | X | ✓ | X | ✓ | X | ✓ |
| *Blidingia chadefaudii* (Feldmann) Bliding 1963 | | | | | X | ✓ |
| *Blidingia subsalsa (*Kjellmann) Kornmann & Sahling ex Scagel et al. 1989 | | | | | X | ✓ |
| *Blidingia* sp. 1 | ✓ | X | ✓ | X | ✓ | X |
| *Blidingia* sp. 2 | | | | | ✓ | X |
| *Kornmannia leptoderma (*Kjellmann) Bliding 1969 | ✓ | X | ✓ | ✓ | ✓ | ✓ |
| *Ulva compressa* Linnaeus 1753 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Ulva pseudocurvata* Koeman & Hoek 1981 | | | | | X | ✓ |
| *Ulva curvata* (Kützing) De Toni 1889 | | | X | ✓ | | |
| *Ulva flexuosa* Wulfen 1803 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Enteromorpha flexuosa* subsp. *linziformis* (Bliding) Bliding 1963 | | | X | ✓ | | |
| *Ulva flexuosa* subsp. *paradoxa* (C. Agardh) M.J. Wynne 2005 | | | X | ✓ | X | ✓ |
| *Ulva californica* Wille 1899 | ✓ | X | ✓ | X | ✓ | X |
| *Ulva intestinalis* Linnaeus 1753 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Ulva lactuca* Linnaeus 1753 | X | ✓ | X | ✓ | ✓ | ✓ |
| *Ulva tenera* Kornmann & Sahling 1994 | | | X | ✓ | X | ✓ |
| *Ulva linza* Linnaeus 1753 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Enteromorpha jugoslavica* Bliding | X | ✓ | | | | |
| *Ulva prolifera* O. F. Müller 1778 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Ulva torta* (Mertens) Trevisan 1841 | ✓ | ✓ | ✓ | ✓ | | |
| *Ulva lobata* (Kützing) Harvey 1855 | | | | | X | ✓ |
| *Ulva radiata* (J.Agardh) H.S.Hayden, Blomster, Maggs, P.C.Silva, M.J.Stanhope & J.R.Waaland 2003 | | | X | ✓ | | |
| *Ulva ralfsii* (Harvey) Le Jolis 1863 | | | X | ✓ | | |
| *Ulva simplex* (K.L.Vinogradova) H.S.Hayden, Blomster, Maggs, P.C.Silva, M.J.Stanhope & J.R.Waaland 2003 | X | ✓ | X | ✓ | | |
| *Ulva clathrata* (Roth) C. Agardh 1811 | X | ✓ | X | ✓ | | |
| *Ulva rigida* C. Agardh 1823 and *Ulva scandinavica* Bliding 1968 | ✓ | X | ✓ | ✓ | ✓ | X |
| *Ulva gigantea* (Kützing) Bliding 1969 | ✓ | X | ✓ | X | | |
| *Ulva australis* Areschoug 1854 | | | ✓ | X | ✓ | X |
| *Ulva* sp. | ✓ | X | ✓ | X | ✓ | X |
| *Umbraulva dangeardii* M.J.Wynne & G.Furnari 2014 | | | | | ✓ | X |
| *Ulvaria fusca* (Postels & Ruprecht) Vinogradova 1967 | X | ✓ | | | | |
| *Percursaria percursa* (C. Argardh)Rosenvinge 1893 | ✓ | ✓ | X | ✓ | X | ✓ |
| *Monostroma grevillei* (Thoret) Wittrock 1866 | ✓ | ✓ | X | ✓ | ✓ | ✓ |
| *Monostroma arcticum* Wittrock1866 | | | | | X | ✓ |
| *Protomonostroma undulatum* (Wittrock) Vinogradova 1969 | | | | | ✓ | ✓ |
| *Gayralia oxysperma* (Kützing) K.L. Vinogradova ex Scagel et al. 1989 | X | ✓ | | | | |

**Fig. 22.** Comparison of molecular (*tuf*A)-based identification from the present study and the inventory list from Schories *et al.* (2009). List of species predicted by Schories *et al.* (2009) and detected in the present study (2019) from the Baltic Sea, Wadden Sea and Helgoland. **X**, species not observed; □, species observed; empty, unexpected by Schories *et al.* (2009) and not observed in present study. Light grey shading indicates agreement between Schories *et al.* (2009) and the present study, whereas dark grey shading indicates disagreement. For additional annotations or taxonomic notes by other authors see also Supplementary table S2.

*Monostroma grevillei* (Saunders & Kucera, 2010). Therefore, a thorough taxonomic reassessment of *G. oxysperma* and its populations is urgently needed.

Some species that were reported to occur only in parts of northern Germany were found to have broader distributions than expected. For instance, *U. rigida*, which was only expected to occur in the Wadden Sea and on Helgoland, was also observed in the Baltic Sea (Table 2, Supplementary table S1), and *K. leptoderma*, which had only been reported to occur on Helgoland, was observed in both the Baltic and Wadden Seas (Table 2, Supplementary table S1).

In summary, the current morphological concepts that are used for the identification of *Ulva* species and related taxa in northern Germany are neither in agreement with the species inventory of the area nor with the actual morphology of species that are present. Past morphological descriptions of *U. linza*, *U. intestinalis* and *U. compressa* have been too restrictive, thereby resulting in frequent misidentifications of these abundant taxa. Furthermore, several cryptic and/or newly introduced species, including *K. leptoderma*, *U. australis*, *U. californica*, *U. gigantea* and *Protomonostroma undulatum*, are now present in northern Germany, and several genetic entities, namely *Ulva* sp., *Blidingia* sp. 1 and *Blidingia* sp. 2, have yet to be identified. Meanwhile, *B. minima* and *G. oxysperma* were either absent or much rarer than expected, and certain other taxa that were expected in the area, namely *U. tenera*, are actually synonyms. The observations of the present study provide a basis for the development of improved identification keys, although it is unlikely that it will be possible to distinguish all species morphologically owing to the considerable overlap of traits. The DNA barcoding approach used in the present study clearly provides better resolution. However, *U. californica* and *U. flexuosa* cannot be clearly distinguished using the analysis of *tuf*A alone and more sequences of type material will be needed to improve the identification of species in the future. Furthermore, additional genetic markers should be investigated and cultivation studies should be performed to resolve remaining issues, such as the taxonomic affiliation of the newly found *Blidingia* species or relations among the genera *Ulva*, *Umbraulva* and *Percursaria*.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

## Supplementary information

Supplementary Information. (1) Distribution and specific characteristics of observed species, (2) nomenclatural history of *Gayralia oxysperma* and (3) seasonal species variation.

**Supplementary table S1**. Full collection data.

**Supplementary table S2**. Comparison of molecular (*tuf*A)-based identification from the present study and the inventory list from Schories *et al.* (2009).

**Supplementary fig. S1.** Maximum likelihood phylogram of *tuf*A sequences from taxa of *Ulva sensu lato* from northern Germany.

**Supplementary fig. S2.** Morphology of *Protomonostroma undulatum* specimens from Helgoland, Germany.

## Author contributions

S. Steinhagen: experimental design, fieldwork and algae collection, laboratory work, macro- and microscopic observation, phylogenetic analysis, drafting and editing manuscript; R. Karez: experimental design, algae collection, drafting and editing manuscript; F. Weinberger: original concept, collection of specimens, drafting and editing manuscript.

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# Cryptic, alien, and lost species: Molecular diversity of *Ulva sensu lato* along the German coasts of the North and Baltic Seas

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**Supplement**

**Content**

## 1. Distribution and specific characteristics of observed species

The distribution, ecology, and morphology of species observed during the present study are described below.

*Ulva gigantea*

Specimens of *U. gigantea* were only found in the Wadden Sea around the ferry terminal of Dagebüll and an adjacent area and at one site in the Baltic Sea. The species' distromatic, sheet-like thalli were mostly lobed or rosette-like and rarely lanceolate. Blades were attached by a small rhizoidal zone during the beginning of the growth season (June–July), and mature thalli, with small holes (0.5–3 mm), were mostly found drifting (August). By the end of the vegetation phase, the holes had widened to up to 3 cm. However, in some cases, it was unclear if the holes were naturally occurring or feeding traces. The margins of the lobed or rosette-like thalli lacked microscopic teeth (sometimes possessed macroscopic teeth, probably due to feeding) and were typically frilled or ruffled. The thalli were relatively rigid, ranging from 12 to 42 cm (up to 50 cm) in length. The polygonal (rarely round) cells of the middle and apical regions had rounded corners; were either arranged in short rows, curved, or unordered; 19–23 × 20–22 µm in surface view; with a marginal chloroplast; and with a single (sometimes 2) pyrenoid. Meanwhile, the elongated cells of the rhizoidal zone contained varying numbers of pyrenoids (1–4).

*Ulva rigida*

Specimens of *U. rigida* were most prominently found in the northern parts of the Wadden Sea but also occurred at one location in the Baltic Sea (Heiligenhafen) and at multiple sites on Helgoland. In the Wadden Sea, both drifting mats and attached specimens of *U. rigida* were observed, whereas only separate attached individuals were observed on Helgoland and in the Baltic Sea. Individuals inhabited remote sites, strongly trafficked harbours, and tourist-used areas. Mature individuals were generally lanciniate, lobed, or rounded and deeply folded, whereas young thalli often grew as rosettes, and both young and mature specimens were obligately distromatic. A minor portion of the specimens possessed small (1–3 mm) holes, and most specimens possessed microscopic teeth along the outer thallus margins. Teeth were often invisible in mature or drifting thalli. The cells were 8–26 × 8–30 µm in surface view and either arranged in short, curved rows or irregular and polygonal with rounded corners. The singular chloroplasts were either marginal or cap-like, and most cells contained two (sometimes 3, rarely 1 or >3) pyrenoids. The vegetative thallus parts either passed straight into the rhizoidal zone, with no clear "stipe-like region", or slowly tapered until the cells of the rhizoidal zone were formed. A distinct disc-like structure resembling a holdfast was not observed in the examined specimens.

*Ulva* sp.

Specimens belonging to this clade were observed at all three main study areas and were usually found in regions of intensive anthropogenic use, such as harbours, marinas, or tourist-trafficked waters. The morphology of these specimens was highly variable. The tubular thalli were either smooth or wrinkled, 5–13 cm in length, and sometimes appeared similar to the unbranched thalli of *U. intestinalis*, whereas the branched specimens possessed first-level, uniseriate branches that overlapped morphologically with young *U. flexuosa* thalli. However, the main-axis of the branched specimens was always apparent. Cells of the middle and apical thallus regions were 9–18 × 12–29 µm in surface view and either rectangular, quadratic, or polygonal. The singular chloroplasts were either cap-like or filled entire cells, and each contained 1–3 (rarely 4, up to 6 in the rhizoidal zone) pyrenoids.

*Ulva flexuosa*

Specimens of *U. flexuosa* were observed in all three main study areas but were relatively rare, possibly due to sampling bias from the species' delicate texture and from the inconspicuous nature of drifting specimens. The specimens were observed in both brackish and fully marine habitats, at both remote and highly trafficked sites, and either attached to substrates or more commonly as drifting mats. Due to the species' scarcity, the following description is based on only three individuals. The *U. flexuosa* specimens were always tubular, either as delicate, narrow cords (1mm thick) or as broader tubes (8 mm thick). The thalli were up to 40 cm in length, and first-level branchlets were even observed in the rhizoidal zone, whereas both first- and secondary-level branches were often observed to cover the middle and apical thallus parts. In the broader thallus parts, the cells formed multiseriate rows that sometimes extended through the entire thallus, usually including the rhizoidal zone, whereas uniseriate branchlets had broader bases and ended in filigree tips. Due to strong proliferation, the main axis could not be identified in some specimens. The rectangular cells of the middle and apical thallus region were 7–26 × 7–32 µm in surface view and contained single cap-like chloroplasts, as well as 1–3 (rarely up to 5, 2–6 in the rhizoidal zone) pyrenoids.

