

The distribution of green algae species from the *Ulva* genera (syn. *Enteromorpha*; Chlorophyta) in Polish inland waters

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Abstract

Marine algae in inland waters in Poland have been rarely recorded. The distribution of 5 species and 1 subspecies of the *Ulva* genus (syn. *Enteromorpha*, Chlorophyta) observed in different inland aquatic ecosystems is reported. The algal distribution was established on the basis of the available literature, unpublished material, and oral reports. Information about the algal morphology and habitat conditions, from all of the 58 reported locations of ulvas in Poland, were assimilated and are presented here.

The most widespread species of *Ulva* in inland waters in Poland was *U. intestinalis* (syn. *Enteromorpha intestinalis*) reported at 34 sites, while the rarest species was *U. paradoxa* (syn. *Enteromorpha paradoxa*), recorded at 2 sites.

Species of *Ulva* have been reported at a range of inland aquatic ecosystems, but most commonly in lakes and small water-courses, such as ditches, channels and creeks. Most of the reported sites of penetration of *Ulva* (*Enteromorpha*) inland are concentrated in northwestern and central Poland.

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INTRODUCTION

Numerous papers outline the inland distribution of macroalgae such as stonewort (Dąbska and Karpacki 1954, Wood and Imahori 1959), resulting from the fact that there are several stonewort species, which are commonly occurring and are often characteristic of freshwater habitats. Information on the inland distribution of other macroalgae such as ulvas (Göppert and Cohn 1850, Preuschoff 1883, Kozłowski 1890, Raciborski 1910, Marczek 1954, Pliński 1971) or red algae (Raciborski 1888, Krawiecowa 1954, Kadłubowska 1960) is much less detailed. Therefore, the aim of this paper is to fill the gap in studies on the distribution of native Polish algae belonging to the genus *Ulva* (Enteromorpha) (Blomster et al. 1998, 2000; Hayden et al. 2003).

Species of *Ulva* are primarily marine taxa found in saline and salty waters (Pliński et al. 1982, Haroon et al. 1999, Lee 1999, Kirchhoff and Pflugmacher 2002, Romano et al. 2003, Żbikowski et al. 2005), but they can also proliferate in freshwater habitats. Most studies concerned with Polish examples of this group of algae examine sites located on the Baltic seashore, with only a few reports on their distribution in inland Poland (Kozłowski 1890; Raciborski 1910; Torcka 1910; Wysocka 1952; Marczek 1954; Piotrowska 1961; Wilkoń-Michalska 1963; Podbielkowski 1969; Pliński 1971, 1973, 1973a; Kowalski 1975; Sitkowska 1999; Messyasz – in press; Messyasz and Rybak 2008). This is at least in part as a result of these species having rarely appeared in inland waters (Starmach 1970), there being few potential sites at which long term survival of the species is possible. However, in the middle of the 20th century these species started to proliferate in anthropogenically impacted environments like marl pits, peat bogs, and ponds, where chloride concentrations are low or variable. Despite reports of such occurrences, little is known about the ecology of the genus in the new habitats, or the consequences of their occurrence in limnic waters (Kowalski 1975, Sitkowska 1999, Valadimirescu 2007, Messyasz – in press).

The *Ulva* (*Enteromorpha*) genus now includes over 130 species, and has repeatedly caused taxonomic difficulties (Koemann and Holk 1981, 1982; Bliding 1963). *Ulva* species are very difficult to identify because morphological differences between taxa are often slight (Leskinen et al. 2004), and so comparisons of morphological structures alone are insufficient to identify to species level. Rather, the colour and the texture of the thalli, the structure and arrangement of cells in different parts of the thallus, the structure of chromatophores, the number of pirenoids, and deviations from the reproductive cycle must all be investigated in order to ascertain identification (Koemann and Holk 1981, 1982; Bliding 1963, 1968). The ecology of marine green algal species has been analysed on numerous occasions (Bliding 1963, Poole and

Raven 1997, Hayden et al. 2003), yet such analyses are insufficient to establish the taxonomy of *Ulva* species (Blomster et al. 1998, 2000; Coat et al. 1998). In addition to morphological deviations of the thallus from a nomenclature type, age related cytological changes are often observed, as well as variations in the phase of the development cycle (gametophyte, sporophyte), and depend on the time of the year in which the thallus was collected (Koeman and Van Den Hoek 1982, Leskinen et al. 2004). In order to reduce mistakes in the identification of closely related species, molecular techniques can be employed (Blomster et al. 1998, 2000; Hayden et al. 2003, Leskinen et al. 2004). In fact, these methods have initiated the revision of common assumptions in the taxonomy of ulvas. As a result, the number of species *Enteromorpha* (135) and of *Ulva* (140) established prior to the late 1990s has been reduced (Index Nominum Algarum 2002), and their systematization put in order (Hayden et al. 2003). The tools of molecular genetics, particularly SDS PAGE and RFLP - PCR (Coat et al. 1998, Blomster et al. 1998, 2000; Tann et al. 1999, Rouxel et al. 2001, Hayden et al. 2003, Leskinen et al. 2004, Kagami et al. 2005), have enabled quick methods to discriminate between *Ulva* species that are morphologically very similar (Coat et al. 1998; Blomster et al. 1998, 2000; Hayden et al. 2003; Leskinen et al. 2004), as well as connecting *Enteromorpha* with *Ulva*, these genera being more closely related than had previously been suspected (Blomster et al. 1998, Hayden et al. 2003). Currently more than 20 species that were previously assigned to *Enteromorpha* are now included in the *Ulva* genus (Blomster et al. 1999, Malta et al. 1999, Tan et al. 1999). A further 110 species will be examined in the near future in order to discriminate relationships between the taxa (Hayden et al. 2003).

