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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 The algal distribution was established on the basis of the available literature, unpublished material, and oral reports.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 (Dąmbska 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 at 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; Torka 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

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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 *Entermorpha* 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 (Zając and Zając, 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 Bilding (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)

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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).

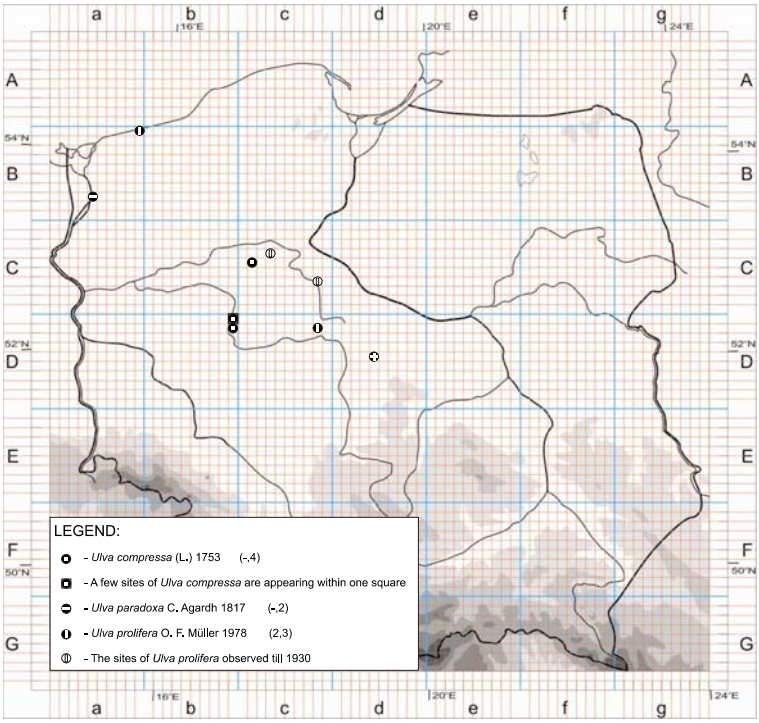

Fig. 1. Locations of recorded distributions of *Ulva compressa*, *Ulva paradoxa* and *Ulva prolifera* at Polish inland sites.

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})	
Messyasz (in press)	Wielkopolskie Province, surroundings of Gołańcz	(VII-VIII – 1993-2006) Lake Laskownickie	6 – 20 0.03 – 2	10 – 15 5.8 – 14.7	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
Messysz and Rybak (2008a)	Wielkopolskie Province, Poznań	(VII-X – 2004, 2006- 2007) Stream Dworski Rów	1.2 – 20 0.02 – 2		present	O_2 pH NH_3 NO_3^- PO_4^{3-} NaCl	0.25 – 0.80 7.56 – 9.22 0.23 – 0.74 0.04 – 1.02 0.08 – 0.29 537 – 776
		Stream Michałówka	2 – 180 0.05 – 8	9.6 – 16 6.2 – 11	present	O_2 pH NH_3 NO_3^- PO_4^{3-} NaCl	0.50 – 4.70 7.71 – 9.69 0.12 – 2.61 0.04- 1.11 0.47 – 0.97 513 – 604
		Stream Świątnica	2.3 – 19.5 0.03 – 2		present	O_2 pH NH_3 NO_3^- PO_4^{3-} NaCl	3.0 – 5.4 7.20 – 7.89 0.05 – 0.33 0.05 – 0.09 0.003 – 0.050 702 – 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})	
		Ulva paradoxa					
Pliński 1971, 1973	Łódzkie Province, surroundings of Łęczyca	(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
		Ulva prolifera					
Liebetanz 1925	Kuyavia – Pomeranian Province: - Słoniawy surroundings of Szubin	(1925) drainage ditch	n.d.	n.d.	n.d.	n.d.	
	- Inowrocław	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.	
Pliński 1971, 1973	Łódzkie Province, surroundings of Łęczyca	(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
Dąmbska 1976	Wielkopolskie Province, surroundings of Konin	(1970 – 1971) Lake Wąsowsko-Mikorzyńskie	n.d.	n.d.	n.d.	n.d.	

