

RESEARCH NOTE



## Occurrence of *Ulva lactuca* L. 1753 (Ulvaceae, Chlorophyta) at the Murman Coast of the Barents Sea

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### ABSTRACT

Findings of *Ulva lactuca* L. on the Murman Coast of the Barents Sea are described for the period 2009–2017. This species has not been found in this area for more than 50 years. The occurrence of *U. lactuca* on the Murman Coast appears to be related to the recent warming of waters in the region.

### KEYWORDS

Sea lettuce; seaweed; climate change; global warming; Arctic; berealization

### Introduction

The present study aims to give an overview on the distribution of *Ulva lactuca* Linnaeus 1753: 1163 (Chlorophyta, Ulvaceae) in the Barents Sea. In the World Ocean, this species is very widespread (Guiry & Guiry 2018), found almost everywhere in shallow waters, including estuaries. The temperature and light tolerance of the species are well studied. Photosynthesis has been observed at temperatures ranging from 0°C to 28°C (Lüning 1984), with the highest growth rate occurring at 10–15°C (Fortes & Lüning 1980). At water temperatures of 7°C and 10°C, *U. lactuca* can adapt to low illumination levels (Vermaat & Sand-Jensen 1987; Sand-Jensen 1988). However, it is still unclear how *U. lactuca* responds to the combination of low illumination and low temperature. At the northern margin of its geographical range, *U. lactuca* findings are random and rare: it has been found on the western, southern and the northern shores of Svalbard (Vinogradova 1995; Gulliksen et al. 1999), Novaya Zemlya (Štrik et al. 2000) and on the coasts of Norway (Brattegard et al. 2001) and Alaska (Hayden & Waaland 2004; Lindeberg & Lindstrom 2010). The harsh wintertime conditions of the polar region – low temperature and lack of light (limiting photosynthesis) – is likely the reason for the weak expansion of species in the Arctic seas.

On the Murman Coast, *U. lactuca* was found in Olenii Strait (22 September 1930), in Kola Bay (1 June 1932) and in Podpakhta Bay 30 years later (2 July 1961) (Vinogradova 1974). Species lists compiled later do not mention *U. lactuca* (e.g., Šošina &

Averintseva 1994; Šošina 2003; Zavalko & Šošina 2008) and even question the presence of this species in the Barents Sea. Analysis of these data indicates the instability of the presence of *U. lactuca* on the Murmansk coast.

In recent decades, temperatures in the Barents Sea have risen following the increased inflow of Atlantic water masses during spring (Matishov et al. 2009; Matishov et al. 2014; MMBI 2017). It is possible that these water masses also brought spores, gametes or zygotes of *U. lactuca*, which developed in Zelenetskaya Bay under the more favourable conditions.

Part of the long-term monitoring of the state of coastal phytocenoses of the Murman Coast and the Russian archipelagos of the Barents Sea, this study aims to present the latest findings of *U. lactuca* on the Murman Coast and to consider their possible relationship with the positive temperature anomalies of the coastal water masses in the Barents Sea.