This paper aims to clarify knowledge about the current distribution of species of *Ulva* in inland Polish waters. The data indicate the direction and scope of the gradual expansion of these halophilous organisms in Polish freshwaters. Further, the results are concerned with present geobotanics and nature protection issues, in considering the bioindicative function of *Ulva*, with particular relevance to the protection of freshwaters. Three maps, which include physico-chemical data of the sites, show the current and historic distribution of one subspecies and five species of ulvas observed in Poland from 1849 to 2008.

MATERIALS AND METHODS

The basic material on which this paper is founded are reports identifying species of *Enteromorpha* in Polish inland ecosystems (Siemińska 1990, Siemińska and Pająk 1992), comprising more than 20 articles, notes, and other written accounts and four unpublished reports.

The distribution of the algal species is presented on the basis of a carthogram. Poland was divided into 3646 squares using the ATPOL grid developed for the Distribution Atlas of Vascular Plants in Poland (Zajac and Zajac, 2001), of which the basic unit is a 10 km × 10 km square.

The location of every site of observed ulvas in Poland was supplemented with tables that include a description of the site. Each table contains information on basic morphometric data of the particular species of *Ulva* (length and width of the thalli and cells, as well as the morphology of the thallus), physico-chemical parameters of the site, and the type of ecosystem in which the sample was found.

Species names and their synonyms are cited after Starmach (1972), while the revisions of names postulated and employed by Bildung (1963), Blomster et al. (1998), and Hayden et al. (2003) are accounted for.

Maps show the distribution and characteristics of sites where *Ulva* species have been observed. Symbols used are:

1. The location of the site:
 - - sites observed prior to 1930;
 - - sites observed between 1950 and 2008;
 - - there are a few reported sites of the species in one square of the ATPOL grid.
2. General number of sites:
for example: (1, 2);
the first digit – sites mentioned prior to 1930;
the second digit – sites reported between 1950 and 2008.
3. Other:
 - * - information on the site is an oral account.

RESULTS

Ulva compressa (L.) 1753

syn. *Conferva compressa* (Linnaeus) Roth 1797, *Tubularia compressa* (Linnaeus) Roussel 1806, *Scytosiphon compressus* (Linnaeus) Lyngbye 1819, *Fistularia compressa* (Linnaeus) Greville 1824, *Solenia compressa* (Linnaeus) C. Agardh 1824, *Ilea compressa* (Linnaeus) Gaillon 1828, *Fistularia intestinalis* var. *compressa* (Linnaeus) J.P. Jones & Kingston 1829, *Hydrosolen compressus* (Linnaeus) Martius 1833, *Enteronia compressa* (Linnaeus) Chevallier 1836, *Enteromorpha compressa* (Ness) Greville 1840, *Enteromorpha vulgaris* var. *compressa* (Linnaeus) Edmondston 1845, *Ulva enteromorpha* var. *compressa* (Linnaeus) Le Jolis 1863, *Enteromorpha usneoides* J. Agardh 1883, *Enteromorpha intestinalis* var. *compressa* (Linnaeus)

Rosenvinge 1893, *Enteromorpha intestinalis* subsp. *compressa* (Linnaeus)
M.W.R.N. de Silva & E.M. Burrows 1973, *Enteromorpha complanata*
(Kützing) Silva 1996.

This species has been observed at four positions in the Wielkopolska area
(Fig. 1, Tab. 1).