n.d.- no data

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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
Pliński 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 Wierzbno	(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, Warołęki, Podgródź	(IX, 1970) Lagun Szczecin					n.d.
	- surroundings of Ognica	(IX, 1970) Canal Piastowski					n.d.

n.d. - no data

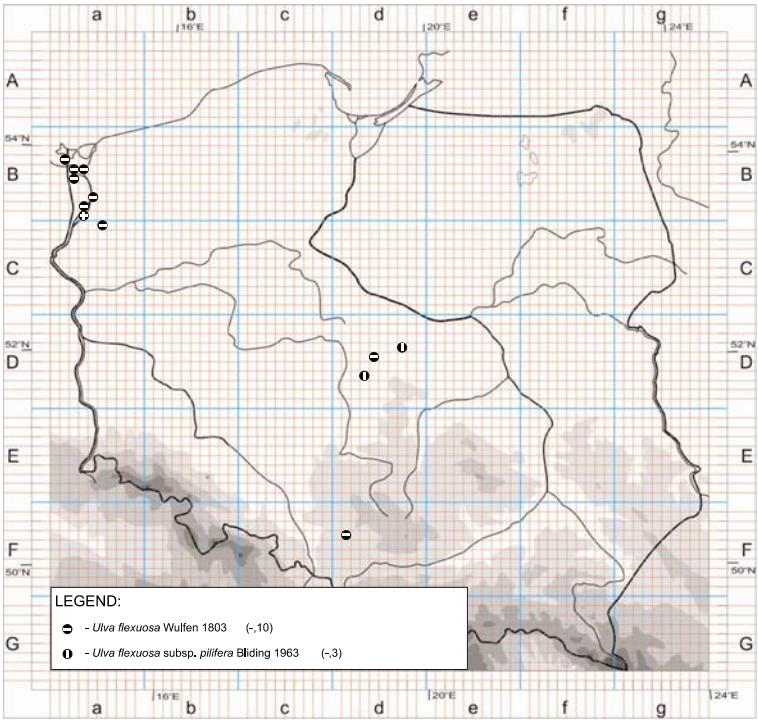

Fig. 2. Locations of recorded distributions of *Ulva flexuosa* and *Ulva flexuosa* subsp. *pilifera* at Polish inland sites.

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

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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 Międzyodrzu	15 – 25 1.5 – 3.0	14.8 – 19.7 9.9 – 15.6	present	n.d.	
Sitkowska 1999	Łódzkie 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
	Łódzkie 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).

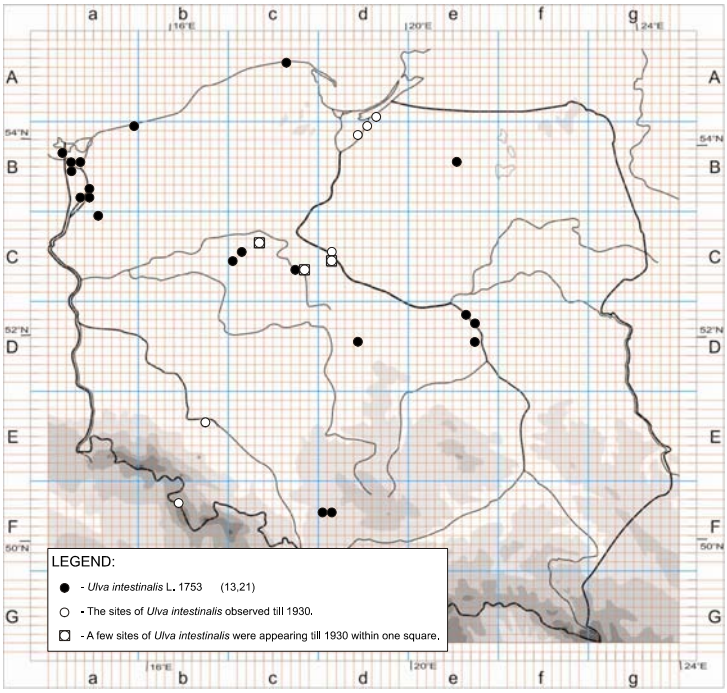

Fig. 3. Locations of recorded distributions of *Ulva intestinalis* at Polish inland sites.

