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 The algal distribution was established on the basis of the available literature, unpublished material, and oral reports.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 (Lesken 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 pirenoiids, 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 *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 Pajań 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 cartogram. 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), physicochemical 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

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

*Ulva paradoxa* C. Agardh 1817


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*.

<table>
<thead>
<tr>
<th>Author</th>
<th>Site location</th>
<th>Type of ecosystem and date of reported appearance</th>
<th>Length and width of thallus (cm)</th>
<th>Length and width of cells (μm)</th>
<th>Branching of thallus</th>
<th>Physico-chemical parameters (mg l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Messyasz (in press)</td>
<td>Wielkopolskie Province, surroundings of Gołębiewo</td>
<td>(VII-VIII – 1993-2006)</td>
<td>6 – 20</td>
<td>10 – 15</td>
<td>present</td>
<td>O₂ 0.0 – 9.8, pH 7.47 – 8.68, NH₃ 0.42 – 1.05, NO₃ 0.00 – 0.70, PO₄ 0.00 – 1.01, NaCl 98 – 133, cond. 648 – 1136</td>
</tr>
<tr>
<td></td>
<td>Lake Laskownickie</td>
<td></td>
<td>0.03 – 2</td>
<td>5.8 – 14.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Messyasz and Rybak (2008a)</td>
<td>Wielkopolskie Province, Poznań</td>
<td>(VII-X – 2004, 2006- 2007)</td>
<td>1.2 – 20</td>
<td>9.6 – 16</td>
<td>present</td>
<td>O₂ 0.25 – 0.80, pH 7.56 – 9.22, NH₃ 0.23 – 0.74, NO₃ 0.04 – 1.02, PO₄ 0.08 – 0.29, NaCl 537 – 776</td>
</tr>
<tr>
<td></td>
<td>Stream Dworski Rów</td>
<td></td>
<td>0.02 – 2</td>
<td>6.2 – 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stream Michałkowska</td>
<td></td>
<td>2.1 – 180</td>
<td>4.8 – 12.5</td>
<td>present</td>
<td>O₂ 3.0 – 5.4, pH 7.20 – 7.89, NH₃ 0.05 – 0.09, NO₃ 0.04 – 1.11, PO₄ 0.04 – 1.02, NaCl 513 – 604</td>
</tr>
<tr>
<td></td>
<td>Stream Święcińska</td>
<td></td>
<td>0.03 – 2</td>
<td>4.8 – 12.5</td>
<td>present</td>
<td>O₂ 0.50 – 4.70, pH 7.71 – 9.69, NH₃ 0.12 – 2.61, NO₃ 0.47 – 0.97, PO₄ 0.08 – 0.29, NaCl 537 – 776</td>
</tr>
<tr>
<td>cond. – conductivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

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

<table>
<thead>
<tr>
<th>Author</th>
<th>Site location</th>
<th>Type of the ecosystem and the period of appearing</th>
<th>Length and width of thallus (cm)</th>
<th>Length and width of cells (μm)</th>
<th>Branching of thallus</th>
<th>Physico-chemical parameters (mg l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kowalski 1975</td>
<td>West Pomeranian Province, surroundings of Łubczyce</td>
<td>(IX, 1970)</td>
<td>10 – 15</td>
<td>4.8 – 12.5</td>
<td>present</td>
<td>pH 8.0, PO₄ 0.17, NaCl 95.80</td>
</tr>
</tbody>
</table>

n.d. – no data
**Ulva prolifera** O. F. Müller 1978


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


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*.

<table>
<thead>
<tr>
<th>Author</th>
<th>Site location</th>
<th>Type of ecosystem and date of reported appearance</th>
<th>Length and width of thallus (cm)</th>
<th>Length and width of cells (μm)</th>
<th>Branching of thallus</th>
<th>Physico-chemical parameters (mg l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marczeック 1954</td>
<td>Silesian Province, Biskupice surroundings of Zabrz (IX, 1953) pond</td>
<td>up to 83 up to 0.1</td>
<td>13.3 – 46.2 10 – 23</td>
<td>absent</td>
<td>O₂ 8.49</td>
<td>pH 7.5, PO₄³⁻ 10.0, NaCl 48.9</td>
</tr>
<tr>
<td>- West Pomeranian Province:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- surroundings of Wietrzcno</td>
<td>(IX, 1970) Pond Miedwie</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- surroundings of Łączyza</td>
<td>(IX, 1970) Lake Dużyńskie</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Szczecin, district Nad Odrą</td>
<td>(IX, 1970) Ponds Portowy</td>
<td>up to 36 0.009 – 0.013</td>
<td>15.0 – 30 12.1 – 18.0</td>
<td>present, little up to 150 μm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- surroundings of Czarnosc, Warołe, Podgórki</td>
<td>(IX, 1970)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- surroundings of Ogienia</td>
<td>(IX, 1970) Canal Piastowski</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n.d. - no data

www.oandhs.org
Ulva flexuosa subsp. pilifera (Kützing) Bliding 1963

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. Coniferia intestinalis (Linnaeus) Roth 1797, Tetraspora intestinalis (Linnaeus) Desvaux 1818, Sclysiphon 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, Hydrorhiza intestinalis (Linnaeus) Martius 1833, Sclysiphon intestinalis var. nematodes Wallroth 1833, Enteronia simplex Chevallier 1836, Enteromorpha vulgaris var. lacustris Edmondston
Information concerning the site locations, morphometric features and habitats of *Ulva flexuosa* subsp. *pilifera*.