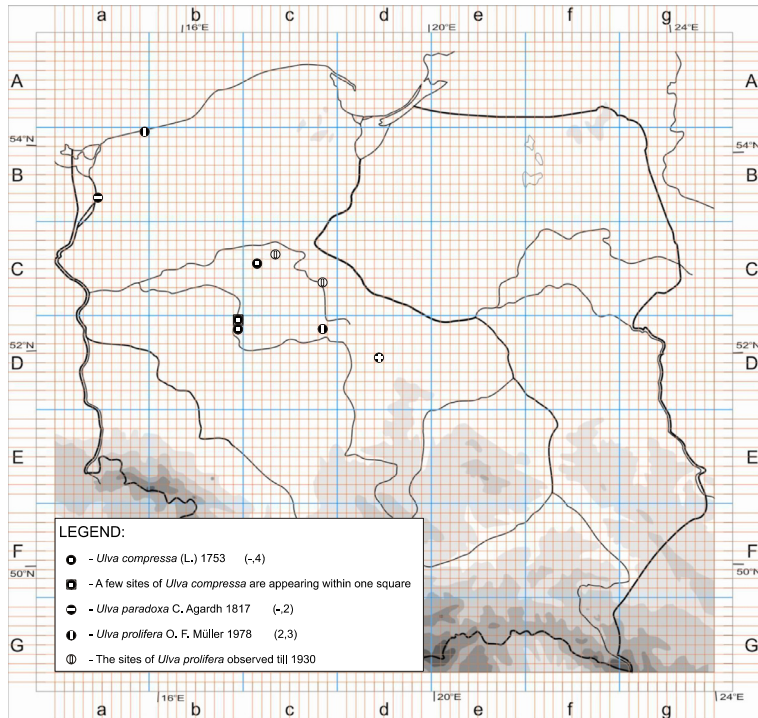


Fig. 1. Locations of recorded distributions of *Ulva compressa*, *Ulva paradoxa* and *Ulva prolifera* at Polish inland sites.

Ulva paradoxa C. Agardh 1817

syn. *Enteromorpha paradoxa* (C. Agardh) Kützing 1845, *Enteromorpha erecta* (Lyngbye) J. Agardh 1883, *Enteromorpha flexuosa* subsp. *paradoxa* (C. Agardh) Bliding 1963, *Enteromorpha plumosa* (Kützing) Bliding 1963, *Conferva paradoxa* Dillwyn 1809.

Before 1930 this species was not recorded in inland waters. Subsequently it has been reported at two sites: the peaty hole and lake (Fig. 1, Tab. 2).

Table 1

Information concerning the site locations, morphometric features and habitats of *Ulva compressa*.

Author	Site location	Type of ecosystem and date of reported appearance	Length and width of thallus (cm)	Length and width of cells (µm)	Branching of thallus	Physico-chemical parameters (mg l ⁻¹)	
						O ₂	
Messyasz (in press)	Wielkopolskie Province, surroundings of Golańcz	(VII-VIII – 1993-2006)	6 – 20 0.03 – 2	10 – 15 5.8 – 14.7	present	O ₂	0.0 – 9.8
		pH				7.47 – 8.68	
Messyasz and Rybak (2008a)	Wielkopolskie Province, Poznań	(VII-X – 2004, 2006- 2007)	1.2 – 20 0.02 – 2	9.6 – 16 6.2 – 11	present	NH ₃	0.42 – 1.05
		Stream Dworski Rów				NO ₃ ⁻	0.00 – 0.70
						PO ₄ ³⁻	0.00 – 1.01
						NaCl	98 – 133
						cond.	648 – 1136
		Stream Michałowka				O ₂	0.25 – 0.80
						pH	7.56 – 9.22
						NH ₃	0.23 – 0.74
						NO ₃ ⁻	0.04 – 1.02
	PO ₄ ³⁻	0.08 – 0.29					
	NaCl	537 – 776					
		O ₂	0.50 – 4.70				
		pH	7.71 – 9.69				
		NH ₃	0.12 – 2.61				
		NO ₃ ⁻	0.04 – 1.11				
		PO ₄ ³⁻	0.47 – 0.97				
		NaCl	513 – 604				
		O ₂	3.0 – 5.4				
		pH	7.20 – 7.89				
		NH ₃	0.05 – 0.33				
		NO ₃ ⁻	0.05 – 0.09				
		PO ₄ ³⁻	0.003 – 0.050				
		NaCl	702 – 740				

cond.- conductivity

Table 2

Informations concerning the sites, morphometric features and habitat of *Ulva paradoxa* and *Ulva prolifera*.

Author	Site location	Type of the ecosystem and the period of appearing	Length and width of thallus (cm)	Length and width of cells (µm)	Branching of thallus	Physico-chemical parameters (mg l ⁻¹)	
<i>Ulva paradoxa</i>							
Pliški 1971, 1973	Lódzkie Province, surroundings of Łęczysza	(V – VII, 1968 – 1969) peaty hole	2.1 – 7.8 0.0085 – 0.0154	12 – 15 21 – 27	present, little up to 1530 µm	NaCl	700 – 3600
Kowalski 1975	West Pomeranian Province, surroundings of Lubczyny	(IX, 1970) Lake Dąbskie	10 – 15 to 0.15	4.8 – 12.5 4.8 – 12.5	present	pH PO ₄ ³⁻ Cl ⁻	8.0 0.17 95.80
<i>Ulva prolifera</i>							
Liebetanz 1925	Kuyavia – Pomeranian Province: - Słoniawy surroundings of Szubin - Inowrocław	(1925) drainage ditch	n.d.	n.d.	n.d.		n.d.
		drainage ditch	n.d.	n.d.	n.d.		n.d.
Piotrowska 1961	West Pomeranian Province, surroundings of Kołobrzeg	(1961) water-courses, ponds	n.d.	n.d.	n.d.		n.d.
Pliški 1971, 1973	Lódzkie Province, surroundings of Łęczysza	(V – VIII, 1968 – 1969) peaty hole	5.8 – 14.5 90 – 160	9 – 11 11 – 13	present, little up to 1600 µm	NaCl	700 – 3600
Dąbska 1976	Wielkopolskie Province, surroundings of Konin	(1970 – 1971) Lake Wąsowski-Mikorzyński	n.d.	n.d.	n.d.		n.d.