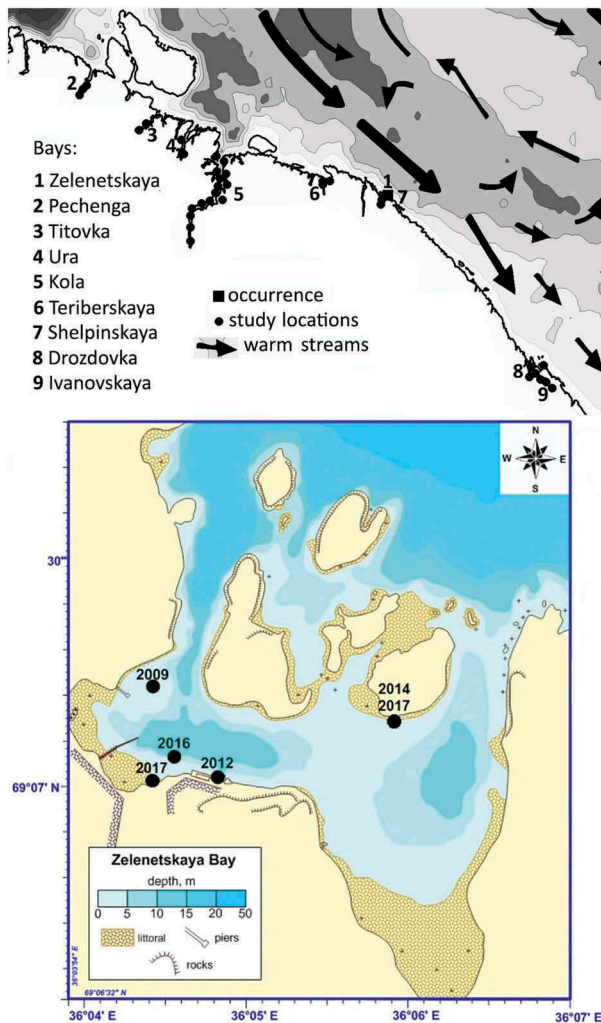
### Materials and methods

A study of the species composition of the phytocenoses of the Murman Coast was carried out each year from 2009 to 2017, mainly in the summer (June–September). During this period 12 different sites from Pechenga Bay in the east (69° 36′ N 31° 21′ E) to Ivanovskaja Bay in the west (68° 17′ N 38° 44′ E) of the Murman Coast were investigated, spanning a distance of about 300 km (Fig. 1). Algae were sampled with a standard geobotanic method, using a frame with an area of

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 Supplementary data for this article can be accessed [here](#).

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**Figure 1.** The study area on the Murman Coast. Inset: Zelenetskaya Bay, indicating where *Ulva lactuca* was found in 2009–2017.

0.25 × 0.25 m, with three replicas, on the upper, middle and lower littoral. On the entire accessible part of the littoral of the bays, qualitative surveys of species composition were also carried out.

*Ulva lactuca* was identified using the description of Vinogradova (1974). We relied on morphological features because the genetic analysis of *Ulva lactuca* and another species of *Ulva* gathered in other areas (Malta et al. 1999; Hayden & Waaland 2002; Hayden et al. 2004) has shown these to characterize the species. *Ulva lactuca* is characterized by a bright green solid thallus, attached to the substrate by a small rhizoid part (stems and sack-like base are absent). The thallus is bilayered, without a cavity. The cells are arranged chaotically, somewhat elongated in the transverse section, their size ranging from 12 to 23 µm, in most cases 15–20 µm. The chloroplasts are lamellar, in mature thallus, granular. There are one to two (occasionally three) pyrenoids in the cells, but sometimes they are indistinctly visible.

Differentiation of *U. lactuca* and *U. rigida* was not carried out in this study due to the lack of clear

species criteria. All the found thalli with the described set of characteristics were considered *U. lactuca*. *Ulva rigida* has not previously been noted in the Barents Sea, and we do not consider it reasonable to introduce this species into the flora on the basis of this single sample. Further study is needed in order to determine whether *U. rigida* is present in the region.

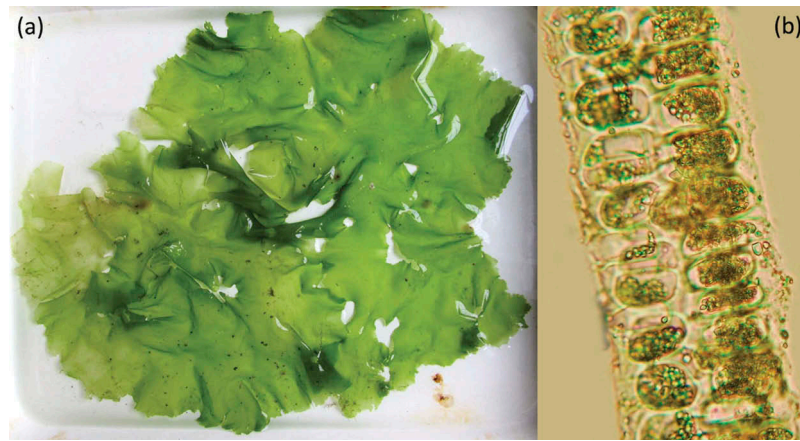
The material is stored at the Murmansk Biological Institute (Murmansk, Russia). One of the samples was given to the Herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences (St. Petersburg, Russia).