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

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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 Wisła (1952)	n.d.	n.d.	n.d.	n.d.	
Marczek 1954	Lublin Province, Biskupice - Zabrz	(IX, 1953-1954) pond	up to 40 up to1.25	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 Czerniakowskie	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 Kołobrzeg	(1961) water-courses and ponds	n.d.	n.d.	n.d.	n.d.	
Wilkoń-Michalska 1963	Kuyavia - Pomeranian Province: - Ciechocinek	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: - Baniocha, surroundings of Warszawa	(1967) clay pit	n.d.	n.d.	n.d.	n.d.	
Pliński 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
Pliński 1973a	Pomeranian Province, surroundings of Lubkowa	(VII - X, 1967-70) Lake Żarnowieckie	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 Wierzbno	(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 NO_3^- PO_4^{3-} Cl^-	7.2 0.25 0.04 38.20
	- surroundings of Szczecin	(IX, 1970) River Płonia				pH NO_3^- PO_4^{3-} Cl^-	7.1 0.43 0.05 39.70
	- surroundings of Lubczyny	(IX, 1970) Lake Dąbskie				pH PO_4^{3-} Cl^-	8.0 0.17 95.80
	- Szczecin, Nad Odrą district	(IX, 1970) Pond Portowy				pH NO_3^- PO_4^{3-} Cl^-	7.3 0.61 0.03 130.50
	- surroundings of Czarnocin, Warołęki and Podgrodzie	(IX, 1970) Lagoon Szczecin				n.d.	
	- surroundings of Karsibor	(IX, 1970) Canal Piastowski				n.d.	
Endler 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 Gołańcz	(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
	- Wągrowiec	(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
Enteromorpha torta (Mertes) Reinhold 1893	+	-
Enteromorpha prolifera J. Ag. 1882-1883	+	+
Enteromorpha ramulosa (Engl. Bot.) Hooker 1833	+	-
Enteromorpha flexuosa (Wulf. ex Roth) J. Ag. 1883	+	+
Enteromorpha compressa Ness 1820	+	+
Enteromorpha linza (L.) J. Ag. 1883	+	-
Enteromorpha intestinalis (L.) Link 1820	+	+
Enteromorpha clathrata (Roth) Greville 1830	+	+
Enteromorpha ahlneriana 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

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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* (*Entermorpha*) 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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REFERENCES

Bäck S., Lehvo A., Blomster J., 1993, *Mass occurrence of unattached Enteromorpha intestinalis on the Finnish Baltic Sea coast.* Ann. Bot. Fennici., 37: 155-161

Biernacka I., 1961, *Badania porastania impregnowanego drewna w Zatoce Gdańskiej*. Rozpr. Hydrotechn, 9(1): 37-78

Biernacka I., 1968, *Wpływ zanieczyszczenia wód Władysławowa na zespoły porośli i bytujących w nich pierwotniaków*. Ekol. Pol. Ser. A, 16(9): 213-241

Bliding C., 1963, *A critical survey of European taxa in Ulvales. Part 1. Casosiphonia, Blidingia, Enteromorpha.* Opera Bot., 8 (3): 1-160

Bliding C., 1968, *A critical survey of European taxa in Ulvales. Part 2. Ulva, Ulvaria, Monostoma, Kornmannia.* Bot. Not., 121: 534-629

Blomster J., Maggs C. A., Stanhope M., 1998, *Molecular and morphological analysis of Enteromorpha intestinalis and E. compressa (Chlorophyta) in the British Isles.* Journal of Phycology, 2: 319 pp.

Blomster J., Maggs C. A., Stanhope M., 1999, *Extensive intraspecific morphological variation in Enteromorpha muscoides (Chlorophyta) revealed by molecular analysis.* Journal of Phycology, 35: 575-586

Blomster J., Hoey E. M., Maggs C. A., Stanhope M. J., 2000, *Species-specific oligonucleotide probes for macroalgae: molecular discrimination of two marine fouling species of Enteromorpha (Ulvophyceae).* Molecular Ecology, 2: 177 pp.