n.d.- no data

Ulva prolifera O. F. Müller 1978

syn. *Solenia compressa* var. *prolifera* (O.F. Müller) C. Agardh 1824, *Enteromorpha compressa* var. *prolifera* (C. Agardh) Greville 1840, *Enteromorpha salina* Kützing 1845, *Enteromorpha compressa* f. *prolifera* (O.F. Müller) Ahlner 1877, *Enteromorpha prolifera* (O. F. Müller) J. Agardh 1883, *Enteromorpha intestinalis* f. *prolifera* (O.F. Müller) Hauck 1884, *Ulva enteromorpha* f. *prolifera* (O.F. Müller) Van Heurck 1908, *Enteromorpha torta* (Mertens) Reinhold 1893, Burrows 1991.

This species was reported at two locations in drainage ditches in 1925. In the second half of the 20th century it was reported at three sites, in the regions of Kołobrzeg, Łęczyca and Konin (Fig. 1, Tab. 2).

Ulva flexuosa Wulfen 1803

syn. *Conferva flexuosa* Roth 1800, *Conferva compressa* var. *flexuosa* (Wulfen) Roth 1806, *Enteromorpha intestinalis* var. *tubulosa* Kützing 1845, *Enteromorpha flexuosa* (Wulfen) J. Agardh 1883, *Enteromorpha tubulosa* (J. Agardh) Lakowitz 1929, *Enteromorpha compressa* var. *flexuosa* (Wulfen) G. Hamel 1931, *Enteromorpha prolifera* var. *flexuosa* (Wulfen) M.S. Doty 1947.

This species was reported at ten locations, which had increased chloride concentrations in the water, mainly in the West Pomeranian Province (Fig. 2, Tab. 3).

Table 3

Information concerning the site locations, morphometric features and habitats of *Ulva flexuosa*.

Author	Site location	Type of ecosystem and date of reported appearance	Length and width of thallus (cm)	Length and width of cells (µm)	Branching of thallus	Physico-chemical parameters (mg l ⁻¹)	
Marczek 1954	Silesian Province, Biskupice surroundings of Zabrz	(IX, 1953) pond	up to 83 up to 0.1	13.3 – 46.2 10 – 23	absent	O ₂ pH PO ₄ ³⁻ NaCl	8.49 7.5 10.0 48.9
Piński 1971, 1973	Łódzkie Province, Błonie surroundings of Łęczyca	(IV - IX, 1968 -1969) 3 peaty holes	6 – 9 14 – 45	9 – 14 10 – 14	present, little 24 – 3950 µm	NaCl	700 – 3600
Kowalski 1975	West Pomeranian Province: - surroundings of Wierzбно	(IX, 1970) Lake Miedwie	up to 36 0.009 – 0.013	15.0 – 30 12.1 – 18.0	present, little up to 150 µm	pH NO ₃ ⁻ PO ₄ ³⁻ Cl ⁻	7.2 0.25 0.04 38.20
	- surroundings of Lubczyny	(IX, 1970) Lake Dąbskie				pH PO ₄ ³⁻ Cl ⁻	8.0 0.17 95.80
	- Szczecin, district Nad Odrą	(IX, 1970) Pond Portowy				pH NO ₃ ⁻ PO ₄ ³⁻ Cl ⁻	7.3 0.61 0.03 130.50
	- surroundings of A6 road	(VI – X, 1970) Canal on Międzyodrze					n.d.
	- surroundings of Czarnocin, Waroleki, Podgródz	(IX, 1970) Lagun Szczecin					n.d.
	- surroundings of Ognica	(IX, 1970) Canal Piastowski					n.d.

n.d. - no data

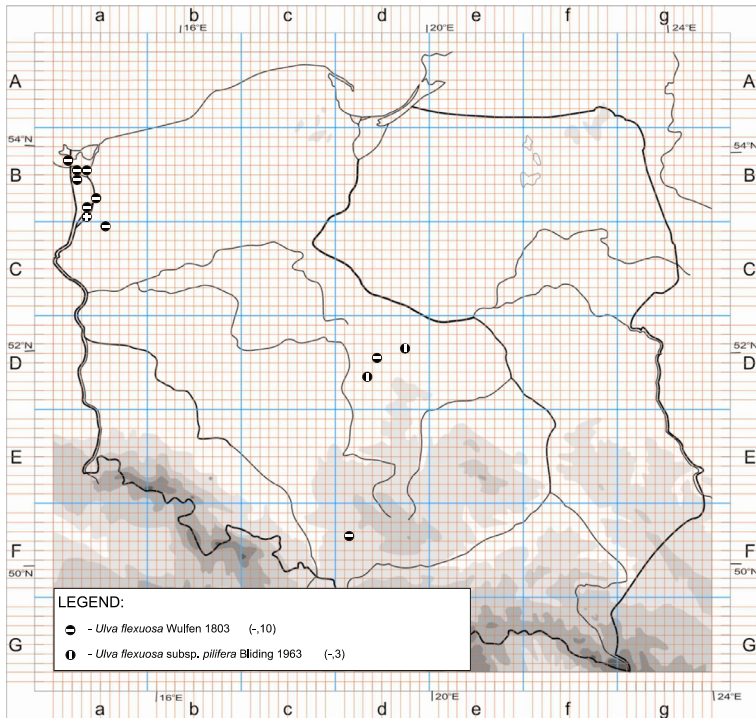


Fig. 2. Locations of recorded distributions of *Ulva flexuosa* and *Ulva flexuosa* subsp. *pilifera* at Polish inland sites.