*Ulva californica*

This species was first observed on Wangerooge, a German island in the North Sea, in 2008 (Lackschewitz et al. 2015) and, six years later (i.e., during the present study), was observed in the Baltic Sea (>180 km [through Kiel Canal] or >1000 km [through Skagerrak] from first introduction), the Wadden Sea (>110 km from first introduction), and on the remote off-shore island of Helgoland (>40 km from first introduction). Accordingly, *U. californica* specimens were collected from a broad range of salinities. The morphology of the specimens varied from branched to unbranched tubes up to lanceolate thalli or thalli of amorphous shape and were mostly found attached to artificial substrate, such as concrete, groynes, or jetties. The *tuf*A sequences of the *U. californica* specimens were identical to reference sequences from California, USA (KM255003; Fig. 2, Table 2). Even though the cluster representing *U. californica* delimits from other clusters it is not clearly separated from the closely related species *U. flexuosa* (70/-).

*Ulva torta*

Specimens of *U. torta* were collected infrequently from the Baltic Sea and from a single site in the Wadden Sea (Nordstrand) but not from Helgoland. The specimens were usually found drifting in shallow water or disused areas of harbours but also formed mats of entangled thalli in the upper intertidal zone. The delicate, filigree thalli were 35–80 µm in width and 12–30 cm in length. However, the lengths of individuals were difficult to measure since specimens found in entangled mats often lack rhizoidal zones, probably due to rupture, and are sometimes fragmented. The thalli were unbranched and straight, and the cells were arranged in multiple longitudinal rows, 8–27 × 4–17 µm in surface view, rectangular to quadratic with rounded corners, and contained singular parietal chloroplasts, mostly averted from the lumen, as well as singular pyrenoids, which were marginal and embedded in the chloroplasts. The young thalli of *U. torta* specimens could be easily distinguished by a central lumen, which was 3–11 µm in surface view and observed to run through the complete length of the thallus.

*Ulva linza*

Specimens of *U. linza* were observed at all three main sampling areas and in a broad range of habitats, including both remote and strongly trafficked sites. Specimens grew on a variety of substrates, including hard substrates (e.g., stones, mussel shells, or artificial structures), but were also observed as epiphytes on other phytobenthic species (e.g., *Fucus* spp., *Gracilaria vermiculophylla*, Laminariales, etc.) or on intertidal vegetation (e.g., *Phragmites* sp.). Even though *U. linza* specimens were usually observed attached to substrates (especially in harbours with low wave movement or in shallow lagoons) drifting, inflated individuals were also observed. The strongest morphological variation among the investigated samples was encountered for specimens of *U. linza*, the phenotypes of which varied from unbranched tubes to branched individuals and even included mixed morphologies where the basal part was tubular and the apical thallus parts were sheet-like and distromatic. The tubular thalli could appear ruffled with hollow margins (typical "*linza*-morphology") or progressively tapering from apical to basal thallus parts, with some specimens only exhibiting branches at the basal thallus region. Besides compressed unbranched individuals also "bottle-brush morphologies" of strongly branched thalli were found (similar to "*procera-ahlneriana* morphology"). In addition, the overall size of *U. linza* thalli ranged from 1–8 cm in length and 0.5–1 cm in width in small epiphytes to greater than 160 cm in length and 10 cm in width in specimens found in sheltered bays, calm inlets, and ditches. The cells were arranged in longitudinal and transverse rows throughout, 13–19 × 13–25 µm in surface view, and apical cells were mostly quadrangular or rectangular, although sometimes polygonal, whereas cells in the middle thallus section were either rectangular or quadrangular. Cells of the apical and middle thallus sections contain singular (rarely 2) pyrenoids and singular marginal chloroplasts that were not necessarily orientated in same direction in all cells, and the rhizoidal cells also contained singular (less frequently 2) pyrenoids observed. The phylogenetic analysis of *U. linza* is discussed in the main text.

*Ulva prolifera*

Specimens of *U. prolifera* were abundant in the intertidal zones of all three main study areas. The specimens were always found attached, never drifting. The thalli were mostly compressed and frequently branched, with both uniseriate and multiseriate branches of varying length. Unbranched individuals were less frequent and sometimes possessed thalli constrictions. Specimens ranged from 1 to 25 cm in length and from 0.5 to 2 cm in width. Even though the stipe-like region was characteristically twisted and "corkscrew-like" in some specimens, other specimens exhibited straight basal regions. Some individuals exhibited a basal part that was slowly tapering and ends in a small (sometimes very reduced) rhizoidal zone. Cells were often paired, rectangular to polygonal, 8–22 × 8–26 µm in surface view and arranged in distinct longitudinal and transverse rows (rarely short rows). A prominent central pyrenoid (rarely two) and a parietal or cell-filling chloroplast were observed in each cell. Most samples possessed only a few rhizoidal cells, and those cells were similar in both the size and number of pyrenoids to those of the apical and middle thallus regions. Cells with elongated tails, as frequently observed in other species, were nearly absent.

*Ulva lactuca*

Please see main document.

*Ulva intestinalis*

Specimens of *U. intestinalis* were abundant in all three main study areas and in a variety of ecosystems, including fully marine, brackish, and freshwater ecosystems and were often observed as epiphytes on perennial seaweeds (e.g., *Fucus* spp.). *U. intestinalis* was a dominant species in overflow basins, rock pools, and water bodies with salinities of <5 PSU and formed dense communities in areas of fresh water inflow to the sea (small streams or drainage ditches). Notably, the texture of thalli collected from areas of low salinity was rigid and inelastic, thereby corresponding to descriptions of var. *crispa* Roth (Greville), which is listed in the species inventory by Schories *et al.* (2009), but differing strongly from the rather soft and fragile texture of *U. intestinalis* specimens at fully marine sites. All the specimens from the study sites were obligately tubular, and the thalli were usually inflated, although sometimes compressed, with tubes that either appeared to be corrugated with ruffled margins, smooth with pale margins, or with multiple constrictions. Meanwhile, the majority of the specimens were unbranched, although several specimens were highly branched and, thus, differed from the unbranched type material. Furthermore, even though the branched specimens were usually found in low salinity environments, they were also observed haphazardly in fully marine habitats.

The thalli ranged from 4 to 35 cm in length in unsheltered or wave-exposed habitats and up to 140 cm in length in sheltered lagoons or overflow basins. Cells of the apical and middle thallus regions were 12–21 × 14–28 cm in surface view, rectangular, quadratic, or polygonal, and either arranged in short, longitudinal rows or unordered. The chloroplasts were either parietal and arranged in the same direction in every cell or filled the entire cells. One pyrenoid, often marginal, was observed in each cell. The apical thallus part often ended in a tapered stipe-like section that transitioned into the rhizoidal zone. Cells of the rhizoidal zone were cone-shaped and possessed 1–3 pyrenoids.

*Ulva compressa*

Specimens of *U. compressa* were abundant at all three main study areas and inhabited a variety of habitats, ranging from sheltered and remote locations to strongly trafficked harbours, drain channels, and overflow basins, and a variety of salinities, ranging from brackish (9 PSU) to fully marine (32 PSU). The thalli were highly variable in overall morphology. For example, only tubular, mostly branched, and generally attached individuals were observed on Helgoland, whereas only distromatic, sheet-like and generally attached specimens were found along the Baltic coast. Meanwhile, in the Wadden Sea, both morphologies were observed, and sheet-like specimens could be encountered drifting or attached. The different morphotypes were not separated by the phylogenetic analysis of *tuf*A sequences. For further details about the morphology of *U. compressa* see Steinhagen *et al.* (2018a). During the summer (July–August), the species strongly proliferated in sheltered lagoons of the Baltic Sea and formed “green tide-like” states in the Wadden Sea (see also Steinhagen *et al.*, 2018a).

*Umbraulva dangeardii*

Specimens of *U. dangeardii* were only found on Helgoland at a depth of 8 m, where they grew attached to the solid rock pedestal in communities with other annual and perennial algae. Specimens were conspicuous, owing to their dark olive colour and typical thin, soft texture (Brodie et al. 2007). The *tuf*A sequences of the species were identical to a reference sequences from southern Italy (MF172091; Fig. 2, Table 2).

*Percursaria percursa* (Morphological data was recorded at one population only)

Specimens of *P. percursa* were only observed at one site in the Baltic Sea (Heiligenhafen), where it grew unattached in dense mats of entangled specimens in the supralittoral zone. The length of single individuals was hard to determine, but single disentangled thalli ranged from 3 to 6 cm in length. Rhizoidal zones were not observed. The thalli were mostly biseriate, with opposing, quadratic cells that were 5–14 µm in surface view and that contained singular chloroplasts along the interior cell wall and 1–3 pyrenoids. Additional populations should be surveyed in order to assess the species' morphological variation.

*Blidingia marginata*

Specimens of *B. marginata* were observed at all three main study areas, and the species was observed to grow as dense populations in the upper intertidal and supralittoral zones. Especially in freshwater-influenced microhabitats that were not directly connected to the sea and that fell dry for longer periods (e.g., in the immediate vicinity of beach showers or rain water drainages), specimens of *B. marginata* and sometimes *U. intestinalis* were found. *Blidingia marginata* grew on a variety of substrates, ranging from stones, concrete, and plastic sheathings of pillars to wood and, at some sites, was observed as an epiphyte on beach vegetation, such as on roots of higher plants or on *Phragmites* sp. The species was abundant at remote sites and protected areas as well as in harbours and highly frequented marinas. Specimens were either observed growing as single individuals or in tufts. The thalli were either corrugated, with slightly to strongly ruffled margins, or straight and compressed and varied from thin compressed tubes of no more than 200 µm in width and 1–3 cm in height to broad, inflated thalli of 0.5–1 cm in width and 5–18 cm in length. Different forms were also observed in the same populations. In addition to the most commonly observed unbranched specimens, individuals with small microscopic branchlets or with macroscopic branches were also observed. The cells were rectangular to polygonal with rounded corners, 3–8 µm in diameter, arranged in distinct longitudinal or sometimes short, curved rows, and possessed both a central, cell-filling chloroplast and a central pyrenoid. Seemingly randomly occurring large round cells (5–9 µm) were also observed.

*Blidingia minima*, *Blidingia* sp. 1 and *Blidingia* sp. 2

Please see main document

*Monostroma grevillei* (gametophyte)

This species was abundant in the Baltic Sea and occurred on Helgoland. However, the species was only observed during spring (March–May), and in late spring, drifting mats of *M. grevillei* frequently developed in sheltered bays, harbours, and lagoons. The thalli were 2–13 cm (rarely >20 cm) in length, monostromatic, and sac-like, lanceolate, or amorphous, and especially in May, individuals began to rupture and appeared deeply cut. The specimens lacked a stipe-region, but the microscopic rhizoidal zone was clearly separated from the basal thallus region. Cell shape and size varied with the respective thallus position. The apical cells were quadrangular to round with rounded corners, 5–20 × 5–26 µm in surface view, and arranged in distinct cell rows, often forming tetrads. In addition, each cell contained a single central pyrenoid and a chloroplast that mostly filled the cell. Thickened cell walls were more prominent in cells of the distal thallus regions than in the other regions but were also observed in cells of the middle thallus region. The cells of the mid-region cells were rectangular to quadrangular, sometimes polygonal, with distinct angular corners, and arranged in distinct rows. Each of the cells contained a single pyrenoid (rarely 2) and a cell-filling chloroplast. The basal cells were distinctly angular, elongated into drawn-out rectangles of 5–12 × 15–32 (46) µm, and were arranged in small but distinct rows. The rhizoidal cells were club-shaped, restricted to the rhizoidal zone, and directed proximal.