Blomster J., Back S., Fewer D. P., Kiirikki M., Lehvo A., Maggs C. A., Stanhope M. J., 2002, *Novel morphology in Enteromorpha (Ulvophycae) forming green tides.* American Journal of Botany, 89: 1756-1763

Bonsdorff E., Blomqvist E. M., Mattila J., Norkko A., 1997, *Coastal eutrophication: cause, consequences and perspectives in the archipelago areas of the northern Baltic Sea.* Estuar. Coast Shelf Sci., 44: 63-72

Boszke L., Siepak J., Falandysz J., 2003, *Total Mercury Contamination of Selected Organisms in Puck Bay, Baltic Sea, Poland*. J. Environ. Studies, 12(3): 275-285

Callow M. E., Callow J. A., Pickett - Heaps J. D., Wetherbee R., 1997, *Primary adhesion of Enteromorpha (Chlorophyta, Ulvales) propagules: quantitative settlement studies and video microscopy.* Journal of Phycology, 33: 938-947

Castilla J. C., 1996, *Copper mine tailing disposal in northern Chile rocky shores: Enteromorpha compressa (Chlorophyta) as a sentinel species.* Environmental Monitoring and Assessment, 2: 171-184

Coat G., Dion P., Noailles M., Reviers B., Fontaine J. M., Berger-Perrot Y., Loiseaux-de Goër S., 1998, *Ulva amoricana (Ulvales, Chlorophyta) from the coasts of Brittany (France). II. Nuclear rDNA ITS sequence analysis*. Eur. J. Phycol., 33: 81-86

Dąmbska I., Karpacki J., 1954, *Ramienice. Klucz do oznaczania gatunków krajowych*. Państwowe Wydawnictwo Naukowe, Warszawa, 7-122

Dąmbska I., 1976, *Materiały do poznania peryfitonu jezior konińskich. Badania hydrobotaniczne jezior podgrzanych w okolicy Konina*. Uniw. A. Mickiewicza w Poznaniu, Seria Biol., 6: 85-90

Endler Z., Goździejewska A., Jaworska B., Grzybowski M., 2006, *Wpływ małej elektrowni wodnej na organizmy planktonowe w wodzie rzecznej.* Acta. Sci. Pol. Formatio Circumiectus, 5 (2): 121-134

Farina J., Castilla J., Ojeda F., 2003, *The idiosyncratic effect of a sentinel species on contaminated rocky intertidal communities*. Ecological Applications, 6: 1533-1552

Fish J. D., Fish S., 1989, *A student's guide to seashore*. Unwin Hyman Ltd, London, 11, 35-36

Fletcher R. L., 1992, *The "Green Tide" problem*. [In]: Schramm W., Nienhuis P. (eds.) Ecological studies, Marine benthic vegetation, EEC. Brussels: 29 - 33

Fletcher R. L., 1996, *The occurrence of "Green tide" problem*. [In]: Schramm W., Nienhuis P. (eds.) Ecological studies, Marine benthic vegetation, EEC., Brussels, 123: 7-43

Fronczak M., Pliński M., 1982, *Charakterystyka ekologiczna peryfitonu roślinnego Zatoki Puckiej*. Zesz. nauk. Wydz. Biol. Nauk Ziemi, Oceanografia., Uniw. Gdańsk, 9(1): 49-64

Göppert H. R., Cohn F., 1850, *Ueber die Algen Schlesiens*. Übers. Arbeiten Veränd. Schles. Ges. Vaterl. Cultur., 1: 93-95

Haroon M. A., Szaniawska A., Pliński M., 1999, *The distribution, species composition and abundance of Enteromorpha sp. in the Gulf of Gdańsk*. Oceanlogical Studies, 28(1-2):31-39

Hayden H. S., Blomster J., Maggs C. H., Silva P., Stanhope M., Waaland R., 2003, *Linnaeus was right all along: Ulva and Enteromorpha are not distinct genera.* Eur. J. Phycol., 38: 277-294

Index Nominum Algarum, 2002, *University Herbarium, University of California, Berkeley*. Compiled by Paul Silva. Available online at http:/ucjeps.herb.berkeley.edu/INA.html.