***Ulva flexuosa* subsp. *pilifera* (Kützing) Bliding 1963**

syn. *Enteromorpha flexuosa* subsp. *prolifera* (A. Ag.) Greville

This taxon was reported in small channel and pond ecosystems in the surroundings of Szczecin and Łódź (Fig. 2, Tab. 4).

***Ulva intestinalis* L. 1753**

syn. *Conferva intestinalis* (Linnaeus) Roth 1797, *Tetraspora intestinalis* (Linnaeus) Desvaux 1818, *Scytosiphon intestinalis* (Linnaeus) Lyngbye 1819, *Enteromorpha intestinalis* (Linnaeus) Nees 1820, *Fistularia intestinalis* (Linnaeus) Greville 1824, *Solenia intestinalis* (Linnaeus) C. Agardh 1824, *Ilea intestinalis* (Linnaeus) Leiblein 1827, *Hydrosolen intestinalis* (Linnaeus) Martius 1833, *Scytosiphon intestinalis* var. *nematodes* Wallroth 1833, *Enteronia simplex* Chevallier 1836, *Enteromorpha vulgaris* var. *lacustris* Edmondston

Table 4

Information concerning the site locations, morphometric features and habitats of *Ulva flexuosa* subsp. *pilifera*.

Author	Site location	Type of ecosystem and date of reported appearance	Length and width of thallus (cm)	Length and width of cells (μm)	Branching of thallus	Physico-chemical parameters (mg l ⁻¹)	
Kowalski 1975	West Pomeranian Province, Szczecin, surroundings of A6 highway	(VI – X, 1970) Canal on Międzyodrze	15 – 25 1.5 – 3.0	14.8 – 19.7 9.9 – 15.6	present	n.d.	
Sitkowska 1999	Lódzkie Province, Piotrowice surroundings of Łódź	(1984 - 1987) pond	20 – 30 1 – 2	14.4 – 19.0 12.0 – 14.2	present	pH NO ₃ ⁻ NO ₂ ⁻ PO ₄ ³⁻ NH ₃ NaCl	7.5 – 8 0.39 0.037 0.23 0.5 20
	Lódzkie Province, Kuciny surroundings of Łódź	(1994 - 1995) pond	20 – 30 1 – 2	14.4 – 24 12.0 – 16.8	absent	pH NO ₃ ⁻ NO ₂ ⁻ NH ₃ NaCl	8.5 0.08 0.001 0.5 20

n.d. - no data

1845, *Ulva enteromorpha* var. *intestinalis* (Linnaeus) Le Jolis 1863, *Ulva bulbosa* var. *intestinalis* (Linnaeus) Hariot 1889, *Enteromorpha compressa* var. *intestinalis* (Linnaeus) G. Hamel 1931.

Prior to 1930 *Ulva intestinalis* was reported at 13 locations (Fig. 3). The first inland site of *U. intestinalis* was located in 1849 in the Lower Silesia Province in Miękinia and Duszniki Zdrój (Göppert and Cohn 1850). In the 19th century *U. intestinalis* was reported in the Pomeranian Province, where it was present in ditch surroundings of Nidowa (Preuschoff 1883), and at Kuyavia, Pomeranian Province, in the surroundings of Ciechocinek (Kozłowski 1890). Moreover, Kozłowski (1890) reported that thalli of this species were found in ditches in Stary Ciechocinek, in which the waters contained from 127 to 7680 g NaCl m⁻³. In 1895 – 1896 thalli of *U. intestinalis* were identified in the Warmia – Masuria Province area in Tolkmick, floating in Lagoon Wiślany (Nitardy 1898). In 1904 it appeared in Elbląg (Nitardy 1904) in the Warmia – Masuria Province. The next reported sites were lake ecosystems at Słoniawy, in the surroundings of Szubin and Inowrocław (Torka 1910). In the Kuyavia – Pomeranian Province (in the surroundings of Ciechocinek) on the 23rd June 1910 *U. intestinalis* was found in suburban salty waters (Racibórz and Wóycicki 1910). In 1913 it was reported in the old river bed of the Vistula at new sites around Słońsk, in the surroundings of Ciechocinek (Rouppert 1913). In 1925 thalli appeared in the Kuyavia - Pomeranian Province: at Słoniawy, in the surroundings of Szubin, and in Inowrocław. Thalli collected from a drainage ditch at this site achieved lengths of 30 cm and widths up to 0.2 cm (Liebetanz 1925). The last report of *U. intestinalis* from the 1920s is from the Kuyavia - Pomeranian Province area, where thalli appeared in the salty waters of Ciechocinek (Namysłowski 1927).

