

**LONG-TERM CHANGES IN THE FLORA
AND VEGETATION OF OLECKO WIELKIE LAKE, ELK
LAKE DISTRICT, POLAND**

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Key words: urban lake; anthropogenic pressure; macrophytes; protected, threatened and rare plant species.

Abstract

The paper presents detailed results of research into floristic and phytosociological studies on the vegetation of Olecko Wielkie Lake, carried out in 2009. During the study 28 hydrophytic taxa, 27 helophytic taxa and 14 species classified as co-existing were identified, including of those forming the structure of particular plant communities. In total 69 plant taxa were found, without trees and shrubs growing on the lake shoreline. The paper presents the occurrence of protected, endangered, and rare species in Poland. The paper also presents a comparison of recent studies with does carried out in the period in 1983–1986, allowing for the identification of changes in the flora and vegetation of Olecko Wielkie Lake between 1983 and 2009.

**DŁUGOTERMINOWE ZMIANY FLORY I ROŚLINNOŚCI JEZIORA
OLECKO WIELKIE NA POJEZIERZU ELCKIM**

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Słowa kluczowe: jezioro miejskie; antropopresja; makrofity; rośliny chronione, zagrożone i rzadkie.

Abstrakt

W pracy przedstawiono wyniki badań florystyczno-fitosocjologicznych szaty roślinnej jeziora Olecko Wielkie, które prowadzono w roku 2009. W trakcie badań stwierdzono występowanie 28 taksonów hydrofitów, 27 gatunków szuwarowych i bagiennych oraz 14 gatunków określonych jako gatunki towarzyszące, z podaniem które z nich uczestniczą w budowie określonych zbiorowisk roślinnych. Łącznie odnotowano występowanie 69 taksonów roślin z wyłączeniem drzew i krzewów,

które rosną na brzegu jeziora. W pracy przedstawiono występowanie gatunków chronionych, zagrożonych i rzadkich. Porównano także otrzymane wyniki badań z wynikami z lat 1983–1986. Na tej podstawie podsumowano zmiany, które zaszły w obrębie flory i roślinności jeziora Olecko Wielkie na przestrzeni lat 1983–2009.

Introduction

Lakes are habitats for specific aquatic plant species known as macrophytes, which are a group of plants with highly diversified morphology (e.g. FLEMING et al. 2012). Macrophytes include all *Charophyta* species native to Poland, selected *Bryophyta*, very few ferns (*Pteridophyta*), and a small group of seed plants (*Spermatophyta*). Macrophytes have a number of important ecological functions in reservoirs, e.g. by affecting the water's trophic state and the composition of plant and animal biocenosis. They are places of feeding and breeding, create refugia for many aquatic invertebrate and fish species, and are also favourable habitats for birdlife (SUTELA et al. 2013, FLEMING and DIBBLE 2015, LAURIDSENET al. 2015). The presence of macrophytes also increases the biodiversity of ecosystems (FLEMING et al. 2012, ALAHUHTA et al. 2013). Macrophytes are relatively stable groups of aquatic plants. Nevertheless, they undergo rapid degradation under extreme conditions (BAKKER and NOLET 2014, JUSIK and MACIOŁ 2014, FLEMING and DIBBLE 2015).

Lakes are exposed to endogenic and exogenic factors, and respond by the transformation of their ecological structure, including that of macrophytes. Very important is also the manner of management in lake's catchment area. Changes in lakes trophy may lead to decline of valuable and rare species in the lakes, as well as decline of valuable habitats, including Nature 2000 habitats (SUTELA et al. 2013, HANSEN and SNICKARS 2014, JUSIK and MACIOŁ 2014, KOLADA et al. 2014, SOANA and BARTOLI 2014, LAURIDSEN et al. 2015).

The aim of this study was to determine the changes in the flora of the urban lake Olecko Wielkie Lake during 25 years and making an inventory of natural valuable and protected species. The main reason for the implementation of the research was observed in recent years, more and more anthropopressure (extension Olecko city, tourism and recreation) on featured lake (own study – unpublished).