Kadłubowska J., 1960, *Nowe stanowisko Batrachospermum sagum*. Ag. Zesz. Nauk. UŁ Ser. 2, 8: 89-92

Kagami Y., Fujishita M., Matsuyama - Serisawa K., Yamamoto M., Kuwano K., Saga N., Kawano S., 2005, *DNA content of Ulva compressa (Ulvales, Chlorophyta) nuclei determined with laser scanning cytometry*. Phycological Research, 53: 77-83

Kautsky L., 1982, *Primary production and uptake kinetics of ammonium and phosphate by Enteromorpha compressa in an ammonium sulphate industry outlet area.* Aq. Bot., 12: 23-40

Kirchhoff A., Pflugmacher S., 2002, *Comparison of the detoxification capacity of limnic and marine forms of the green alga Enteromorpha compressa.* Marine Environmental Research, 1-5: 2-73

Koemann R., Van den Hoek C., 1981, *The taxonomy of Ulva (Chlorophyceae) in The Netherlands.* Br. J. Phycol., 16: 9-53

Koemann R., Van den Hoek C., 1982, *The taxonomy of Enteromorpha link, 1820 (Chlorophyceae) in The Netherlands. I. The section Enteromorpha.* Arch. Hydrobiol. Suppl., 63: 279-330

Kornaś J., Medwecka-Kornaś A., 1949, *Podwodne zespoły roślinne Zatoki Gdańskiej. Les associations végétales sous-marines des le golfe du Gdańsk (Baltique Polonaise)*. Bull. intern. Acad. Polon. Sci. Lettres. Cl. Sci. Math. Nat., Sér. B 1: Sci. Nat. 1:71-88

Kowalski W., 1975, *Występowanie gatunków morskiej zielenicy Enteromorpha Link (1982) w wodach śródlądowych Pomorza Szczecińskiego.* Fragm. Flor. Geobot., Ser. Polonica, 21: 527-536

Kozłowski W., 1890, *Przyczynek do flory wodorostów okolic Ciechocinka*. Pam. Fizjogr., 10: 1-3

Krawiecowa A., 1954, *Glony. Bielawskie Błoto ginące torfowisko atlantyckie Pomorza*. Ochr. Przyr., 22: 101-128

Lee R. E., 1999, *Phycology.* Cambridge University Press, III: 614 pp.

Leskinen E., Alström - Rapaport C., Pamilo P., 2004, *Phytogeographical structure, distribution and genetic variation of the green algae Ulva intestinalis and U. compressa (Chlorophyta) in the Baltic Sea area.* Molecular Ecology, 13: 2257-2265

Liebetanz B., 1925, *Studja hydrobiologiczne solanek Kujawskich* - Hydrobiologische Studien an Kujawischen Brackwässern. Bull. Intern. Acad. Polon. Sci. Lettres. Sci. Math. Nat., Ser. B., Sci. Mat.: 116 pp.

Lois A., Pfiester O., Felker W., 1975, *Enteromorpha, a marine alga in Oklahoma.* Department of Botany and Microbiology, University of Oklahoma, Norman, Oklahoma, 56-66

Lucks R., 1907, *Planktonstudien in westpreußischen Seen*. Ber. Westpreuss. Bot. Zool. Vereins Danzig, 29(1): 55-65

Copyright© by Institute of Oceanography, University of Gdańsk, Poland

Malta E. J., Draisma S. G. A., Kamermans P., 1999, *Free floating Ulva in the southwest Netherlands: species or morphotypes? A morphological, molecular and ecological comparison.* Eur. J. Phycol., 34: 443-454

Marczek E., 1954, *Nowe stanowisko Enteromorpha intestinalis (L.) Link Kützig [(L.) Greville] i Enteromorpha tubulosa J. G. Agardh*. Fragm. Flor. Geobot., Ser. Polonica, 2, 2: 105-111

McAvoy K. M., Klug J. L., 2005, *Positive and negative effects of riverine input on the estuarine green alga U. intestinalis (syn. E. intestinalis) (Linneus).* Hydrobiologia, 545: 1-9

Messyasz B., (in press), *Enteromorpha (Chlorophyta) populations in River Nielba and Lake Laskownickie.* Hydrobiological and Oceanological Studies

Messyasz B., Rybak A., 2008a, *Nowe śródlądowe stanowiska halofilnej zielenicy Enteromorpha compressa (L.) Ness w Polsce.* Badania Fizjograficzne nad Polską Zachodnią, Seria B- Botanika, 57: 77-88