<table>
<thead>
<tr>
<th>Author</th>
<th>Site location</th>
<th>Type of ecosystem and date of reported appearance</th>
<th>Length and width of thallus (cm)</th>
<th>Length and width of cells (μm)</th>
<th>Branching of thallus</th>
<th>Physico-chemical parameters (mg L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kowalski 1975</td>
<td>West Pomeranian Province, Szczecin, surroundings of A6 highway</td>
<td>(VI – X, 1970) Canal on Międyodrzu</td>
<td>15 – 25</td>
<td>1.5 – 3.0</td>
<td>present</td>
<td>pH 7.5 – 8 NO₃⁻ 0.39 NO₂⁻ 0.037 PO₄³⁻ 0.23 NH₄⁺ 0.5 NaCl 20</td>
</tr>
<tr>
<td>Sitkowska 1999</td>
<td>Łódź Province, Piotrowice surroundings of Łódź</td>
<td>(1984 – 1987) pond</td>
<td>20 – 30</td>
<td>1 – 2</td>
<td>present</td>
<td>pH 8.5 NO₃⁻ 0.08 NO₂⁻ 0.001 NH₄⁺ 0.5 NaCl 20</td>
</tr>
</tbody>
</table>

n.d. - no data


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 Wiśłany (Nitardy 1898). In 1904 it appeared in Elblag (Nitardy 1904) in the Warmia – Masuria Province. The next reported sites were lake ecosystems at Słoniawy, in the surroundings of Szubin and Inowroclaw (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 Wójcicki 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 Inowroclaw. 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).
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*.

<table>
<thead>
<tr>
<th>Author</th>
<th>Site location</th>
<th>Type of ecosystem and date of reported appearance</th>
<th>Length and width of thallus (cm)</th>
<th>Length and width of cells (μm)</th>
<th>Branching of thallus</th>
<th>Physico-chemical parameters (mg l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marczeck 1954</td>
<td>Lublin Province, Biskupice - Zabrze (IX, 1953-1954) pond</td>
<td>up to 40 up to 1.25</td>
<td>6.5 – 23.2</td>
<td>3.3 – 13.3</td>
<td>absent</td>
<td>Cl⁻ 8.49, PO₄³⁻ 7.5, NaCl 10.0</td>
</tr>
<tr>
<td>Pilski 1973, 1973a</td>
<td>Łódzkie Province, surroundings of Łęczyca (IV - IX, 1968 -1969) 5 peaty holes</td>
<td>5 – 23</td>
<td>0.2 – 1.2</td>
<td>7 – 18</td>
<td>9 – 18</td>
<td>present, little up to 140 μm</td>
</tr>
<tr>
<td>Kowalski 1975</td>
<td>West Pomeranian Province: - surroundings of Wierzbnio (VI - IX, 1970) Lake Medwie</td>
<td>18 – 42</td>
<td>0.4 – 1.4</td>
<td>7.3 – 27.2</td>
<td>6.5 – 18.1</td>
<td>present, little up to 900 μm</td>
</tr>
<tr>
<td>- surroundings of Łęczyca (IX, 1970) Lake Dąbkie</td>
<td>18 – 42</td>
<td>0.4 – 1.4</td>
<td>7.3 – 27.2</td>
<td>6.5 – 18.1</td>
<td>present, little up to 900 μm</td>
<td>pH 7.1, NO₃ - 0.43, Cl⁻ 39.70</td>
</tr>
<tr>
<td>- Szczecin, Nad Odrą district (IX, 1970) Pond Portowy</td>
<td>18 – 42</td>
<td>0.4 – 1.4</td>
<td>7.3 – 27.2</td>
<td>6.5 – 18.1</td>
<td>present, little up to 900 μm</td>
<td>pH 8.0, PO₄³⁻ 0.17, Cl⁻ 95.80</td>
</tr>
</tbody>
</table>

cond. – conductivity;
* - information on the site is an oral account;
n.d. – no data
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 Pfugmacher 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

<table>
<thead>
<tr>
<th>Species</th>
<th>sea ecosystem</th>
<th>inland ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Enteromorpha torta</em> (Mertes) Reinhold 1893</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><em>Enteromorpha prolifera</em> J. Ag. 1882-1883</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Enteromorpha ramulosa</em> (Engl. Bot.) Hooker 1833</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Enteromorpha flexuosa</em> (Wall. ex Roth) J. Ag. 1883</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Enteromorpha compressa</em> Ness 1820</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Enteromorpha linza</em> (L.) J. Ag. 1883</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Enteromorpha intestinalis</em> (L.) Link 1820</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Enteromorpha clathrata</em> (Roth) Greville 1830</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Enteromorpha ahlneriana</em> Blinding 1933</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

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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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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