Material and Methods

Study area

Olecko Wielkie Lake (*jezioro Olecko Wielkie*) is located in an urban area in north-east part of Poland (54°03'27"N/ 22°29'42"E). The town of Olecko, with

a population of about 22,038 (data for 31 December 2014), spreads out on the western shoreline of the lake. According to CHMIELEWSKI et al. (2007), the lake covers an area of 227.3 ha and has a maximum depth of 45.2 m. The lake basin is ribbon-shaped, with a maximum length of 4,860 m and a maximum width of 1,110 m, stretching from the north-west towards the south-east (Figure 1). Olecko Wielkie Lake is located near the eastern border of Elk Lake District, a mesoregion within the macroregion of the Masurian Lake District (KONDRACKI 2011).

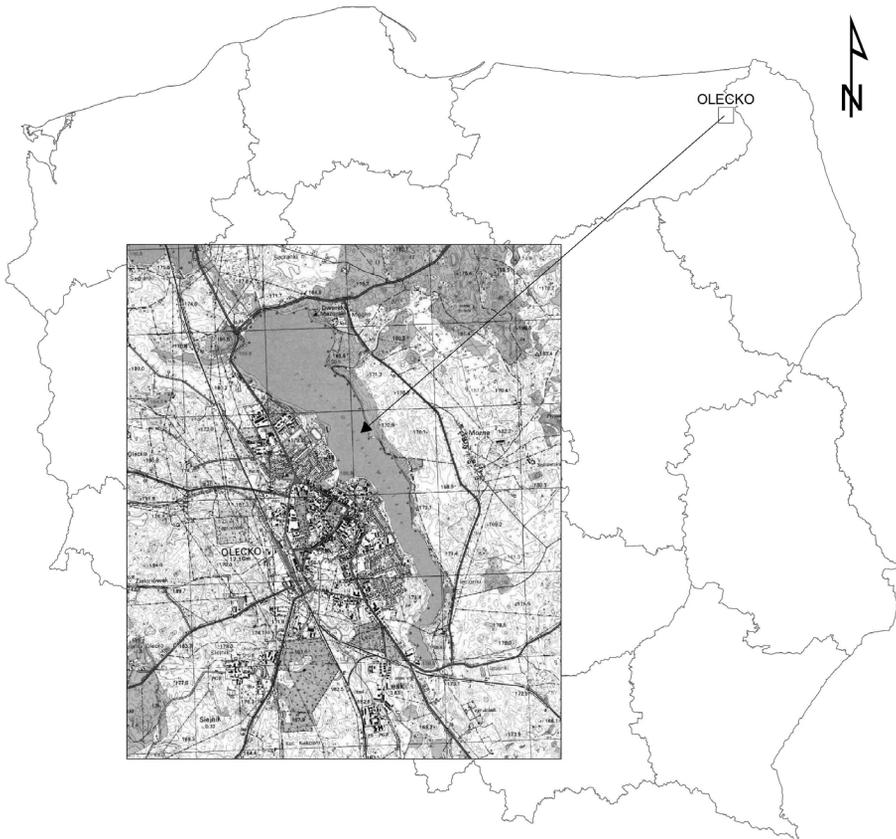


Fig. 1. The location of the study site

Olecko Wielkie Lake is a flow-through reservoir. The mouth of the Lega river is in the lake's northern bay, and the river's outflow is located in the central part of the western shoreline. The Lega, through subsequent rivers (Małkinia and Jegrznia), and further through the rivers Elk, Biebrza and

Narew, discharges water into the Vistula river (CHMIELEWSKI et al. 2007). Since 2003 Olecko Wielkie Lake has been a part of the Olecko Wielkie Lake Protected Landscape and the Lega Valley Protected Landscape (O.J. of Warmia and Mazury 2003, No. 52, item. 725). In 2007 and the “Długi Mostek” Ecological Site, located in the bay of Olecko Wielkie Lake near the outflow of the Lega river, were established (O.J. of Warmia and Mazury 2007, No. 1, item 1).

Sampling and data collection

In 1989 research was conducted using classic method of profiles made from the shore to a depth of occurrence of plant communities. Phytocoenoses were documented by phytosociological records performed according to generally used method of Braun-Blanquet. On the basis of documented positions 59 phytosociological records were made.