*Protomonostroma undulatum*

Only *P. undulatum* specimens from Helgoland were genetically validated. These specimens were predominately observed growing on stone but were also found on piers in the lower and middle intertidal zone. The thalli were monostromatic, lobed, and rosette-like or round and ranged from 2 to 18 cm in length and from 4 to 13 cm in width. The cells of the apical and middle thallus parts were angular, polygonal, 6–16 × 6–24 µm in surface view and arranged in packs of 2–8 in distinct rows. In some individuals, the cell walls were thickened, similar to those of *K. leptoderma* specimens. The cells also contained 1–3 pyrenoids and a marginal to cell-filling chloroplast. Instead of a smooth transition zone between the basal and rhizoidal cells, abrupt changes in cell shape were observed. Cells of the rhizoidal zone generally ranged from 60 to 90 µm in length, with some individuals reaching 110 µm, extended basally as rhizoids and contained 1–3 pyrenoids.

*Kornmannia leptoderma*

Please see main document and Weinberger *et al*., (2018).

**2. The nomenclatural history of *Gayralia oxysperma***

The basionym of *Gayralia oxysperma* is *Ulva oxysperma,* which was described by Kützing (1843) on the basis of material from the Schlei (Winning [Schaalby], Schleswig-Holstein, Germany, site 127 in Fig. 1). Today, this type locality is a freshwater habitat (salinity 1 PSU) that is characterised by extensive stands of *Phalaris arundinacea* and the presence of *Ulva intestinalis* var. *crispa*. Similar environmental conditions certainly existed 150 years ago, since no important geological changes have occurred since then. Kützing characterized the morphology of *U. oxysperma* as follows: "*U. late expansa, plicato-crispa, foraminibus irregularibus perforata; cellularum interaneis monogonimicis, homogeneis, turgidis, primo globosis, demum in spermatia elongate basi acuminata transeuntibus. Ostsee: Schleybusen bei Winning: Frölich (als Ulva lactuca)*" [translation: A wide spread *Ulva*, being multiply folded, perforated by irregularly appearing holes, cells in rows, of uniform shape, then turgid (probably referring to thickened cell walls), initially round (unclear, perhaps referring to early crust-like thallus stages), then changing into an elongated fertile thallus with a tapering, elongated base. Baltic Sea; Schlei near Winning: Frölich (as *Ulva lactuca*)]. Two years later, Kützing (1845) synonymized the validly published species *U. oxysperma* with *U. oxycocca* Kützing nom. illeg., notably in opposition of taxonomic rules, which require the use of the first legitimate epithet, in this case *U. oxysperma*. More than one century later, Doty (1947) changed the affiliation to *Monostroma oxyspermum*, and Bliding (1968) later moved *M. oxyspermum* to the genus *Ulvaria* on the basis of its single-row filament, which is similar to representatives of the family Ulvaceae. However, Vinogradova (1968) introduced the nomen novum *Gayralia oxysperma* and placed the species in a newly introduced family, the Gayraliaceae, within the independent genus *Gayralia*. As stated by Vinogradova (1969), this taxonomic replacement was widely based on the morphologic observations made by Gayral (1965). Vinogradova (1969) also considered Bliding's transfer of the species to the Ulvaceae as incorrect due to major differences in spore release. Probably because the original type material of *Ulva oxysperma* was lost, a lectotype that was collected from the coast of Calvados, France, was established (Womersley, 1984). Since the annotations made by Scagel et al. (1989), the species *Gayralia oxysperma* (Kützing) K.L. Vinogradova ex Scagel *Helgoland*. is validly established.

### 3. Seasonal species variation

The species composition of the study sites investigated in the present study was found to vary by season (Supplementary Table S1). During the summer (June–September), representatives of *Ulva sensu lato* were observed at nearly all the study sites and formed conspicuous intertidal or subtidal communities, whereas, during the winter (November–March), only reduced algal growth was observed and, if any, only small remaining pieces or fragments of thallus were found. Maximum vegetation was only observed during the summer (June–August). In early April, the typical spring algal blooms of *Monostroma grevillei* were observed in the Baltic Sea and on Helgoland but not along the mainland coasts of the North Sea. The bloom of monostromatic thalli from this species lasted for 3–4 weeks, and individuals were only recorded until the end of May (Supplementary Table S1), which indicates the brevity of the species' lifecycle.

## 4. Full collection data

**Table S1:** *Ulva sensu lato* samples collected from northern Germany (Accession No. = GenBank accession number; Voucher = Identification number of voucher specimen; Station map = Numbers used in Figure 1).

| Accession No. | Species | Voucher | Date | Region | Country | Lat | Lon | Station map |
|---|---|---|---|---|---|---|---|---|
| MH538542 | *Blidingia marginata* | S_129 | 30. Jul 2014 | Wadden Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,6813333 | E 8,7544167 | 14 |
| MH538543 | *Blidingia marginata* | S_147_B | 31. Jul 2014 | Wadden Sea | Germany: Schleswig-Holstein, Schobuell | N 54,5078167 | E 8,9955667 | 25 |
| MH538544 | *Blidingia marginata* | S_661 | 21. Apr 2015 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4707167 | E 8,8068333 | 23 |
| MH538545 | *Blidingia marginata* | S_708 | 23. Apr 2015 | Helgoland | Germany: Helgoland | N 54,1780333 | E 7,8887167 | 51 |
| MH538546 | *Blidingia marginata* | S_474 | 12. Sep 2014 | Wadden Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,68435 | E 8,75385 | 13 |
| MH538547 | *Blidingia marginata* | S_737 | 24. Apr 2015 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,8906167 | 49 |
| MH538548 | *Blidingia marginata* | S_156 | 05. Aug 2014 | Wadden Sea | Germany: Schleswig-Holstein, Woehrden | N 54,1173167 | E 8,9359333 | 35 |
| MH538549 | *Blidingia marginata* | S_327 | 25. Aug 2014 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3765333 | E 10,9800667 | 103 |
| MH475464 | *Blidingia marginata* | S_147_A | 31. Jul 2014 | Wadden Sea | Germany: Schleswig-Holstein, Pellworm | N 54,49882 | E 8,8087 | 21 |
| MH475465 | *Blidingia marginata* | S_577 | 14. Apr 2015 | Wadden Sea | Germany: Schleswig-Holstein, Brunsbuettel estuary | N 53,889 | E 9,101133 | 41 |
| MH538691 | *Blidingia* sp. 1 | S_93 | 24. Jul 2014 | Wadden Sea | Germany:Schleswig-Holstein, Aschau | N 54,4608 | E 9,92665 | 65 |
| MH538692 | *Blidingia* sp. 1 | S_622 | 16. Apr 2015 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3787167 | E 10,95545 | 99 |
| MH538693 | *Blidingia* sp. 1 | S_21 | 23. Jul 2014 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,890617 | 49 |
| MH475455 | *Blidingia* sp. 1 | S_828 | 24. Jul 2014 | Wadden Sea | Germany: Schleswig-Holstein, Schobuell | N 54,50782 | E 8,995567 | 25 |
| MH475456 | *Blidingia* sp. 1 | S_818 | 24. Jul 2017 | Wadden Sea | Germany: Schleswig-Holstein, Husum | N 54,47113 | E 9,027917 | 26 |
| MH475457 | *Blidingia* sp. 1 | S_815 | 24. Jul 2017 | Wadden Sea | Germany: Schleswig-Holstein, Finkhaushallig | N 54,41558 | E 8,903633 | 27 |
| MH475458 | *Blidingia* sp. 1 | S_813 | 24. Jul 2017 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,83735 | E 8,6122 | 6 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| MH475459 | *Blidingia* sp. 1 | S_179 | 06. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Brunsbuettel estuary | N 53,889 | E 9,101133 | 41 |
| MH475460 | *Blidingia* sp. 2 | S_34 | 23. Jul 2014 | Helgoland | Germany: Helgoland | N 54,17195 | E 7,8993 | 53 |
| MH475461 | *Blidingia* sp. 2 | S_1 | 22. Jul 2014 | Helgoland | Germany: Helgoland | N 54,18367 | E 7,888633 | 48 |
| MH475462 | *Blidingia* sp. 2 | S_39 | 23. Jul 2014 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,890617 | 49 |
| MH475463 | *Blidingia* sp. 2 | S_124 | 30. Jul 2014 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,73007 | E 8,689167 | 11 |
| MH720546 | *Kornmannia leptoderma* | Lin_1 | 08. Jul 2018 | Baltic Sea | Germany:Schleswig-Holstein, Lindaunis | N 54,5852667 | E 9,8173833 | 61 |
| MH720547 | *Kornmannia leptoderma* | Lin_2 | 08. Jul 2018 | Baltic Sea | Germany: Schleswig-Holstein, Lindaunis | N 54,5852667 | E 9,8173833 | 61 |
| MH720545 | *Kornmannia leptoderma* | Lin_3 | 08. Jul 2018 | Baltic Sea | Germany: Schleswig-Holstein, Lindaunis | N 54,5852667 | E 9,8173833 | 61 |
| MH538551 | *Kornmannia leptoderma* | S_204 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiekut | N 54,4476 | E 9,8716833 | 64 |
| MH538552 | *Kornmannia leptoderma* | S_223 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4369167 | E 10,1734667 | 69 |
| MH538553 | *Kornmannia leptoderma* | S_248 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Falckenstein | N 54,3903667 | E 10,1922 | 76 |
| MH538554 | *Kornmannia leptoderma* | S_334 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,37945 | E 10,9823833 | 101 |
| MH538555 | *Kornmannia leptoderma* | S_337 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,382131 | E 10,96375 | 100 |
| MH538556 | *Kornmannia leptoderma* | S_342 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3758 | E 10,9874167 | 110 |
| MH538557 | *Kornmannia leptoderma* | S_376 | 27. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Grossenbrode | N 54,3566167 | E 11,0610167 | 123 |
| MH538558 | *Kornmannia leptoderma* | S_382 | 27. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Wulfen | N 54,4089167 | E 11,1731333 | 121 |
| MH538559 | *Kornmannia leptoderma* | S_525 | 17. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Grossenbrode | N 54,3581 | E 11,0655 | 122 |
| MH538560 | *Kornmannia leptoderma* | S_535 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Brodten | N 54,9911667 | E 10,8322833 | 127 |
| MH538561 | *Kornmannia leptoderma* | S_698 | 23. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Aschau | N 54,4608 | E 9,92665 | 65 |
| MH538562 | *Kornmannia leptoderma* | S_705 | 23. Apr | Helgoland | Germany: Helgoland | N 54,1780 | E 7,8887 | 51 |