Messyasz B., Rybak A., 2008, *Występowanie Enteromorpha compressa [syn. Ulva compressa (L.)] (Chlorophyta) w Wielkopolsce.* Fragm. Flor. Geobot., Ser. Polonica, 15, 1: 17-19

Namysłowski B., 1927, *Studja hydrobiologiczne I. Études hydrobiologiques*. Prace Komis. Mat. – Przyrod. Pozn. Tow. Przyj. Nauk, Ser. B, Nauk. Biolog, 1: 1-13

Nielsen R., Kristiansen A., Mathiesen L., Mathiesen H., 1995, *Distributional index of the benthic macroalgae of the Baltic Sea area.* Acta Botanica Fennica, 155: 1-51

Nitardy E., 1898, *Die Algen des Kreises Elbing.* Schr. Natur. Ges. Danzig, 3 - 4: 101-106

Nitardy E., 1904, *Die Kryptogamenflora des Kreises Elbing*. Hedwigia, 43: 314-342

Pankow H., 1971, *Algenflora der Ostsee. I. Benthos*. Jena, VEB. G. Fisher, 413 pp.

Preuschoff P., 1883, *Beiträge zur Kryptogamenflora der Provinz Westpreussen*. Schr. Natur. Ges. Danzig, 4 - 5: 69-74

Piotrowska H., 1961, *Roślinność solniskowa pod Kołobrzegiem*. Chrońmy Przyr. Ojcz., 17 (4): 24-28

Pliński M., 1971, *Gatunki z rodzaju Enteromorpha (Link) Agardh z terenu solnisk podłęczyckich.* Zesz. Nauk. UŁ Biol., 41:159-169

Pliński M., 1973, *Glony solnisk podłęczyckich.* Monogr. Bot., 39: 3-88

Pliński M., 1973, *Nowe stanowisko Enteromorpha intestinalis (L.) Greville w Polsce*. Fragm. Flor. Geobot., Ser. Polonica., 19 (1): 135-137

Pliński M., Manasterska M., Florczyk I. 1982, Wstępna *charakterystyka ekologiczna rozwoju Enteromorpha* (*Link*) *w Zatoce gdańskiej*. Zesz. nauk. Wydz. Biol. Nauk Ziemi, Oceanografia. Uniw. Gdańsk, 9 (1):65-80

Podbielkowski Z., 1969, *Roślinność glinianek woj. warszawskiego*. Monogr. Bot., 30: 119 -156

Poole L., Raven J. A., 1997, *The biology of Enteromorpha*. Progress in Phycological Research, 12: 1-148

Raciborski M., 1888, *Materiały do flory glonów Polski.* Spraw. Kom. Fizjograf., AU, 22: 80 -122

Raciborski M., 1910, *Phycotheca polonica*. Cz. 1, Kosmos, 35: 80-89 and 1001-1006

Reed R., Russell G., 1978, *Salinity fluctuations and their influence on "bottle brush" morphogenesis in Enteromorpha intestinalis (L.) Link.* British Physiological Journal, 13: 149-153

Reed R., Russell G., 1979, *Adaptation to salinity stress in populations of Enteromorpha intestinalis (L.) Link.* Estuarine Costal Mar. Sci., 8: 251-258

Reed R., Moffat L., 2003, *Copper toxicity and copper tolerance in Enteromorpha compressa (L.) Grev.* Journal of Experimental Marine Biology and Ecology, 1: 85-103

Romano C., Windows J., Brinsley M. D., Staff F. J., 2003, *Impact of Enteromorpha intestinalis mats on near-bed currents and sediment dynamics: flume studies.* Marine Ecology Progress Series, 256: 63-74

Rouppert M. K., 1913, *O dwu planktonowych okrzemkach (Chaetoceros Zachariasi i Attheya Zachariasi). Über Zwei Plankton – Diatomeen (Chaetoceros Zachariasi und Attheya*

Zachariasi). Bulletin International de L' Akademie des Science de Cracovie, Classe des Science Mathèmatiques et Naturelles, Sèrie B, Sciences Naturelles, 1914: 298-308