In June and July 2009 field research were carried out using a GPS eTrex Vista satellite receiver (Garmin). 179 geographical locations corresponded with the sites of protected, rare or declining plant taxa (classification is made in accordance with RUTKOWSKI 2011) and endangered or vulnerable *Charophyte* species (classification is made in accordance with SIEMIŃSKA et al. 2006). Protected species in this paper are presented according to the classification published in the Regulations of the Minister of the Environment. The survey was carried out using grappling hooks and dragging rakes down to the depth of plant occurrence. The distribution range for individual species was established using the ArcMAP 9.3.1 application.

Nomenclature of vascular plant species was adopted after MIREK et al. (2002), and for charophyte species after DĄBBSKA (1964), PEŁECHATY, PUKACZ (2008) and URBANIAK, GĄBKA (2014).

Results and Discussion

Studies investigating the status of flora in Olecko Wielkie Lake were carried out in June and July 2009, in parallel with research aimed at the identification and distribution of plant communities. Results demonstrated that the vegetation of Olecko Wielkie Lake included phytocenoses of 13 hydrophytic associations and 11 helophytic associations (DZIEDZIC, DYNOWSKI 2009).

Floristic studies carried out in 2009 revealed the presence of 23 hydrophytic taxa (Table 1), 26 helophytic taxa, and 14 other species classified as co-existing

Systematic classification of hydrophytes in Olecko Wielkie Lake in 2009

Table 1

No. of hydroph.	R – rooted S – semi-rooted F – floating	Taxa in systematic order
Division: Chlorophyta		
Class: Charophyceae		
(1.) Family: Characeae		
1.	S	<i>Ch. fragilis</i> Desvaux = <i>Chara globularis</i> Thuillier
2.	S	<i>Chara contraria</i> A. Braun ex Kutzing
3.	S	<i>Nitella flexilis</i> (L.) Agardh
4.	S	<i>Chara tomentosa</i> L.
5.	S	<i>Nitellopsis obtusa</i> J. Groves
Division: Telomophyta		
Subdivision: Bryophytina		
(2.) Family: Fontinalaceae		
1.	F	<i>Fontinalis antipyretica</i> Hedw
Subdivision: Magnoliophyta (Angiospermae)		
Class: Magnoliopsida (Dicotyledones)		
(4.) Family: Polygonaceae		
1.	R	<i>Polygonum amphibium</i> L. f. <i>natans</i> Moench
(5.) Family: Nymphaeaceae		
2.	R	<i>Nuphar lutea</i> (L.) Sibth.
3.	R	<i>Nuphar x intermedia</i> Leder. (= <i>N x spenneriana</i> Gaudin)
4.	R	<i>Nymphaea alba</i> L.
(6.) Family: Ceratophyllaceae		
5.	F	<i>Ceratophyllum submersum</i> L.
6.	F	<i>Ceratophyllum demersum</i> L.
(7.) Family: Ranunculaceae		
7.	R	<i>Batrachium circinatum</i> (Sibth.) Fr.
(8.) Family: Holoragaceae (Holorrhagidaceae)		
8.	R	<i>Myriophyllum spicatum</i> L.
(9.) Family: Lentibulariaceae		
9.	F	<i>Utricularia vulgaris</i> L.
Class: Liliopsida (Monocotyledones)		
(10.) Family: Lemnaceae		
10.	F	<i>Lemna minor</i> L.
(11.) Family: Alismataceae		
11.	R	<i>Alisma gramineum</i> Lej.
(12.) Family: Hydrocharitaceae		
12.	S	<i>Stratiotes aloides</i> L.
(13.) Family: Potamogetonaceae		
13.	R	<i>Potamogeton pectinatus</i> L.
14.	R	<i>Potamogeton crispus</i> L.
15.	R	<i>Potamogeton lucens</i> L.
16.	R	<i>Potamogeton perfoliatus</i> L.
17.	R	<i>Potamogeton praelongus</i> Wulfen

plants (Table 2). In total 63 plant taxa were recorded, without trees and shrubs growing on the lake shore.