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| | | | 15 | | | 333 | 167 | |
| MH538563 | *Kornmannia leptoderma* | S_715 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,177167 | E 7,892944 | 52 |
| MH538564 | *Kornmannia leptoderma* | S_716 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,177167 | E 7,892944 | 52 |
| MH475466 | *Kornmannia leptoderma* | S_154 | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Finkhaushallig | N 54,41558 | E 8,903633 | 27 |
| MH475467 | *Kornmannia leptoderma* | SH_698 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,17967 | E 7,889583 | 50 |
| MH475468 | *Kornmannia leptoderma* | S_337 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,37945 | E 10,98238 | 101 |
| MH538580 | *Monostroma grevillei* | S_529 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Neustadt | N 54,1107167 | E 10,8135333 | 126 |
| MH538581 | *Monostroma grevillei* | S_530 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Neustadt | N 54,1107167 | E 10,8135333 | 126 |
| MH538582 | *Monostroma grevillei* | S_533 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Neustadt | N 54,1107167 | E 10,8135333 | 126 |
| MH538583 | *Monostroma grevillei* | S_537 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Brodten | N 54,9911667 | E 10,8322833 | 127 |
| MH538584 | *Monostroma grevillei* | S_541 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Grossenbrode | N 54,3566167 | E 11,0610167 | 123 |
| MH538585 | *Monostroma grevillei* | S_543 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Grossenbrode | N 54,3554667 | E 11,0863667 | 124 |
| MH538586 | *Monostroma grevillei* | S_545 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Grossenbrode | N 54,3554667 | E 11,0863667 | 124 |
| MH538587 | *Monostroma grevillei* | S_548 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Wulfen | N 54,4089167 | E 11,1731333 | 121 |
| MH538588 | *Monostroma grevillei* | S_550 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Wulfen | N 54,4089167 | E 11,1731333 | 121 |
| MH538589 | *Monostroma grevillei* | S_554 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Hohwacht | N 54,31815 | E 10,6807333 | 94 |
| MH538590 | *Monostroma grevillei* | S_585 | 15. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Moenkeberg | N 54,3526667 | E 10,1779 | 84 |
| MH538591 | *Monostroma grevillei* | S_587 | 15. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Moenkeberg | N 54,3526667 | E 10,1779 | 84 |
| MH538592 | *Monostroma grevillei* | S_593 | 15. Apr 15 | Baltic Sea | Germany:Schleswig-Holstein, Aschau | N 54,4608 | E 9,92665 | 65 |
| MH538593 | *Monostroma grevillei* | S_599 | 15. Apr 15 | Baltic Sea | Germany:Schleswig-Holstein, Eckernfoerde | N 54,4732167 | E 9,8330833 | 63 |
| MH53 | *Monostroma* | S_604 | 15. | Baltic Sea | Germany:Schleswig-Holstein, | N | E | 56 |

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| 8594 | *grevillei* | | Apr 15 | | Gluecksburg | 54,83675 | 9,5230333 | |
| MH538595 | *Monostroma grevillei* | S_605 | 15. Apr 15 | Baltic Sea | Germany:Schleswig-Holstein, Gluecksburg | N 54,839204 | E 9,517577 | 55 |
| MH538596 | *Monostroma grevillei* | S_616 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,37945 | E 10,9823833 | 101 |
| MH538597 | *Monostroma grevillei* | S_614 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3765333 | E 10,9800667 | 103 |
| MH538598 | *Monostroma grevillei* | S_623 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3759333 | E 10,9797333 | 104 |
| MH538599 | *Monostroma grevillei* | S_624 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3787167 | E 10,95545 | 99 |
| MH538600 | *Monostroma grevillei* | S_627 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3787167 | E 10,95545 | 99 |
| MH538688 | *Monostroma grevillei* | FM 6 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,17195 | E 7,8993 | 53 |
| MH538689 | *Monostroma grevillei* | FM 1 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1796667 | E 7,8895833 | 50 |
| MH538690 | *Monostroma grevillei* | FM 5 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH475469 | *Monostroma grevillei* | S_548 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Wulfen | N 54,40892 | E 11,17313 | 121 |
| MH475470 | *Monostroma grevillei* | S_617 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,37945 | E 10,98238 | 101 |
| MH475500 | *Percursaria percursa* | S_360 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,37945 | E 10,98238 | 101 |
| MH475501 | *Protomonostroma undulatum* | S_733 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,890617 | 49 |
| MH538642 | *Ulva australis* | R_9 | 13. Aug 14 | Helgoland | Germany: Helgoland | N 54,17195 | E 7,8993 | 53 |
| MH538643 | *Ulva australis* | R_10 | 13. Aug 14 | Helgoland | Germany: Helgoland | N 54,17195 | E 7,8993 | 53 |
| MH538644 | *Ulva australis* | TD_11 | 24. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Wesselburenerkoog | N 54,23823661 | E 8,78568942 | 33 |
| MH475471 | *Ulva australis* | TD_10 | 24. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Norderfriedrichskoog | N 54,41362 | E 8,878922 | 28 |
| MH475472 | *Ulva australis* | TD_34 | 15. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, St. Peter-Ording | N 54,2857 | E 8,703204 | 30 |
| MH475473 | *Ulva australis* | TD_36 | 16. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, St. Peter-Ording | N 54,32695 | E 8,585063 | 29 |

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| MH538645 | *Ulva californica* | S_233 | 13. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Schilksee | N 54,4278 | E 10,1717167 | 73 |
| MH538646 | *Ulva californica* | TD_67 | 23. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Buesum | N 54,1253667 | E 8,87305 | 34 |
| MH475454 | *Ulva californica* | S_791 | 23. Sep 15 | Helgoland | Germany: Helgoland | N 54,18367 | E 7,888633 | 48 |
| MH475450 | *Ulva californica* | S_106 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,73007 | E 8,689167 | 11 |
| MF979360 | *Ulva compressa* | S_112 | 30. Jul 14 | Wadden Sea | Germany:Schleswig-Holstein, Dagebuell 1 | N 54,730067 | E 8,6891667 | 11 |
| MF979645 | *Ulva compressa* | S_14_B | 22. Jul 14 | Helgoland | Germany:Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MF979646 | *Ulva compressa* | S_29 | 23. Jul 14 | Helgoland | Germany: Helgoland | N 54,1698167 | E 7,8894167 | 53 |
| MF979647 | *Ulva compressa* | S_115 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,730067 | E 8,6891667 | 11 |
| MF979648 | *Ulva compressa* | S_254 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel | N 54,3538 | E 10,14125 | 78 |
| MF979649 | *Ulva compressa* | S_459 | 16. Mar. 16 | Wadden Sea | Germany: Schleswig-Holstein, Emmelsbuell | N 54,7948667 | E 8,6580667 | 8 |
| MF979650 | *Ulva compressa* | S_ 305 | 20. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Stein | N 54,41775 | E 10,2645 | 91 |
| MF979651 | *Ulva compressa* | S_672 | 21. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Finkhaushallig | N 54,415583 | E 8,90363 | 27 |
| MF979652 | *Ulva compressa* | S_514_B | 19. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Wullfen | N 54,4089167 | E 11,17313 | 121 |
| MF979653 | *Ulva compressa* | S_ 356 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen inland lake | N 54,3787167 | E 10,95545 | 99 |
| MF979654 | *Ulva compressa* | S_361 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen natural reserve ´´Graswader´´ | N 54,37925 | E 11,0050167 | 111 |
| MF979655 | *Ulva compressa* | S_381 | 27. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Wullfen | N 54,4089167 | E 11,17313 | 121 |
| MF979656 | *Ulva compressa* | S_383 | 27. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Wullfen | N 54,4089167 | E 11,17313 | 121 |
| MF979657 | *Ulva compressa* | S_113 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,730067 | E 8,6891667 | 11 |
| MF979658 | *Ulva compressa* | S_6 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,1698167 | E 7,8894167 | 53 |
| MF979659 | *Ulva compressa* | S_563 | 09. Apr | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke- | N 54,8333 | E 8,6142 | 7 |

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| MF97 9661 | *Ulva compressa* | S_ 79 | 24. Jul 16 | Baltic Sea | Germany: Schleswig-Holstein, Wackerballig | N 54,7586 3 | E 9,8778 3 | 59 |
| MG57 5234 | *Ulva compressa* | S_107 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,7300 67 | E 8,6891 667 | 11 |
| MG57 5235 | *Ulva compressa* | S_120 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,7300 67 | E 8,6891 667 | 11 |
| MG57 5236 | *Ulva compressa* | S_128_pl u | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,6813 | E 8,7544 167 | 14 |
| MG57 5237 | *Ulva compressa* | S_151 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Schobuell | N 54,5078 167 | E 8,9955 667 | 25 |
| MG57 5238 | *Ulva compressa* | S_155 | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Woehrden | N 54,1173 167 | E 8,9359 3 | 35 |
| MG57 5239 | *Ulva compressa* | S_157 | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Woehrden | N 54,1173 167 | E 8,9359 3 | 35 |
| MG57 5240 | *Ulva compressa* | S_166 | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Meldorf | N 54,0776 33 | E 8,9681 17 | 38 |
| MG57 5241 | *Ulva compressa* | S_171_A | 06. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrichskoog-Spitze | N 54,0374 3 | E 8,8448 5 | 39 |
| MG57 5242 | *Ulva compressa* | S_182 | 11. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8824 83 | E 8,6031 | 4 |
| MG57 5243 | *Ulva compressa* | S_183 | 11. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8824 83 | E 8,6031 | 4 |
| MG57 5244 | *Ulva compressa* | S_188 | 12. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Rickelsbuellerkoog, Hindenburgdamm | N 54,8911 3 | E 8,6068 3 | 3 |
| MG57 5245 | *Ulva compressa* | S_443 | 08. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8567 | E 8,6034 3 | 5 |
| MG57 5246 | *Ulva compressa* | S_447 | 09. Sep 14 | Wadden Sea | Germany:Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MG57 5247 | *Ulva compressa* | S_452 | 09. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MG57 5248 | *Ulva compressa* | S_468 | 10. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Galmsbuellkoog | N 54,7611 5 | E 8,6967 | 9 |
| MG57 5249 | *Ulva compressa* | S_473 | 10. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Galmsbuellkoog | N 54,7611 5 | E 8,6967 | 9 |
| MG57 5250 | *Ulva compressa* | S_506 | 16. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,5989 83 | E 8,8121 67 | 18 |
| MG57 5251 | *Ulva compressa* | S_514_C | 18. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Wullfen | N 54,4089 167 | E 11,173 13 | 121 |
| MG57 | *Ulva* | S_631 | 17. | Wadden | Germany: Schleswig-Holstein, | N | E | 11 |