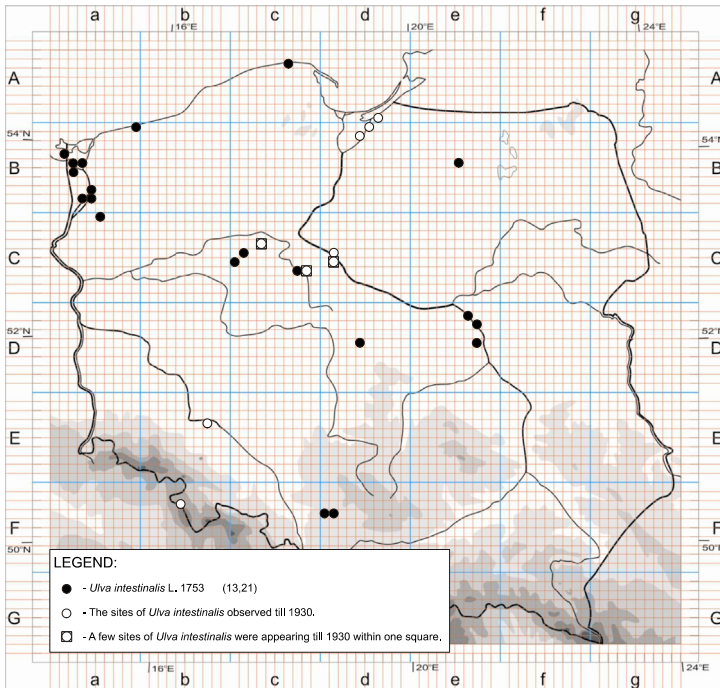


Fig. 3. Locations of recorded distributions of *Ulva intestinalis* at Polish inland sites.

Further reports of sightings of *U. intestinalis* are listed in chronological order in Table 5 (see also Fig. 3).

DISCUSSION

Species of the genus *Ulva* are cosmopolitan (Bäck et al. 2000, Hayden et al. 2003, Leskinen et al. 2004), being present in all types of sea and ocean waters, except the arctic area (Leskinen et al. 2004). In the Baltic basin they are concentrated in northwestern parts, where higher levels of salinity positively impact on their occurrence (Leskinen et al. 2004). Masses of ulvas frequently accumulate on seashore rocks, where they attach themselves using small hooks (Fish and Fish 1989). Under circumstances favourable for their development these macroalgae can become dominant in the littoral zone, covering rocks or creating free floating *Ulva* mats up to several square meters in size (Fletcher

Table 5

Information concerning the site locations, morphometric features and habitats of *Ulva intestinalis*.

Author	Site location	Type of ecosystem and date of reported appearance	Length and width of thallus (cm)	Length and width of cells (μm)	Branching of thallus	Physico-chemical parameters (mg l^{-1})		
Wysoka 1952	Mazovian Province, - Nowodwory, surroundings of Warszawa	River Wisla (1952)	n.d.	n.d.	n.d.	n.d.		
Marezek 1954	Lublin Province, Biskupiec - Zabrz	(IX, 1953-1954) pond	up to 40 up to 1.25	6.5 – 23.2 3.3 – 13.3	absent	O ₂ , pH, PO ₄ ³⁻ , NaCl	8.49 7.5 10.0 48.9	
Wysocka* 1954	Kuyavia - Pomeranian Province, Kujawy	(1953) lake	n.d.	n.d.	n.d.	n.d.		
	Mazovian Province, surroundings of Warszawa	(1953) Lake Czerniakowski	n.d.	n.d.	n.d.	n.d.		
Jasielski and Zabawski 1954	Silesia Province, Gliwice	(1954) swimming pool	n.d.	n.d.	n.d.	n.d.		
Piotrowska 1961	West Pomeranian Province, surroundings of Kolobrzeg	(1961) water-courses and ponds	n.d.	n.d.	n.d.	n.d.		
Wilkoń-Michalska 1963	Kuyavia - Pomeranian Province: - Ciechoćnek	salted waters (1962)	n.d.	n.d.	n.d.	n.d.		
	- Mątwy, surroundings of Inowrocław	- (1962)	n.d.	n.d.	n.d.	n.d.		
Podbielkowski 1969	Masuria province: - Baniocza, surroundings of Warszawa	(1967) clay pit	n.d.	n.d.	n.d.	n.d.		
Piński 1971, 1973a	Łódzkie Province, surroundings of Łęczyca	(IV - IX, 1968 -1969) 5 peaty holes	5 – 23 0.2 – 1.2	7 – 18 9 – 18	present, little up to 140 μm	NaCl	700 – 3600	
Piński 1973a	Pomeranian Province, surroundings of Lubkowa	(VII - X, 1967-70) Lake Zarnowieckie	8 – 30 0.05 – 0.5	12 – 18 5 – 10	present, little up to 150 μm	Cl ⁻	40	
Kowalski 1975	West Pomeranian Province: - surroundings of Wierzbo	(VI - IX, 1970) Lake Miedwie	18 – 42 0.4 – 1.4	7.3 – 27.2 6.5 – 18.1	present, little up to 900 μm	pH	7.2	
						NO ₃ ⁻	0.25	
						PO ₄ ³⁻	0.04	
						Cl ⁻	38.20	
		- surroundings of Szczecin				(IX, 1970) River Płonia	pH	7.1
							NO ₃ ⁻	0.43
							PO ₄ ³⁻	0.05
			Cl ⁻	39.70				
	- surroundings of Lubczyny	(IX, 1970) Lake Dąbskie	pH	8.0				
			PO ₄ ³⁻	0.17				
			Cl ⁻	95.80				
	- Szczecin, Nad Odrą district	(IX, 1970) Pond Portowy	pH	7.3				
			NO ₃ ⁻	0.61				
			PO ₄ ³⁻	0.03				
			Cl ⁻	130.50				
	- surroundings of Czarnocin, Warołki and Podgrodzie	(IX, 1970) Lagoon Szczecin				n.d.		
	- surroundings of Karsibor	(IX, 1970) Canal Piastowski				n.d.		
Enderl 2006	Warmia-Masuria Province, Nowe Marcinkowo surroundings of Olsztyn	River Dymer (VII, 2005)	n.d.	n.d.	n.d.	n.d.		
Messyasz (in press)	Wielkopolskie Province: - surroundings of Golańcz	(V - VII, 1993 - 2006) Lake Laskownickie	13 – 23 5 – 7	12 – 16 13 – 15	present	O ₂ , pH, NH ₃ , NO ₃ ⁻ , PO ₄ ³⁻ , NaCl cond.	0.0 – 9.8 7.47 – 8.68 0.42 – 1.05 0.00 – 0.70 0.00 – 1.01 98 – 133 648 – 1136	
	- Wagrowiec	(V - VII, 1993 - 2006) River Nielba	15 - 17 5 - 6	12 - 13 14 - 15	present	O ₂ , pH, NH ₃ , NO ₃ ⁻ , PO ₄ ³⁻ , NaCl cond.	4.5 – 9.7 6.44 – 8.71 0.49 – 1.59 0.12 – 0.810 0.05 – 1.40 80 – 127 648 – 1136	