## Results and discussion

Murman's coastal biocenoses were first systematically studied in the period from 1912 through the 1930s. The Barents Sea underwent a warming in the early 1930s (Matishov et al. 2009; Matishov et al. 2014), when findings of *U. lactuca* (Vinogradova 1974) on the Murman Coast were first described. The second period of intensive algological research was from 1985 to the 1990s, when the list of species of Yarnyshnaya Bay, in the eastern part of the Murman Coast, was drawn up (Šošina & Averintseva 1994). At that time, negative temperature anomalies were observed (Matishov et al. 2009; Matishov et al. 2014) and the species was not on the list.

The most recent period in the study of the algal communities of the Murman Coast began in 2009. Thalli of *U. lactuca* (Fig. 2) were found exclusively in Zelenetskaya Bay (69.10 N, 36.05 E) in 2009, 2012, 2014, 2016 and 2017 (Table 1). Although Zelenetskaya Bay had been carefully surveyed in earlier years, 2009 was the first year in which signs of *U. lactuca* were observed there. In 2009, 2012, 2014 and 2016, single specimens of this species were encountered in Zelenetskaya Bay, with the first finding being made in the sublittoral community (Fig. 1). In 2017, *U. lactuca* was noted many times on the boulders of the lower littoral, protected from the surf (Supplementary Fig. S1), and also at the experimental farm of *Saccharina latissima* (Linnaeus) Lane, Mayes, Druehl & Saunders 2006 and *Fucus vesiculosus* L. 1753. Attachment of *U. lactuca* spores on the ropes of the experimental plot could only happen by way of self-planting from the water column since the thalli of *S. latissima* and *F. vesiculosus*, woven into lines, were sampled directly from the bay. The other seaweeds came from the bay, so *U. lactuca* must have landed on the ropes by itself, via the water.

In 2016 and 2017, the size of the cells of *U. lactuca* specimens grown on the farm ropes had smaller cells (7–12 × 12–18 µm, height 14–17 µm), which separates these algae from those grown at the bottom



**Figure 2.** (a) The appearance of the *Ulva lactuca* thallus found in Zelenetskaya Bay, July 2017; (b) the transverse section of the thallus, viewed through a microscope.

**Table 1.** Brief description of the sites in Zelenetskaya Bay where *Ulva lactuca* was found and the morphological parameters of the specimens. Sporangia were present only in the specimen found on 3 August 2016 (marked in boldface).

Date (dd/mm/yy)	Site description	T (°C)	Number of specimens	Thallus size (cm)	Cell size (µm)	
26/08/09	Sublittoral, 2 m, bottom community of <i>Saccharina latissima</i>	7.2	2	15 × 20	7 × 10	15–20
03/07/12	Littoral, bottom community of <i>Fucus distichus</i> + <i>F. vesiculosus</i>	7.7	2	3 × 4	4 × 5	15–20
10/08/14	Littoral, bottom community of <i>Fucus distichus</i> + <i>F. vesiculosus</i>	6.7	1	17	× 15	15–18
03/08/16	Seaweed farm ( <i>S. latissima</i> ), on the rope, near the surface	9.2	<b>1</b>	<b>18 × 25</b>		<b>10–15</b>
13/08/17	Lower littoral, an area protected from the violent churning along coastline, between <i>Monostroma grevillei</i> at the bottom substrate	7.5	1	1 × 2		15–20
14/08/17	Seaweed farm ( <i>S. latissima</i> ), on the rope, near the surface	8.7	1	6 × 7		12–15
21/08/17	Lower littoral of Zhiloi Island, at the margin of the rockweeds and kelp	9.3	> 20	0.2 × 1–2	× 5	15–20
05/09/17	Lower littoral of Zhiloi Island, at the margin of the rockweeds and kelp		2	2 × 3 and 3 × 4		15–20

substrate, although the plants themselves were outwardly typical (Supplementary Fig. S2).

Finding *U. lactuca* in Zelenetskaya Bay confirms the presence of the species on the Murman Coast, and adds to observations of the occurrence of the species on other Barents Sea coasts. It also raises a number of questions, since, of all the areas of the Murman Coast that were surveyed in recent years, *U. lactuca* was found only in Zelenetskaya Bay.