Sites of protected, rare and declining plants in Poland are presented in Figures 2–5.

Table 2

Systematic classification of helophytes in Olecko Wielkie Lake in 2009

Division: <i>Telomorphyta</i>	
Subdivision: <i>Sphenophytina</i> Class: <i>Sphenopsida</i> (1.) Family: <i>Equisetaceae</i> 1. <i>Equisetum fluviatile</i> L. (<i>E. limosum</i> L.)	
Subdivision: <i>Magnoliophytina (Angiospermae)</i> Class: <i>Magnoliopsida (Dicotyledones)</i> (2.) Family: <i>Polygonaceae</i> 2. <i>Rumex hydrolapathum</i> Hudson (3.) Family: <i>Brassicaceae (Cruciferae)</i> 3. <i>Rorippa amphibia</i> (L.) Besser (4.) Family: <i>Apiaceae (Umbelliferae)</i> 4. <i>Berula erecta</i> (Huds.) Coville 5. <i>Cicuta virosa</i> L. 6. <i>Sium latifolium</i> L. (5.) Family: <i>Primulaceae</i> 7. <i>Lysimachia thyrsoiflora</i> L. (6.) Family: <i>Rubiaceae</i> 8. <i>Galium palustre</i> L. (7.) Family: <i>Lamiaceae (Labiatae)</i> 9. <i>Lycopus europaeus</i> L. 10. <i>Scutellaria galericulata</i> L.	
Subdivision: <i>Magnoliophytina (Angiospermae)</i> Class: <i>Liliopsida (Monocotyledones)</i> (8.) Family: <i>Alismataceae</i> 11. <i>Alisma plantago-aquatica</i> L. (9.) Family: <i>Iridaceae</i> 12. <i>Iris pseudacorus</i> L. (10.) Family: <i>Poaceae (Gramineae)</i> 13. <i>Glyceria maxima</i> (Hartman) Holmb. (<i>G. aquatica</i> (L.) R. Br. 14. <i>Phalaris arundinacea</i> L. 15. <i>Phragmites australis</i> (Cav.) Trin. ex Steud. (<i>P. communis</i> Trin.) (11.) Family: <i>Araceae</i> 16. <i>Acorus calamus</i> L. (12.) Family: <i>Sparganiaceae</i> 17. <i>Sparganium erectum</i> L. em. Rchb. 18. <i>Sparganium emersum</i> Rehmann (<i>S. Simplex</i> Hudson) (13.) Family: <i>Typhaceae</i> 19. <i>Typha angustifolia</i> L. 20. <i>Typha latifolia</i> L. (14.) Family: <i>Cyperaceae</i> 21. <i>Carex acutiformis</i> Ehrh. 22. <i>Carex gracilis</i> Curtis (<i>C. acuta</i> L.) 23. <i>Carex pseudocyperus</i> L. 24. <i>Eleocharis acicularis</i> (L.) Roem. et Sch. 25. <i>Eleocharis palustris</i> (L.) Roem. et Sch. 26. <i>Schoenoplectus lacustris</i> (L.) Palla (<i>Scirpus lacustris</i> L.)	