cond. – conductivity;

* - information on the site is an oral account;

n.d. – no data

1996, Callow et al. 1997, Blomster et al. 2002). Ulvas are generally tolerant to periodic decreases in water salinity, and as a result can proliferate in estuaries (Bäck et al. 2000, McAvoy and Klug 2005). However, some species, for example *U. intestinalis*, do not settle in Baltic waters where the salinity is lower than 2 ppt, and *U. compressa* was not recorded in the Baltic Sea in areas where the salinity did not exceed 15 ppt (Leskinen et al. 2004). This implies that the distribution of particular species of *Ulva* in the Baltic basin is more restricted than was previously assumed, and that it depends to a large degree on water salinity (Nielsen et al. 1995, Tolstoy and Willén 1997).

Species of *Ulva* have also been reported in inland salt habitats globally, e.g. in reservoirs located at salt mines or at ore mines in North America (Lois et al. 1975). In addition, they have been observed in big European rivers (Kirchhoff and Pflugmacher 2002) and salty swamps (Fish and Fish 1989).

Nine species of *Ulva* (Table 6) have been identified in Poland (Pankow 1971, Starmach 1972), most of them appearing at the Baltic seashore, primarily near Gdańsk (Lucks 1907, Kornaś and Medwecka-Kornaś 1949, Biernacka 1961, Pliński et al. 1982, Haroon et al. 1999), Puck Bay (Starmach 1972, Fronczak and Pliński 1982, Wojtusiak et al. 1984, Boszke et al. 2003, Skwarzec et al. 2003, Żbikowski et al. 2005) and near Władysławowo (Biernacka 1968).

Table 6

Species of *Ulva* (*Enteromorpha*) appearing in salt and freshwaters in Poland (see Starmach 1972).

Species	sea ecosystem	inland ecosystem
<i>Enteromorpha torta</i> (Mertes) Reinhold 1893	+	-
<i>Enteromorpha prolifera</i> J. Ag. 1882-1883	+	+
<i>Enteromorpha ramulosa</i> (Engl. Bot.) Hooker 1833	+	-
<i>Enteromorpha flexuosa</i> (Wulf. ex Roth) J. Ag. 1883	+	+
<i>Enteromorpha compressa</i> Ness 1820	+	+
<i>Enteromorpha linza</i> (L.) J. Ag. 1883	+	-
<i>Enteromorpha intestinalis</i> (L.) Link 1820	+	+
<i>Enteromorpha clathrata</i> (Roth) Greville 1830	+	+
<i>Enteromorpha ahneriana</i> Blinding 1933	+	-

Only five *Ulva* species have been recorded in inland freshwater and salty reservoirs (Göppert and Cohn 1850; Preuschoff 1883; Kozłowski 1890; Raciborski 1910; Torka 1910; Wysocka 1952; Marczek 1954; Piotrowska 1961; Wilkoń-Michalska 1963; Podbielkowski 1969; Pliński 1971, 1973, 1973a; Kowalski 1975; Sitkowska 1999; Messyasz and Rybak 2008; and others).