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| 5252 | *compressa* | | Apr 15 | Sea | Dagebuell 1 | 54,7300 67 | 8,6891 667 | |
| MG57 5253 | *Ulva compressa* | S_652 | 21. Apr 16 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4707 167 | E 8,8068 3 | 23 |
| MG57 5254 | *Ulva compressa* | S_713 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1771 56 | E 7,8929 52 | 52 |
| MG57 5255 | *Ulva compressa* | S_742 | 01. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4860 52 | E 8,8185 74 | 22 |
| MG57 5256 | *Ulva compressa* | S_743_A | 01. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4860 52 | E 8,8185 74 | 22 |
| MG57 5257 | *Ulva compressa* | S_744 | 02. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4860 52 | E 8,8185 74 | 22 |
| MG57 5258 | *Ulva compressa* | S_748_A | 04. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4604 17 | E 8,8445 67 | 24 |
| MG57 5259 | *Ulva compressa* | S_749 | 05. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4604 17 | E 8,8445 67 | 24 |
| MG57 5260 | *Ulva compressa* | S_803 | 27. Sep 15 | Helgoland | Germany: Helgoland | N 54,1881 7 | E 7,8742 33 | 46 |
| MG57 5261 | *Ulva compressa* | CL_1_A | 17. Jul 15 | Wadden Sea | Germany: Schleswig-Holstein, Husum | N 54,4711 33 | E 9,0279 17 | 26 |
| MG57 5262 | *Ulva compressa* | CL_1_B | 17. Jul 15 | Wadden Sea | Germany: Schleswig-Holstein, Husum | N 54,4711 33 | E 9,0279 17 | 26 |
| MG57 5263 | *Ulva compressa* | FLS_1_A | 16. Jun 15 | Wadden Sea | Germany: Schleswig-Holstein, Sylt | 55.0352 05 | E 8,4001 6 | 1 |
| MG57 5264 | *Ulva compressa* | FLS_1_B | 16. Jun 15 | Wadden Sea | Germany: Schleswig-Holstein, Sylt | 55.0352 05 | E 8,4001 6 | 1 |
| MG57 5265 | *Ulva compressa* | FLS_2(1) | 16. Jun 15 | Wadden Sea | Germany: Schleswig-Holstein, Sylt | 55.0352 05 | E 8,4001 6 | 1 |
| MG57 5266 | *Ulva compressa* | FLS_3(3) | 16. Jun 15 | Wadden Sea | Germany: Schleswig-Holstein, Sylt | 55.0183 2 | E 8,4395 8 | 2 |
| MG57 5267 | *Ulva compressa* | S_171_B | 06. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrichskoog-Spitze | N 54,0374 3 | E 8,8448 5 | 39 |
| MG57 5268 | *Ulva compressa* | S_104 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,7300 67 | E 8,6891 667 | 11 |
| MG57 5269 | *Ulva compressa* | S_125 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 2 | N 54,7304 | E 8,6939 | 10 |
| MG57 5270 | *Ulva compressa* | S_126 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 2 | N 54,7304 | E 8,6939 | 10 |
| MG57 5271 | *Ulva compressa* | S_12 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,1881 67 | E 7,8742 3 | 46 |

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| MG57 5272 | *Ulva compressa* | S_134 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Amsinck Haus | N 54,6153 67 | E 8,8668 83 | 16 |
| MG57 5273 | *Ulva compressa* | S_135 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Amsinck Haus | N 54,6153 67 | E 8,8668 83 | 16 |
| MG57 5274 | *Ulva compressa* | S_137 | 01. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,5166 3 | E 8,8543 67 | 20 |
| MG57 5275 | *Ulva compressa* | S_141 | 02. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Pellworm | N 54,4988 167 | E 8,8087 | 21 |
| MG57 5276 | *Ulva compressa* | S_143 | 02. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Pellworm | N 54,4988 167 | E 8,8087 | 21 |
| MG57 5277 | *Ulva compressa* | S_144_A | 02. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Pellworm | N 54,4988 167 | E 8,8087 | 21 |
| MG57 5278 | *Ulva compressa* | S_158 | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Woehrden | N 54,1173 167 | E 8,9359 3 | 35 |
| MG57 5279 | *Ulva compressa* | S_159 | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Woehrden | N 54,1173 167 | E 8,9359 3 | 35 |
| MG57 5280 | *Ulva compressa* | S_160 | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Woehrden | N 54,1173 167 | E 8,9359 3 | 35 |
| MG57 5281 | *Ulva compressa* | S_172 | 06. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrichskoog-Spitze | N 54,0374 3 | E 8,8448 5 | 39 |
| MG57 5282 | *Ulva compressa* | S_174_A | 07. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrichskoog-Spitze | N 54,0374 3 | E 8,8448 5 | 39 |
| MG57 5283 | *Ulva compressa* | S_174_C | 08. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrichskoog-Spitze | N 54,0374 3 | E 8,8448 5 | 39 |
| MG57 5284 | *Ulva compressa* | S_177 | 08. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Kaiser-Wilhelm-Koog | N 53,9360 33 | E 8,9052 5 | 40 |
| MG57 5285 | *Ulva compressa* | S_185 | 11. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Rickelsbuellerkoog, Hindenburgdamm | N 54,8911 3 | E 8,6068 3 | 3 |
| MG57 5286 | *Ulva compressa* | S_190 | 13. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhem-Luebke-Koog | N 54,8373 5 | E 8,6122 | 6 |
| MG57 5287 | *Ulva compressa* | S_192 | 13. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhem-Luebke-Koog | N 54,8373 5 | E 8,6122 | 6 |
| MG57 5288 | *Ulva compressa* | S_193 | 13. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhem-Luebke-Koog | N 54,8373 5 | E 8,6122 | 6 |
| MG57 5289 | *Ulva compressa* | S_335 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen inland lake | N 54,3794 5 | E 10,982 383 | 101 |
| MG57 5290 | *Ulva compressa* | S_340 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen natural reserve ´´Graswader´´ | N 54,3789 83 | E 10,987 2167 | 105 |
| MG57 5291 | *Ulva compressa* | S_346 | 25. Aug | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen inland lake | N 54,3833 | E 10,950 | 98 |

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| | | | 14 | | | 67 | 2167 | |
| MG57 5292 | *Ulva compressa* | S_348 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen inland lake | N 54,3833 67 | E 10,950 2167 | 98 |
| MG57 5293 | *Ulva compressa* | S_353 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen inland lake | N 54,3833 67 | E 10,950 2167 | 98 |
| MG57 5294 | *Ulva compressa* | S_362 | 26. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen natural reserve ´´Graswader´´ | N 54,378 | E 11,008 583 | 112 |
| MG57 5295 | *Ulva compressa* | S_368 | 26. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen inland lake | N 54,1825 | E 7,8906 167 | 49 |
| MG57 5296 | *Ulva compressa* | S_37_plus | 23. Jul 14 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,8906 167 | 49 |
| MG57 5297 | *Ulva compressa* | S_4_plus | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,1698 167 | E 7,8894 167 | 53 |
| MG57 5298 | *Ulva compressa* | S_450 | 25. Aug 17 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MG57 5299 | *Ulva compressa* | S_478 | 12. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,6843 5 | E 8,7538 5 | 13 |
| MG57 5300 | *Ulva compressa* | S_507 | 16. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,5989 83 | E 8,8121 67 | 18 |
| MG57 5301 | *Ulva compressa* | S_511 | 17. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,5989 83 | E 8,8122 | 18 |
| MG57 5302 | *Ulva compressa* | S_512 | 18. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,5989 83 | E 8,8122 | 18 |
| MG57 5303 | *Ulva compressa* | S_513 | 19. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,5989 83 | E 8,8122 | 18 |
| MG57 5304 | *Ulva compressa* | S_549 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Wullfen | N 54,4089 167 | E 11,173 13 | 121 |
| MG57 5305 | *Ulva compressa* | S_651 | 21. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4707 167 | E 8,8068 3 | 23 |
| MG57 5306 | *Ulva compressa* | S_540 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Großenbrode | N 54,3930 3 | E 11,110 2 | 114 |
| MG57 5307 | *Ulva compressa* | S_626 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen inland lake | N 54,3787 167 | E 10,955 45 | 99 |
| MG57 5308 | *Ulva compressa* | S_670 | 21. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Finkhaushallig | N 54,4155 83 | E 8,9036 3 | 27 |
| MG57 5309 | *Ulva compressa* | S_707 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1780 333 | E 7,8887 167 | 51 |
| MG57 5310 | *Ulva compressa* | S_739_A | 31. Aug 15 | Baltic Sea | Germany: Schleswig-Holstein, Wullfen | N 54,4089 167 | E 11,173 13 | 121 |
| MG57 | *Ulva* | S_741 | 31. | Baltic Sea | Germany: Schleswig-Holstein, | N | E | 121 |

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| 5311 | *compressa* | | Aug 15 | | Wullfen | 54,4089167 | 11,17313 | |
| MG575312 | *Ulva compressa* | S_740 | 31. Aug 15 | Baltic Sea | Germany: Schleswig-Holstein, Wullfen | N 54,4089167 | E 11,17313 | 121 |
| MG575313 | *Ulva compressa* | S_743_B | 01. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,486052 | E 8,818574 | 22 |
| MG575314 | *Ulva compressa* | S_743_C | 01. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,486052 | E 8,818574 | 22 |
| MG575315 | *Ulva compressa* | S_745 | 02. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,486052 | E 8,818574 | 22 |
| MG575316 | *Ulva compressa* | S_746 | 03. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,486052 | E 8,818574 | 22 |
| MG575317 | *Ulva compressa* | S_752 | 06. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4604167 | E 8,844567 | 24 |
| MG575318 | *Ulva compressa* | S_754 | 07. Sep 15 | Wadden Sea | Germany:Schleswig-Holstein, Nordstrand | N 54,4604167 | E 8,844567 | 24 |
| MG575319 | *Ulva compressa* | S_756_A | 08. Sep 15 | Wadden Sea | Germany:Schleswig-Holstein, Nordstrand | N 54,4604167 | E 8,844567 | 24 |
| MG575320 | *Ulva compressa* | S_756_B | 09. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4604167 | E 8,844567 | 24 |
| MG575321 | *Ulva compressa* | S_760_A | 16. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,882483 | E 8,6031 | 4 |
| MG575322 | *Ulva compressa* | S_770 | 17. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,730067 | E 8,6891667 | 11 |
| MG575323 | *Ulva compressa* | S_771 | 18. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,730067 | E 8,6891667 | 11 |
| MG575324 | *Ulva compressa* | S_778 | 19. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,730067 | E 8,6891667 | 11 |
| MG575325 | *Ulva compressa* | S_779 | 20. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell 1 | N 54,730067 | E 8,6891667 | 11 |
| MG575326 | *Ulva compressa* | S_780A | 09. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4604167 | E 8,844567 | 24 |
| MG575327 | *Ulva compressa* | S_782 | 10. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4604167 | E 8,844567 | 24 |
| MG575328 | *Ulva compressa* | S_788 | 23. Sep 15 | Helgoland | Germany: Helgoland | N 54,183667 | E 7,888639 | 49 |
| MG575329 | *Ulva compressa* | S_790 | 24. Sep 15 | Helgoland | Germany: Helgoland | N 54,75863 | E 9,87783 | 59 |
| MG575330 | *Ulva compressa* | S_795 | 25. Sep 15 | Helgoland | Germany: Helgoland | N 54,183667 | E 7,888639 | 48 |

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| MG575331 | *Ulva compressa* | S_797 | 26. Sep 15 | Helgoland | Germany: Helgoland | N 54,17803 | E 7,8887167 | 51 |
| MG575332 | *Ulva compressa* | S_747 | 01. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,486052 | E 8,818574 | 22 |
| MG575333 | *Ulva compressa* | S_805 | 27. Sep 15 | Helgoland | Germany: Helgoland | N 54,18817 | E 7,874233 | 46 |
| MG575334 | *Ulva compressa* | S_799 | 28. Sep 15 | Helgoland | Germany: Helgoland | N 54,17803 | E 7,8887167 | 51 |
| MG575335 | *Ulva compressa* | S_146_B | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Schobuell | N 54,5078167 | E 8,995567 | 25 |
| MG575336 | *Ulva compressa* | S_454 | 09. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MG575337 | *Ulva compressa* | S_479 | 12. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,68435 | E 8,75385 | 13 |
| MG575338 | *Ulva compressa* | S_1003 | 16. Mar. 16 | Wadden Sea | Germany: Schleswig-Holstein, Emmelsbuell | N 54,7948667 | E 8,6580667 | 8 |
| MG575340 | *Ulva compressa* | S_1001 | 05. Jul 16 | Baltic Sea | Germany: Schleswig-Holstein, Wulfen | N 54,4089167 | E 11,1731333 | 121 |
| MG575341 | *Ulva compressa* | S_1000 | 17-Mar-2016 | Wadden Sea | Germany: Schleswig-Holstein, Emmelsbuell | N 54,7948667 | E 8,6580667 | 8 |
| MG575342 | *Ulva compressa* | S_441 | 08. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8567 | E 8,6034333 | 5 |
| MG575339 | *Ulva compressa* | S_1002 | 16. Nov 15 | Baltic Sea | Germany: Schleswig-Holstein, Moenkeberg | N 54,3526667 | E 10,1779 | 84 |
| MH475451 | *Ulva flexuosa* | S_257 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel | N 54,3538 | E 10,14125 | 78 |
| MH475452 | *Ulva flexuosa* | S_769 | 16. Aug 15 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,73007 | E 8,689167 | 11 |
| MH475453 | *Ulva flexuosa* | S_794 | 23. Sep 15 | Helgoland | Germany: Helgoland | N 54,17803 | E 7,888717 | 51 |
| MH538550 | *Ulva gigantea* | S_102 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7300667 | E 8,6891667 | 11 |
| MH538696 | *Ulva gigantea* | S_87_A | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Eckernfoerde | N 54,4732167 | E 9,8330833 | 63 |
| MH475474 | *Ulva gigantea* | S_775 | 16. Aug 15 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7304 | E 8,6939 | 10 |
| MH475475 | *Ulva gigantea* | S_564 | 09. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog, Rhymschlot | N 54,8333 | E 8,6142 | 7 |
| MH475476 | *Ulva gigantea* | S_632 | 17. Apr | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7300 | E 8,6891 | 11 |