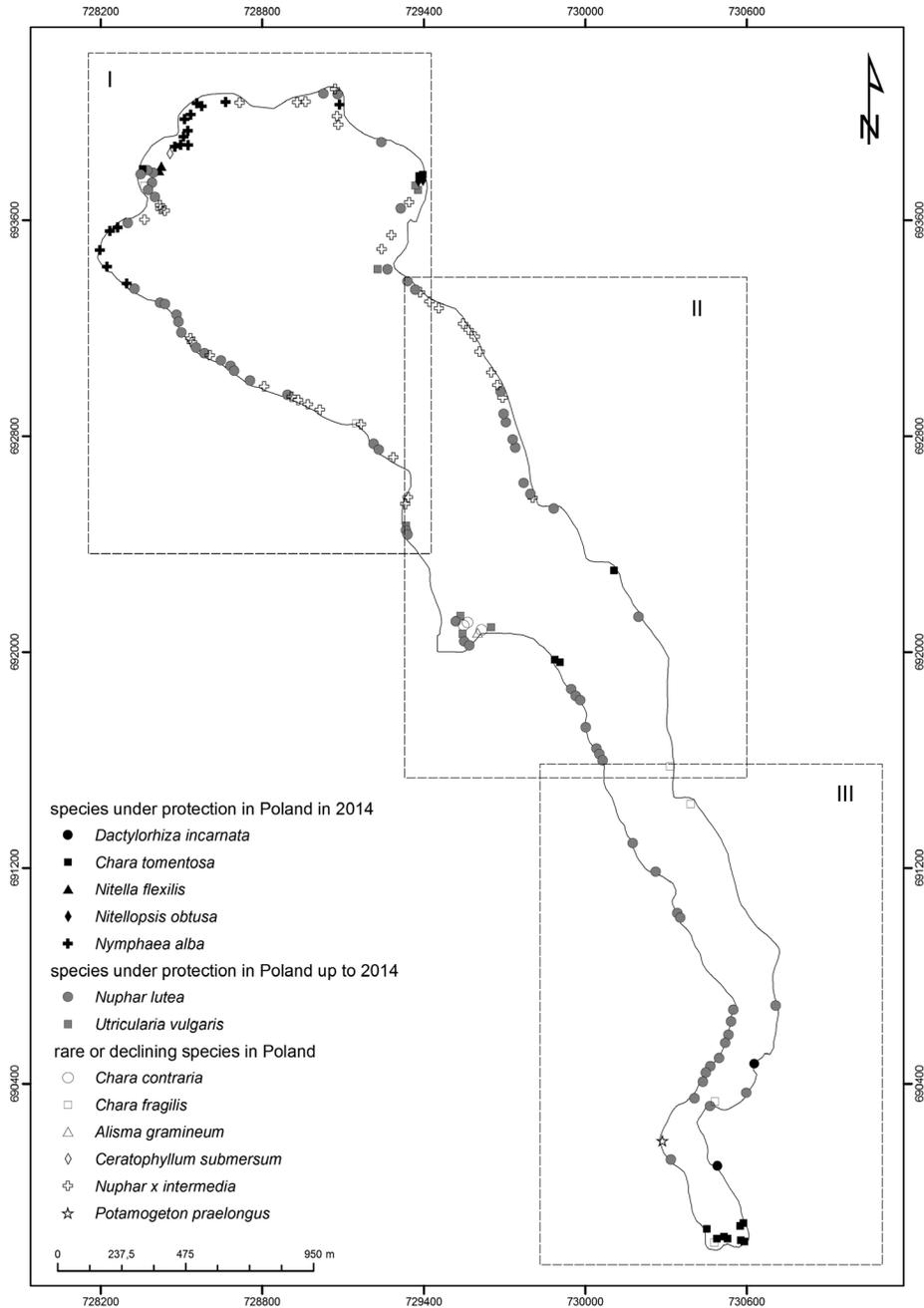


Fig. 2. Olecko Wielkie Lake divided into sheets individual sheets. Sites of protected, rare and declining taxa in Poland