Ulva species are highly mutable, the same species developing into separate forms depending on even slight differences in environmental conditions (higher water temperature, concentrations of nitrate, phosphorus or chlorides, and other physico-chemical parameters) (Starmach 1972, Endler et al. 2006, Sitkowska

1999, Messyasz – in press, Messyasz and Rybak 2008a). This mutability commonly results in identification mistakes, and of establishing new species in the genus. Multiple subspecies and forms previously observed in Poland (Marczek 1954, Piotrowska 1961, Pliński 1971, Starmach 1972, Kowalski 1975) are now assumed to be one species. Synonymous naming of species, subspecies and forms in the *Ulva* genus is employed in this paper (Blomster et al. 1998, Index Nominum Algarum 2002, Hayden et al. 2003).

The distribution of ulvas in Polish waters can be examined with respect to the level of pollution of these waters, as some *Ulva* species have proved to be very useful bioindicators. Their presence can indicate pollution by heavy metals, increased concentrations of chlorides and nitrate, and increases in the trophy of particular water bodies (Sfriso et al. 1987; Fletcher 1992, 1996; Kautsky 1982; Castilla 1996; Bonsdorff et al. 1997; Valiela et al. 1997; Blomster 1998, 2000; Bäck et al. 2000; Farina et al. 2003; Reed and Russel 1978, 1979; Reed and Moffat 2003; Worm and Lotze 2006). The occurrence of free floating *Ulva* mats dominated by *U. compressa* and *U. intestinalis* can indicate Cd, Cu, Pb, Zn or Mn contamination (Reed and Moffat 2003, Żbikowski et al. 2005). Such thick *Ulva* mats, comprised of a couple of species (e.g. mainly *U. compressa* and *U. intestinalis*), can cause local disorders in ecosystem functioning in the littoral zone (Fletcher 1996). It can be argued that similar processes are taking place in inland lake and river ecosystems, in which floating mats of ulvas are observed (Messyasz – in press, Messyasz and Rybak – 2008a).

FINAL CONCLUSIONS

- Five species and one subspecies of the genus *Ulva* (*Enteromorpha*) were recorded at 58 inland sites in Poland (Fig. 1 - 3).
- The location of one site of *U. intestinalis*, reported by Wysocka (1952) was not discovered. The author stated that *Ulva* was found in one of the lakes in the region of Kujawy, but as a result of insufficient site details, it was not marked on the distribution map of *U. intestinalis* reported here.
- The most widespread *Ulva* species in inland Polish waters was *U. intestinalis*, the thalli of which were observed at 34 sites (Fig. 3, Tab. 5). The next most widespread were: *U. flexuosa*, observed at 10 sites (Fig. 2, Tab. 3), *U. prolifera*, observed at 5 sites (Fig. 1, Tab.2), and *U. compressa*, observed at 4 sites (Fig 1, Tab. 1).
- Of the *Ulva* species reported in inland Poland the rarest species are *U. flexuosa* subsp. *pilifera*, found at 3 sites (Fig. 2, Tab. 4), and *U. paradoxa*, which appeared at 2 sites (Fig. 1, Tab. 2).

- The inland locations of species of *Ulva* are concentrated in northwestern and central Poland, but single sites were also found in the North and East of Poland.
- The inland *Ulva* species were mostly recorded in lake ecosystems (13 reports) or small water-courses and ditches (12 reports). Less numerous habitats (3-7 reports) were brine rivers, canals, and peat bogs. Single reports were observed in freshwater bays, a swimming pool, and mar pits (Tab. 1-5).
- *U. intestinalis* was reported at all types of inland water ecosystems, ranging from natural water bodies, such as lakes, rivers, and salt water bodies, to streams and ditches, as well as anthropogenic sites such as fish ponds and mar pits. *U. intestinalis* was found in 8 Polish lakes and other water bodies, implying that this species can endure a wide ecological range. This assumption is confirmed by the physico-chemical parameters of the sites at which the species has been reported (Tab. 5).
- *U. flexuosa*, similar to *U. intestinalis*, has been seen to proliferate in numerous ecosystems of different origin as well as water quality. This species was recorded in lakes, ponds, bog pits, and estuaries (Tab. 3).
- *U. flexuosa* subsp. *pilifera* was found in fish ponds, which were characterised by very low salinities, and in the canal, which has inflows of freshwater (Tab. 4). It is very uncommon for the thalli of species of *Ulva* to be collected from sites with low chloride concentrations.
- *U. paradoxa* and *U. prolifera* were reported in freshwater ecosystems, such as lakes and ponds, but also in peat bogs, although at each site where these two species were reported chloride concentrations were at least moderately high (Tab. 2).
- *U. compressa* was recorded in one lake and three creeks (Tab. 1). This species is tolerant of a wide range of chloride concentrations, which often are of anthropogenic origin, and proliferates in running waters, where water levels frequently fluctuate. In lakes *U. intestinalis* has been found where rivers flow into the water body, which may be as a result of the constant flow of water stimulating the development of the thalli.

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