Zelenetskaya Bay (in some publications, Dal'nezelenetskaya) is protected from the direct action of the surf by a group of islands to the north. The bay shape is square, about 2 km across. Depths do not exceed 18 m. The substrate in the protected part of the bay is silty–sandy, with a small amount of medium-sized and small stones, and in the straits and along the edge of the shore there are boulders. There are two inlets in the bay: the south-western inlet (Oscar Inlet) and a much larger south-eastern inlet. The average annual temperature of the surface waters is  $3.8 \pm 0.1^\circ\text{C}$  (Mitjaev 2014). There are two independent currents in the bay: the waters enter and exit through the western and eastern straits, moving in the inlets counter-clockwise (Mitjaev 2014). The hydrological regime of Zelenetskaya Bay differs even from the adjacent Yarnyshnaya Bay on account of

different physical and geographical conditions (Gromov et al. 2010; Mitjaev 2014).

In 1983–84, the water temperature in the 0–15 m layer of Zelenetskaya Bay dropped to  $-1.5^\circ\text{C}$  in January, and a steady rise in the water temperature was observed only from the end of April. In June–July, the temperature of the water was less than  $7^\circ\text{C}$ , and only at the end of August and September was there an increase to  $9^\circ\text{C}$  (Bardan & Širokolobov 1988). Since 1998, coastal waters have warmed (Matishov et al. 2009; Matishov et al. 2014). In 2002–2012, the average annual temperature of the surface water layer in Zelenetskaya Bay was  $3.8^\circ\text{C}$ , and the average monthly temperature in July–September exceeded  $7^\circ\text{C}$ . In winter, it did not drop below  $0.7^\circ\text{C}$  (Il'in et al. 2016). Oceanographic studies have revealed continuing positive thermohaline anomalies in the spring and summer in 2016 and 2017, indicating the increased inflow of waters of Atlantic origin into the Barents Sea (Moiseev & Žičkin 2017).

Observations of a sharp increase in *U. lactuca* occurrences in Zelenetskaya Bay in 2017 suggest a relationship with the warming of the bay. It is likely that warmer conditions in the spring and in the first half of summer contribute to the survival and growth



of *U. lactuca*. The ability of this species to reproduce vegetatively in extreme environmental conditions, as well as the viability of zygotes for several months, allows them to spread over long distances (Vinogradova 1974). It is probable that *U. lactuca* zygotes are transported to the study area by the currents coming from the coast of the Scandinavian Peninsula, and in warmer periods they can germinate and develop. Adult plants demonstrate a high tolerance to low temperature (Fortes & Lüning 1980; Lüning 1984; Vermaat & Sand-Jensen 1987; Sand-Jensen 1988); however, the temperature sensitivity of spores, gametes and zygotes of this species has not been investigated. Unicellular stages may be more sensitive to stress and are probably unlikely to survive high-latitude wintertime conditions of low temperatures and little light.

A similar pattern in the distribution of the species at the northern margin of the geographical range was noted in Spitsbergen: studies conducted in 1988 in the southern part of the archipelago – Hornsund fjord, Sørkappland – did not find this species; but in 2007–08 it was noted (Weslawski et al. 2010). The authors attribute the appearance of *U. lactuca* with the increase in the mean water temperature: the average temperature in Hornsund in summer also exceeds 7°C. In the Novaya Zemlya Archipelago, *U. lactuca* was identified in the collections made in 1994–95 in the Yugorsky Shar Strait, in Chernaya Bay and at Mestnyi Island, and in Ivanova Bay in 1995 (Štrik et al. 2000), although the species was not found earlier in this region (Gemp & Byzova 1976). These findings may be associated with the warming period of the south-eastern Barents Sea in 1990–95 (Grišenko 2010). The findings of *U. lactuca* in Olenii Strait and in Kola Bay in the 1930s and in Podpakhta Bay in the 1960s (Vinogradova 1974) may also be related to climatic conditions of those times (Matishov et al. 2009; Matishov et al. 2014; Mitjaev 2014).

Thus, the analysis of the periodicity of the findings of *U. lactuca* in various areas of the Barents Sea suggests a connection of its recent poleward expansion with an increase of the water temperature.

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