Rouxel C., Bonnabeze E., Jérôme M., Etienne M., Fleurence J., 2001, *Identification by SDS PAGE of green seaweeds (Ulva and Enteromorpha) used in the food industry.* Journal of Applied Phycology, 3: 215-218

Sfriso A., Marcomini A., Pavoni B., 1987, *Relationships between macroalgae biomass and nutrient concentrations in the hypertrophic area of the Venice lagoon.* Mar. Env. Res., 22: 297-312

Siemińska J., 1990, *Polska bibliografia fykologiczna.* Bibliografie botaniczne. Tom 3. PAN, Instytut Botaniki im. W. Szafera, Kraków – Wrocław: 464 pp.

Siemińska J., Pająk J., 1992, *Polska bibliografia fykologiczna za lata 1981 - 1990*. Bibliografie botaniczne. Tom 6. PAN, Instytut Botaniki im. W. Szafera, Kraków: 181 pp.

Sitkowska M., 1999, *Dwa nowe stanowiska Enteromorpha flexuosa subsp. pilifera (Chlorophyta) w Polsce.* Fragm.. Flor. Geobot., Ser. Polonica, 6: 301-304

Skwarzec B., Ulatowski J., Strumińska D. I., Falandysz J., 2003, *Polonum ^{210}Po in the phytobentos from Puck Bay.* J. Environ. Monit., 5: 308-311

Starmach K., 1972, *Zielenice nitkowate.* – [In]: Starmach K. (ed), Flora słodkowodna Polski, Państwowe Wydawnictwo Naukowe, Warszawa – Kraków, 10: 163 pp.

Tan I., Mann D. G., Sluiman H. J., 1999, *Molecular phylogenetic evidence for a reversible morphogenetic switch controlling the gross morphology of two common genera of green seaweeds, Ulva and Enteromorpha.* Molecular Biology and Evolution, 16: 1011–1018

Tolstoy A., Willén T., 1997, *A preliminary checklist of macroalgae in Sweden. Artdatabanken.* Agricultural University of Sweden. Uppsala: 6-10

Torka V., 1910, *Zur Erforschung Posener Algen.* Zeitschr. d. Naturw. Abt., 16: 179-187

Valiela I., McClelland J., Hauxwell J., Behr P. J., Hersh D., Foreman K., 1997, *Macroalgal blooms in shallow estuaries: controls and ecophysiological and ecosystem consequences.* Limnology and Oceanography, 42: 1105-1118

Vladimirescu A. F., 2007, *Optical microscopy, TEM and molecular investigations on freshwater Enteromorpha in Romania.* Fourth European Phycological Congress, Oviedo, Spain, Book of Abstracts: 149

Wilkoń - Michalska J., 1963, *Halofity Kujaw*. Stud. Soc. Sc. Tor. Sect. D., 7, 1: 1-121

Wojtusiak R., Letkiewicz Z., Majlert Z., Rutkowski J., Wojtusiak H., 1984, *Badania zbiorowisk dennych polskiego Bałtyku przeprowadzone przy użyciu aparatów nurkowych*. Część VI i VII. Zbiorowiska zwierzęce i roślinne Zatoki Puckiej (rewa 1960-1961). Folia biol, 32(1-2): 119-146

Wood R. D., Imahori K., 1959, *Geographical Distribution of Characeae.* Bulletin of the Torrey Botanical Club, 3: 172-183

Worm B., Lotze H. K., 2006, *Effects of eutrophication, grazing, and algal blooms on rocky shores.* Limnol. Oceanogr., I and II, 51: 269-272

Wysocka H., 1952, *Wodorost morski w Wiśle koło Warszawy. (Enteromorpha intestinalis (L.)) Link.* Gazeta Obserwatora PIHM, 5, 4: 7-10

Zając A., Zając M., 2001, *Atlas rozmieszczenia roślin naczyniowych w Polsce.* Nakładem Prac. Chorologii Instytutu Botaniki UJ. Kraków, 716 pp.

Żbikowski R., Szafer P., Latała A., 2005, *Distribution and relationships between selected chemical elements in green alga Enteromorpha sp. from the southern Baltic.* Environmental Pollution, 3: 435-448

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