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| | | | 15 | | | 7 | 67 | |
| MH538514 | *Ulva intestinalis* | S_200 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiekut | N 54,4476 | E 9,8716833 | 64 |
| MH538515 | *Ulva intestinalis* | S_38_A | 23. Jul 14 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,8906167 | 49 |
| MH538516 | *Ulva intestinalis* | S_294 | 19. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Laboe | N 54,39725 | E 10,2126333 | 88 |
| MH538517 | *Ulva intestinalis* | S_195 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Falshoeft | N 54,76845 | E 9,9653333 | 60 |
| MH538518 | *Ulva intestinalis* | S_94 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Aschau | N 54,4608 | E 9,92665 | 65 |
| MH538519 | *Ulva intestinalis* | S_95 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Aschau | N 54,4608 | E 9,92665 | 65 |
| MH538520 | *Ulva intestinalis* | S_569 | 14. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Brokdorf | N 53,8611667 | E 9,3231333 | 44 |
| MH538521 | *Ulva intestinalis* | S_642 | 21. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Schobuell | N 54,5078167 | E 8,9955667 | 25 |
| MH538522 | *Ulva intestinalis* | S_181 | 06. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Brunsbuettel estuary | N 53,889 | E 9,1011333 | 41 |
| MH538523 | *Ulva intestinalis* | S_191 | 11. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Neukirchen | N 54,8018333 | E 9,7554833 | 58 |
| MH538524 | *Ulva intestinalis* | S_214 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4442 | E 10,18125 | 67 |
| MH538525 | *Ulva intestinalis* | S_251 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel-Wik | N 54,3662 | E 10,1488333 | 77 |
| MH538526 | *Ulva intestinalis* | S_271 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Moenkeberg | N 54,3464667 | E 10,1742 | 82 |
| MH538527 | *Ulva intestinalis* | S_303_B | 20. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Stein | N 54,41775 | E 10,2645 | 91 |
| MH538528 | *Ulva intestinalis* | S_307 | 20. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Marina Wendtorf | N 54,42055 | E 10,2899 | 92 |
| MH538529 | *Ulva intestinalis* | S_316 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Hohwacht | N 54,31815 | E 10,6807333 | 94 |
| MH538530 | *Ulva intestinalis* | S_322 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3759333 | E 10,9797333 | 104 |
| MH538531 | *Ulva intestinalis* | S_325 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3759333 | E 10,9797333 | 104 |
| MH538532 | *Ulva intestinalis* | S_343 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3783167 | E 10,99125 | 107 |
| MH53 | *Ulva* | S_359 | 25. | Baltic Sea | Germany: Schleswig-Holstein, | N | E | 107 |

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| 8533 | *intestinalis* | | Aug 14 | | Heiligenhafen | 54,3783167 | 10,99125 | |
| MH538534 | *Ulva intestinalis* | S_381 | 27. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Wulfen | N 54,4089167 | E 11,1731333 | 121 |
| MH538535 | *Ulva intestinalis* | S_415 | 02. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3773 | E 10,9948667 | 108 |
| MH538536 | *Ulva intestinalis* | S_426 | 03. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Kellenhusen | N 54,19275 | E 11,0708167 | 125 |
| MH538537 | *Ulva intestinalis* | S_430 | 03. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Neustadt | N 54,1107167 | E 10,8135333 | 126 |
| MH538538 | *Ulva intestinalis* | S_539 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Grossenbrode | N 54,3566167 | E 11,0610167 | 123 |
| MH538539 | *Ulva intestinalis* | S_607 | 15. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Gluecksburg | N 54,83675 | E 9,5230333 | 56 |
| MH538540 | *Ulva intestinalis* | S_662 | 21. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Finkhaushallig | N 54,4155833 | E 8,9036333 | 27 |
| MH538541 | *Ulva intestinalis* | S_700 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1796667 | E 7,8895833 | 50 |
| MH475477 | *Ulva intestinalis* | S_72 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Gluecksburg | N 54,8392 | E 9,517577 | 55 |
| MH475478 | *Ulva intestinalis* | S_133 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,68435 | E 8,75385 | 13 |
| MH538565 | *Ulva lactuca* | S_5 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,183667 | E 7,888633 | 48 |
| MH538566 | *Ulva lactuca* | S_10 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,188172 | E 7,880024 | 47 |
| MH538567 | *Ulva lactuca* | S_11 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH538568 | *Ulva lactuca* | S_20 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,183667 | E 7,888633 | 48 |
| MH538569 | *Ulva lactuca* | S_673 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,188172 | E 7,880024 | 47 |
| MH538570 | *Ulva lactuca* | S_678 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,188172 | E 7,880024 | 47 |
| MH538571 | *Ulva lactuca* | S_679 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH538572 | *Ulva lactuca* | S_681 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH538573 | *Ulva lactuca* | S_696 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1796667 | E 7,8895833 | 50 |

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| MH538574 | *Ulva lactuca* | S_721 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH538575 | *Ulva lactuca* | S_725 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH538576 | *Ulva lactuca* | S_728 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH538577 | *Ulva lactuca* | S_729 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,8906167 | 49 |
| MH538578 | *Ulva lactuca* | S_734 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1825 | E 7,8906167 | 49 |
| MH538579 | *Ulva lactuca* | S_735 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1796667 | E 7,8895833 | 50 |
| MH475479 | *Ulva lactuca* | S_729 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,18817 | E 7,880024 | 47 |
| MH475480 | *Ulva lactuca* | S_696 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,17967 | E 7,889583 | 50 |
| MH538647 | *Ulva linza* 1 | S_63 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Gluecksburg | N 54,83675 | E 9,5230333 | 56 |
| MH538648 | *Ulva linza* 1 | S_64 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Gluecksburg | N 54,83675 | E 9,5230333 | 56 |
| MH538649 | *Ulva linza* 1 | S_65 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Gluecksburg | N 54,83675 | E 9,5230333 | 56 |
| MH538650 | *Ulva linza* 1 | S_132 | 30. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,6813333 | E 8,7544167 | 14 |
| MH538651 | *Ulva linza* 1 | S_192 | 12. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,83735 | E 8,6122 | 6 |
| MH538652 | *Ulva linza* 1 | S_197_B | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Schoenhagen | N 54,6361167 | E 10,03125 | 62 |
| MH538653 | *Ulva linza* 1 | S_198 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Schoenhagen | N 54,6361167 | E 10,03125 | 62 |
| MH538654 | *Ulva linza* 1 | S_199 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Schoenhagen | N 54,6361167 | E 10,03125 | 62 |
| MH538655 | *Ulva linza* 1 | S_201 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiekut | N 54,4476 | E 9,8716833 | 64 |
| MH538656 | *Ulva linza* 1 | S_203 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiekut | N 54,4476 | E 9,8716833 | 64 |
| MH538657 | *Ulva linza* 1 | S_206 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiekut | N 54,4476 | E 9,8716833 | 64 |
| MH538658 | *Ulva linza* 1 | S_207 | 12. Aug | Baltic Sea | Germany: Schleswig-Holstein, Kiekut | N 54,4476 | E 9,8716 | 64 |

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| MH538659 | *Ulva linza* 1 | S_209 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4442 | E 10,18125 | 67 |
| MH538660 | *Ulva linza* 1 | S_211 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4442 | E 10,18125 | 67 |
| MH538661 | *Ulva linza* 1 | S_212 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4362333 | E 10,1750167 | 70 |
| MH538662 | *Ulva linza* 1 | S_217 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4362333 | E 10,1750167 | 70 |
| MH538663 | *Ulva linza* 1 | S_220 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4362333 | E 10,1750167 | 70 |
| MH538664 | *Ulva linza* 1 | S_222 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4362333 | E 10,1750167 | 70 |
| MH538665 | *Ulva linza* 1 | S_224 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4369167 | E 10,1734667 | 69 |
| MH538666 | *Ulva linza* 1 | S_226 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4349833 | E 10,17015 | 71 |
| MH538667 | *Ulva linza* 1 | S_229 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4349833 | E 10,17015 | 71 |
| MH538668 | *Ulva linza* 1 | S_237 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Falckenstein | N 54,3903667 | E 10,1922 | 76 |
| MH538669 | *Ulva linza* 1 | S_240 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Falckenstein | N 54,399039 | E 10,190814 | 75 |
| MH538670 | *Ulva linza* 1 | S_243 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Falckenstein | N 54,399039 | E 10,190814 | 75 |
| MH538671 | *Ulva linza* 1 | S_250 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel-Wik | N 54,3662 | E 10,1488333 | 77 |
| MH538672 | *Ulva linza* 1 | S_255 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel | N 54,3538 | E 10,14125 | 78 |
| MH538673 | *Ulva linza* 1 | S_260 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel-Wik | N 54,3514667 | E 10,1432 | 79 |
| MH538674 | *Ulva linza* 1 | S_262 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel | N 54,3478833 | E 10,1503 | 80 |
| MH538675 | *Ulva linza* 1 | S_267 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel | N 54,34635 | E 10,1526333 | 81 |
| MH538676 | *Ulva linza* 1 | S_279 | 19. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heikendorf | N 54,3766833 | E 10,1958667 | 85 |
| MH538677 | *Ulva linza* 1 | S_284 | 19. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heikendorf | N 54,3827 | E 10,2025833 | 86 |
| MH53 | *Ulva linza* 1 | S_288 | 19. | Baltic Sea | Germany: Schleswig-Holstein, | N | E | 87 |