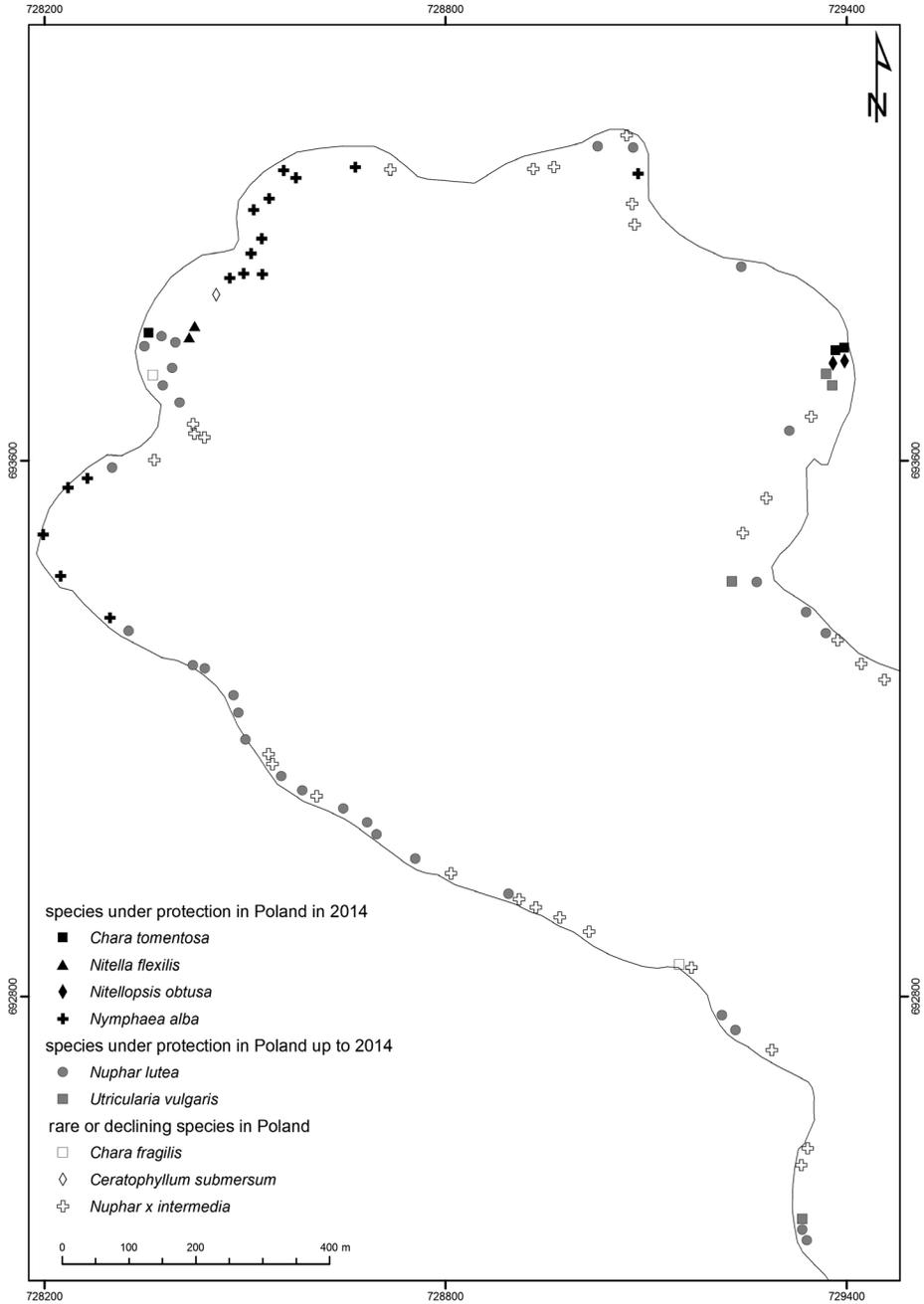


Fig. 3. Olecko Wielkie Lake, Sheet I. Map of sites of protected, rare and declining taxa in Poland