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| 8678 | | | Aug 14 | | Heikendorf | 54,38285 | 10,2028 | |
| MH538679 | *Ulva linza* 1 | S_290 | 19. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Laboe | N 54,4035333 | E 10,2159167 | 89 |
| MH538680 | *Ulva linza* 1 | S_301 | 20. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Stein | N 54,41775 | E 10,2645 | 91 |
| MH538681 | *Ulva linza* 1 | S_314 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Hohwacht | N 54,31815 | E 10,6807333 | 94 |
| MH538682 | *Ulva linza* 1 | S_341 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3783833 | E 10,9879667 | 106 |
| MH538683 | *Ulva linza* 1 | S_364 | 26. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,37925 | E 11,0050167 | 111 |
| MH538684 | *Ulva linza* 1 | S_390 | 01. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3783833 | E 10,9879667 | 106 |
| MH475447 | *Ulva linza* 1 | S_241_U. linza 1 | 18. Aug 14 | Helgoland | Germany: Schleswig-Holstein, Falckenstein | N 54,39037 | E 10,1922 | 76 |
| MH475448 | *Ulva linza* 1 | S_504_U. linza_1 | 16. Sep 14 | Baltic Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,59898 | E 8,8122 | 18 |
| MH475449 | *Ulva linza* 1 | S_64_U.linza_1 | 24. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Gluecksburg | N54,8392 | E 9,517577 | 55 |
| MH538685 | *Ulva linza* 2 | S_726 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1780333 | E 7,8887167 | 51 |
| MH538686 | *Ulva linza* 2 | S_12 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH538687 | *Ulva linza* 2 | S_719 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881667 | E 7,8742333 | 46 |
| MH475445 | *Ulva linza* 2 | S_727_U. linza_2 | 24. Apr 15 | Helgoland | Germany: Helgoland | N 54,17717 | E 7,892944 | 52 |
| MH475446 | *Ulva linza* 2 | S_8_U.linza_2 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,18817 | E 7,874233 | 46 |
| MH538601 | *Ulva prolifera* | S_9 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,188172 | E 7,880024 | 47 |
| MH538602 | *Ulva prolifera* | S_78 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Wackerballig | N 54,7586333 | E 9,8778333 | 59 |
| MH538603 | *Ulva prolifera* | S_114 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7300667 | E 8,6891667 | 11 |
| MH538604 | *Ulva prolifera* | S_136 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,5166333 | E 8,8543667 | 20 |
| MH538605 | *Ulva prolifera* | S_139 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,5166333 | E 8,8543667 | 20 |

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|---|---|---|---|---|---|---|---|---|
| MH538606 | *Ulva prolifera* | S_142 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Pellworm | N 54,4988167 | E 8,8087 | 21 |
| MH538607 | *Ulva prolifera* | S_168_A | 05. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Meldorf | N 54,0776333 | E 8,9681167 | 38 |
| MH538608 | *Ulva prolifera* | S_196 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Falshoeft | N 54,76845 | E 9,9653333 | 60 |
| MH538609 | *Ulva prolifera* | S_358 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3787167 | E 10,95545 | 99 |
| MH538610 | *Ulva prolifera* | S_424_B | 02. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Burg | N 54,4146333 | E 11,21145 | 119 |
| MH538611 | *Ulva prolifera* | S_440 | 08. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8567 | E 8,6034333 | 5 |
| MH538612 | *Ulva prolifera* | S_444 | 08. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MH538613 | *Ulva prolifera* | S_446 | 08. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MH538614 | *Ulva prolifera* | S_461 | 10. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Emmelsbuell | N 54,7948667 | E 8,6580667 | 8 |
| MH538615 | *Ulva prolifera* | S_464 | 10. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Emmelsbuell | N 54,7948667 | E 8,6580667 | 8 |
| MH538616 | *Ulva prolifera* | S_466 | 10. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Emmelsbuell | N 54,7948667 | E 8,6580667 | 8 |
| MH538617 | *Ulva prolifera* | S_470 | 10. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Galmsbuellkoog | N 54,76115 | E 8,6967 | 9 |
| MH538618 | *Ulva prolifera* | S_488 | 12. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Großengaarde | N 54,6636833 | E 8,7909667 | 15 |
| MH538619 | *Ulva prolifera* | S_508 | 16. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,5989833 | E 8,8121667 | 18 |
| MH538620 | *Ulva prolifera* | S_509 | 16. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Hamburger Hallig | N 54,5989833 | E 8,8121667 | 18 |
| MH538621 | *Ulva prolifera* | S_532 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Neustadt | N 54,1107167 | E 10,8135333 | 126 |
| MH538622 | *Ulva prolifera* | S_532_B | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Neustadt | N 54,1107167 | E 10,8135333 | 126 |
| MH538623 | *Ulva prolifera* | S_537_A | 08. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Brodten | N 54,9911667 | E 10,8322833 | 127 |
| MH538624 | *Ulva prolifera* | S_546 | 08. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Wulfen | N 54,4089167 | E 11,1731333 | 121 |
| MH538625 | *Ulva prolifera* | S_552 | 08. Apr | Baltic Sea | Germany: Schleswig-Holstein, Hohwacht | N 54,3181 | E 10,680 | 94 |

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| | | | 15 | | | 5 | 7333 | |
| MH53 8626 | *Ulva prolifera* | S_555 | 09. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MH53 8627 | *Ulva prolifera* | S_619 | 16. Apr 15 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3794 5 | E 10,982 3833 | 101 |
| MH53 8628 | *Ulva prolifera* | S_639 | 17. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Schluettsiel | N 54,6843 5 | E 8,7538 5 | 13 |
| MH53 8629 | *Ulva prolifera* | S_680 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1881 72 | E 7,8800 24 | 47 |
| MH53 8630 | *Ulva prolifera* | S_709 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1719 5 | E 7,8993 | 53 |
| MH53 8631 | *Ulva prolifera* | TD_43 | 18. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, St. Peter Ording | N 54,2857 0206 | E 8,7032 04001 | 30 |
| MH53 8632 | *Ulva prolifera* | TD_65 | 23. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Grothusenkoog | N 54,2885 8739 | E 8,7368 4072 | 31 |
| MH47 5481 | *Ulva prolifera* | S_196 | 12. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Falshoeft | N 54,7684 5 | E 9,9653 33 | 60 |
| MH47 5482 | *Ulva prolifera* | S_9 | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,1881 7 | E 7,8742 33 | 46 |
| MH47 5483 | *Ulva prolifera* | S_466 | 10. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Emmelsbuell | N 54,7948 7 | E 8,6580 67 | 8 |
| MH53 8633 | *Ulva rigida* | R_13 | 13. Aug 14 | Helgoland | Germany: Helgoland | N 54,1719 5 | E 7,8993 | 53 |
| MH53 8634 | *Ulva rigida* | S_116 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7300 667 | E 8,6891 667 | 11 |
| MH53 8635 | *Ulva rigida* | S_121 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7300 667 | E 8,6891 667 | 11 |
| MH53 8636 | *Ulva rigida* | S_189 | 11. Aug 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8373 5 | E 8,6122 | 6 |
| MH53 8637 | *Ulva rigida* | S_442 | 08. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8567 | E 8,6034 333 | 5 |
| MH53 8638 | *Ulva rigida* | S_453_A | 09. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MH53 8639 | *Ulva rigida* | S_558 | 09. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MH53 8640 | *Ulva rigida* | S_560 | 09. Apr 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8333 | E 8,6142 | 7 |
| MH53 8641 | *Ulva rigida* | S_701 | 23. Apr 15 | Helgoland | Germany: Helgoland | N 54,1796 667 | E 7,8895 833 | 50 |
| MH53 | *Ulva rigida* | S_613 | 16. | Baltic Sea | Germany: Schleswig-Holstein, | N | E | 111 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8695 | | | Apr 15 | | Heiligenhafen | 54,3792 5 | 11,005 0167 | |
| MH47 5484 | *Ulva rigida* | S_449 | 09. Sep 14 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog, Rhymschlot | N 54,8333 | E 8,6142 | 7 |
| MH47 5485 | *Ulva rigida* | S_123 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7300 7 | E 8,6891 67 | 11 |
| MH47 5486 | *Ulva rigida* | S_111 | 30. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Dagebuell | N 54,7300 7 | E 8,6891 67 | 11 |
| MH53 8697 | *Ulva* sp. | S_773 | 16. Sep 15 | Wadden Sea | Germany: Schleswig-Holstein, Friedrich-Wilhelm-Luebke-Koog | N 54,8373 5 | E 8,6122 | 6 |
| MH47 5487 | *Ulva* sp. | S_228 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4349 8 | E 10,170 15 | 71 |
| MH47 5488 | *Ulva* sp. | S_269 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Moenkeberg | N 54,3464 7 | E 10,174 2 | 82 |
| MH47 5489 | *Ulva* sp. | S_256 | 18. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Kiel | N 54,3538 | E 10,141 25 | 78 |
| MH47 5490 | *Ulva* sp. | S_2_A | 22. Jul 14 | Helgoland | Germany: Helgoland | N 54,1698 2 | E 7,8894 17 | 53 |
| MH47 5491 | *Ulva* sp. | S_317 | 22. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Sehlendorfer lake | N 54,3088 2 | E 10,688 63 | 95 |
| MH47 5492 | *Ulva* sp. | S_221 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Strande | N 54,4362 3 | E 10,175 02 | 70 |
| MH47 5493 | *Ulva* sp. | S_92 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Aschau | N 54,4608 | E 9,9266 5 | 65 |
| MH53 8694 | *Ulva torta* | S_138 | 31. Jul 14 | Wadden Sea | Germany: Schleswig-Holstein, Nordstrand | N 54,4707 167 | E 8,8068 333 | 23 |
| MH47 5494 | *Ulva torta* | S_81 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Wackerballig | N 54,7586 3 | E 9,8778 33 | 59 |
| MH47 5495 | *Ulva torta* | S_231 | 13. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Schilksee | N 54,4313 2 | E 10,169 33 | 72 |
| MH47 5496 | *Ulva torta* | S_350 | 25. Aug 14 | Baltic Sea | Germany: Schleswig-Holstein, Heiligenhafen | N 54,3787 2 | E 10,955 45 | 99 |
| MH47 5497 | *Ulva torta* | S_73 | 24. Jul 14 | Baltic Sea | Germany: Schleswig-Holstein, Gluecksburg | N 54,8367 5 | E 9,5231 | 56 |
| MH47 5498 | *Umbraulva dangeardii* | R_1 | 08. Aug 14 | Helgoland | Germany: Helgoland | N 54,1874 3 | E 7,8703 | 45 |
| MH47 5499 | *Umbraulva dangeardii* | R_2 | 08. Aug 14 | Helgoland | Germany: Helgoland | N 54,1874 3 | E 7,8703 | 45 |

**Table S 2:** Comparison of molecular (*tuf*A)-based identification from the present study and the inventory list from Schories *et al.* (2009). List of species predicted by Schories et al. (2009) and detected in the present study (2019) from the Baltic Sea, Wadden Sea, and Helgoland.

| Species | Baltic Sea | | Wadden Sea | | Helgoland | | Taxonomic notes |
|---|---|---|---|---|---|---|---|
| | 2019 | 2009 | 2019 | 2009 | 2019 | 2009 | |
| *Blidingia marginata* (J.Agardh) P.J.L.Dangeard ex Bliding 1963 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| *Blidingia minima* (Nägeli ex Kützing) Kylin 1947 | X | ✓ | X | ✓ | X | ✓ | |
| *Blidingia chadefaudii* (Feldmann) Bliding 1963 | | | | | X | ✓ | On Helgoland, *B. chadefaudii* was taxonomically separated from *B. minima* on the basis of developmental differences, habit and zonation. However, a thickened inner cell wall, distinctive for *B. chadefaudii*, was absent from Helgoland´s populations (Kornmann & Sahling, 1978) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Blidingia subsalsa (*Kjellmann) Kornmann & Sahling ex Scagel et al. 1989 | | | | | X | ✓ | First listed as subspecies of *B. marginata* (*Blidingia marginata* subsp. *subsalsa* [Kjellmann] Bliding), *B. subsalsa* was given the rank as a species (Kornmann & Sahling, 1978) on the basis of developmental differences observed on specimens from Helgoland. |
| *Blidingia* sp. 1 | ✓ | X | ✓ | X | ✓ | X | |
| *Blidingia* sp. 2 | | | | | ✓ | X | |
| *Kornmannia leptoderma (*Kjellmann) Bliding 1969 | ✓ | X | ✓ | ✓ | ✓ | ✓ | Indicated as rare species and absent from Helgoland since 1975 (Kornmann & Sahling, 1977) |
| *Ulva compressa* Linnaeus 1753 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Highly variable in overall morphology (Blomster *et al.*, 1998; Maggs *et al.*, 2007*b*; Steinhagen *et al.*, 2018a; Tan *et al.*, 1999); Observation of different morphotypes in northern Germany (Steinhagen *et al.*, 2018a) |
| *Ulva pseudocurvata* Koeman & Hoek 1981 | | | | | X | ✓ | Different studies highlight conspecificity *of U. pseudocurvata* and *U. compressa* (Tan *et al.*, 1999, Loughnane *et al.*, 2008; Steinhagen *et al.*, |