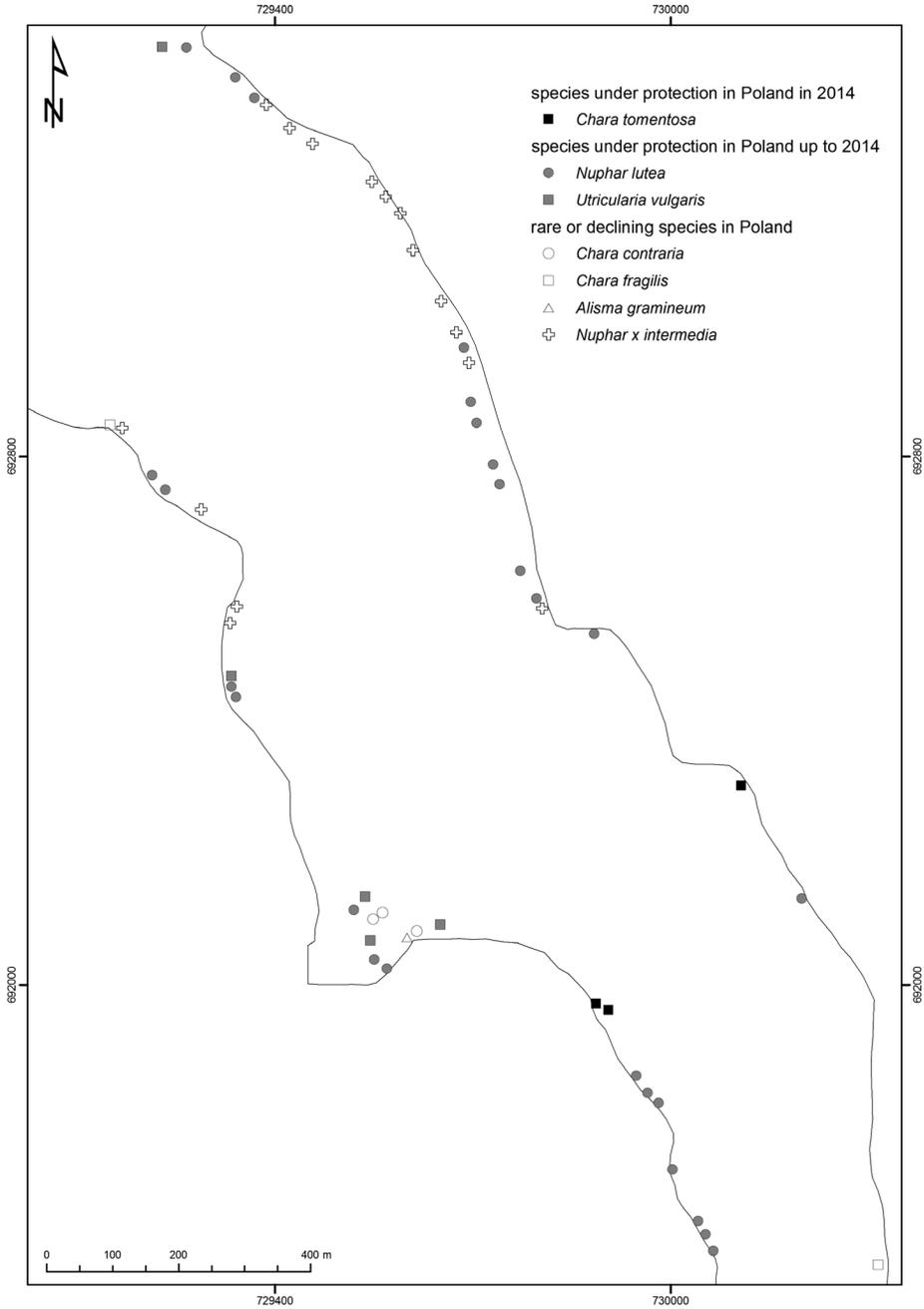


Fig. 4. Olecko Wielkie Lake, Sheet II. Map of sites of protected, rare and declining taxa in Poland