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|---|---|---|---|---|---|---|---|
| | | | | | | | 2018a), but material from Helgoland is shown in this study to be conspecific with *U. lactuca*. |
| *Ulva curvata* (Kützing) De Toni 1889 | | | X | ✓ | | | Specimens formerly identified as *U. curvata* on Helgoland, were later assigned to the species *U. pseudocurvata*, due to morphological reconsiderations (Kornmann & Sahling, 1977; Kornmann & Sahling, 1994) |
| *Ulva flexuosa* Wulfen 1803 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | "Clearly multiple closely related species" (Kirkendale *et al.*, 2013). ITS based species boundaries are ambiguous. Observation of life history and hybridization experiments clarified species boundaries of the "flexuosa-complex" (Hiraoka *et al.*, 2017) |
| *Enteromorpha flexuosa* subsp. *linziformis* (Bliding) Bliding 1963 | | | X | ✓ | | | Regarded as synonym of *Ulva flexuosa var. linziformis* Guiry & Guiry, 2018) |
| *Ulva flexuosa* subsp. *paradoxa* (C. Agardh) M.J. Wynne 2005 | | | X | ✓ | X | ✓ | Regarded as synonym of *U. paradoxa* C. Agardh1817 |
| *Ulva californica* Wille 1899 | ✓ | X | ✓ | X | ✓ | X | Closely related to *U. flexuosa*. complex that is "clearly composed of multiple |

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|---|---|---|---|---|---|---|---|
| | | | | | | | closely related species"(Kirkendale *et al.*, 2013). |
| *Ulva intestinalis* Linnaeus 1753 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Aberrant morphologies induced by various factors (Bliding, 1963; Blomster *et al.*, 2002; Reed and Russell, 1978; Steinhagen *et al.*, 2018b) |
| *Ulva lactuca* Linnaeus 1753 | X | ✓ | X | ✓ | ✓ | ✓ | Based on missing morphological characters Kornmann & Sahling (1994) conclude *that U. lactuca* is absent from Helgoland. Later, its presence was verified by Bartsch & Kuhlenkamp (2000). |
| *Ulva tenera* Kornmann & Sahling 1994 | | | X | ✓ | X | ✓ | Shown in the present work to be conspecific with *U. lactuca* |
| *Ulva linza* Linnaeus 1753 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Gross morphology highly variable (from sheets to proliferous tubes). Several studies stated different closely related genetic groups in the "linza-ahlneriana-procera" cluster (Kirkendale *et al.*, 2013; Kraft *et al.*, 2010), others support the conspecificty of *U. linza* and *U. procera* (Maggs *et al.*, 2007*b*). |
| *Enteromorpha jugoslavica* Bliding | X | ✓ | | | | | Records from the area are conspecific with *U. linza* (Gesche Bock, pers. comm.) |
| *Ulva prolifera* O. F. Müller 1778 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |

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|---|---|---|---|---|---|---|
| *Ulva torta* (Mertens) Trevisan 1841 | ✓ | ✓ | ✓ | ✓ | | |
| *Ulva lobata* (Kützing) Harvey 1855 | | | | | X | ✓ |
| *Ulva radiata* (J.Agardh) H.S.Hayden, Blomster, Maggs, P.C.Silva, M.J.Stanhope & J.R.Waaland 2003 | | | X | ✓ | | |
| *Ulva ralfsii* (Harvey) Le Jolis 1863 | | | X | ✓ | | |
| *Ulva simplex* (K.L.Vinogradova) H.S.Hayden, Blomster, Maggs, P.C.Silva, M.J.Stanhope & | X | ✓ | X | ✓ | | |

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|---|---|---|---|---|---|---|---|
| J.R.Waaland 2003 | | | | | | | |
| *Ulva clathrata* (Roth) C. Agardh 1811 | X | ✓ | X | ✓ | | | Type locality: Fehmarn, SW Baltic (original material missing) (Guiry & Guiry 2018) |
| *Ulva rigida* C. Agardh 1823 and *Ulva scandinavica* Bliding 1968 | ✓ | X | ✓ | ✓ | ✓ | X | *U. rigida*, *U. scandinavica* and *U. armoricana* are considered as conspecific (Loughnane *et al.*, 2008) |
| *Ulva gigantea* (Kützing) Bliding 1969 | ✓ | X | ✓ | X | | | "*U. gigantea* is notoriously difficult to separate from *U. pseudocurvata* on morphological grounds alone"(Loughnane *et al.*, 2008). First Observations in Ireland and Britain byLoughnane *et al.* (2008). |
| *Ulva australis* Areschoug 1854 | | | ✓ | X | ✓ | X | *U. australis* and *U. pertusa* can be regarded as conspecific (Kirkendale *et al.*, 2013). Likely to be a NIS in Australia (Kirkendale *et al.*, 2013). |
| *Ulva* sp. | ✓ | X | ✓ | X | ✓ | X | |

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|---|---|---|---|---|---|---|---|
| *Umbraulva dangeardii* M.J.Wynne & G.Furnari 2014 | | | | | ✓ | X | The name *Umbraulva dangeardii* was proposed to replace the invalid names *Ulva olivascens* J.P.L.Dangeard nom. inval. and *Umbraulva olivascens* (P.J.L.Dangeard) G. Furnari nom. inval. |
| *Ulvaria fusca* (Postels & Ruprecht) Vinogradova 1967 | X | ✓ | | | | | |
| *Percursaria percursa* (C. Argardh)Rosenvinge 1893 | ✓ | ✓ | X | ✓ | X | ✓ | |
| *Monostroma grevillei* (Thoret) Wittrock 1866 | ✓ | ✓ | X | ✓ | ✓ | ✓ | Samples identified as *M. grevillei* segregated into two clusters in phylogenetic analyses of (Saunders & Kucera, 2010), suggesting crypticity. |
| *Monostroma arcticum* Wittrock1866 | | | | | X | ✓ | Regarded as a synonym of *Monostroma grevillei* var. *arcticum* (Guiry & Guiry, 2018) |
| *Protomonostroma undulatum* | | | | | ✓ | ✓ | |

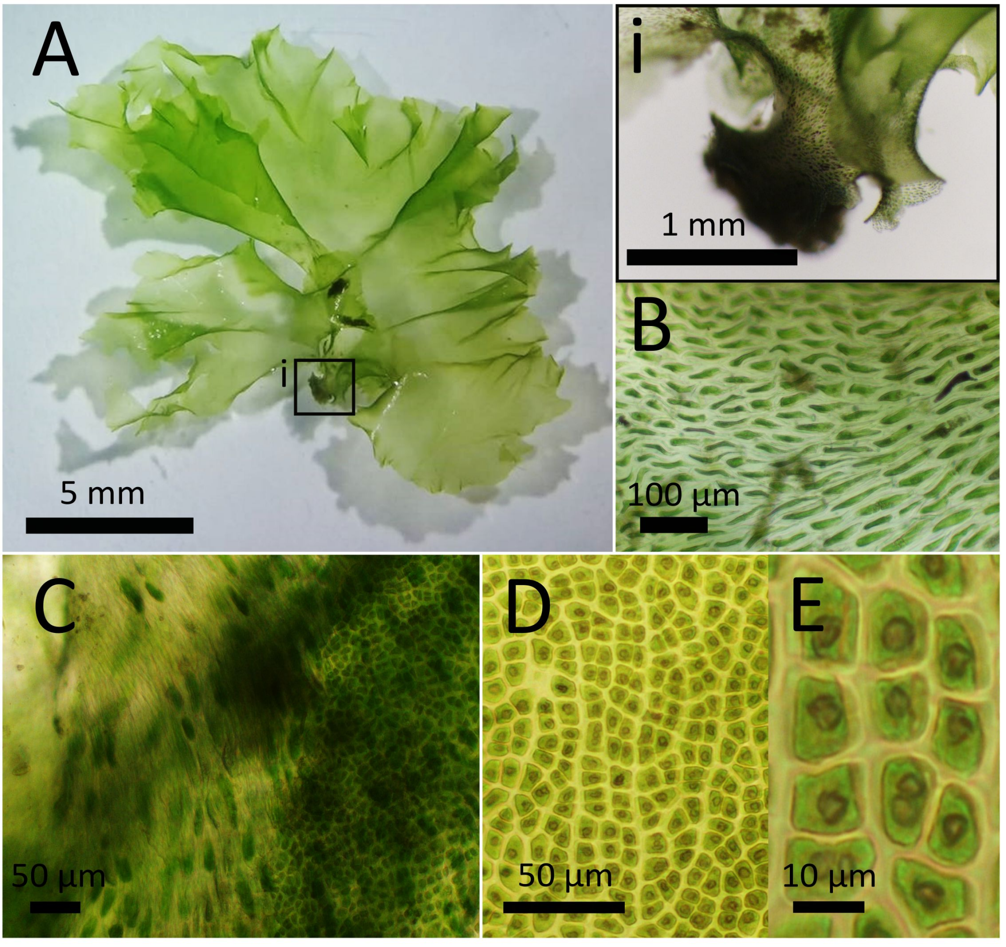
| | | | | |
|---|---|---|---|---|
| (Wittrock) Vinogradova 1969 | | | | |
| *Gayralia oxysperma* (Kützing) K.L. Vinogradova ex Scagel et al. 1989 | **X** | ✓ | | Type locality: Winning, SW Baltic (original material missing) |

Annotations or taxonomic notes by other authors are marked respectively. X, species not observed; ✓, species observed; empty, unexpected and not observed. Green shading indicates agreement between Schories *et al*. (2009) and the present study, whereas red shading indicates disagreement.

## 5. Supplementary Figure Legends

**Figure S1:** Maximum likelihood phylogram of *tuf*A sequences from taxa of *Ulva sensu lato* from northern Germany. Solid triangles indicate herbarium vouchers (see also Table 2). The two shades of grey indicate clades that were present in the study area. Hatched boxes indicate species complexes and, thus, taxonomic entities that could not be clearly resolved phylogenetically. Numbers at nodes indicate bootstrap values (left) and Bayesian posterior probabilities (1000 replicates; right). Poorly supported nodes (<70% bootstrap and <0.70 Bayesian support) are not labelled. Branch lengths are proportional to sequence divergence.

**Figure S2:** Morphology of *Protomonostroma undulatum* specimens from Helgoland, Germany. (A) Monostromatic thallus, with (i) close-up of the rhizoidal zone. (B) Elongated cells of the rhizoidal zone. (C) Transition zone between cells of the rhizoidal zone and the basal thallus. (D) Cell rows of the middle and apical thallus regions, with vein-like thickened cell walls. (E) Rectangular- to polygonal-shaped cells, each with 1–3, mostly centrally arranged, pyrenoids.


A
i
5 mm
i
1 mm
B
100 µm
C
50 µm
D
50 µm
E
10 µm