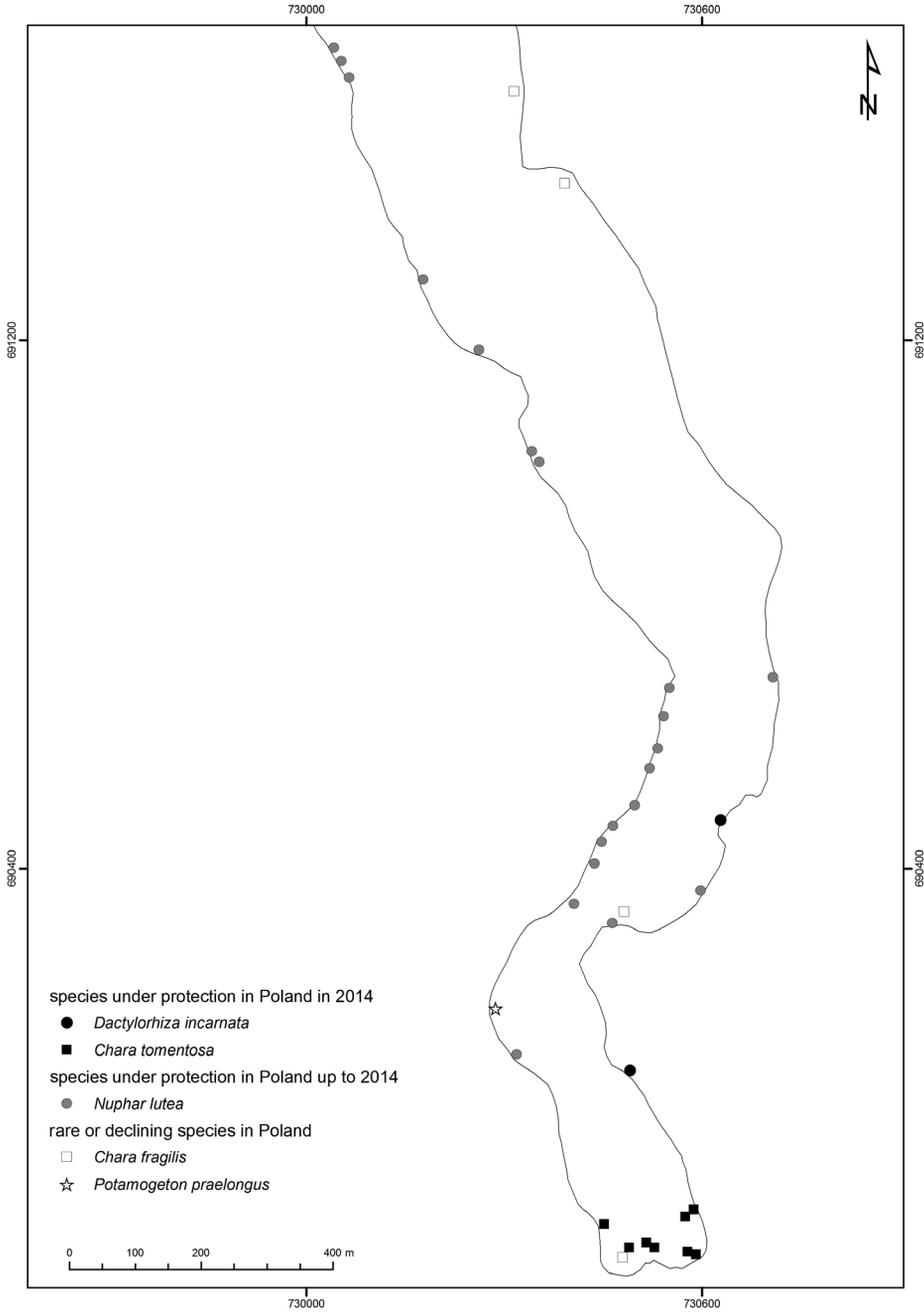


Fig. 5. Olecko Wielkie Lake, Sheet III. Map of sites of protected, rare and declining taxa in Poland

In the 1980s the recorded communities were formed by 4 charophyta species: *Chara globularis* (Thuiller), *Chara rudis* [(Braun) von Leonhardi], *Chara contraria* (Braun ex Kutzing), *Nitellopsis obtusa* [(Desvaux) Groves] (DZIEDZIC 2004a). In 2009 four charophyta species were also recorded: *Chara globularis*, *Chara contraria*, *Nitellopsis obtusa*, *Chara tomentosa* (L.). In 2009, the decline of communities formed by *Chara rudis* is being observed, while those formed by *Chara tomentosa* are emerging. Most likely, *Chara tomentosa* also occurred in the 1980s, but was not found due to the use of low-precision research methods. The emergence of this macroalgae may also be associated with the fact that it has a very wide ecological spectrum and can grow, unlike other *Charophyte* species found in the lake, in waters from highly eutrophic to polytrophic. Studies carried out in the 1980s revealed that all recorded *Charophyte* species formed their own communities (DZIEDZIC 2004 a). However, research from 2009 demonstrated that *Chara globularis* and *Chara contraria* no longer form their own phytocenoses but occur only as co-existing species within other plant communities. This is most likely associated with the increase in the trophic state of the lake caused by the inflow of large amounts of biogenic compounds to the catchment area and intense exploitation of the lake for recreational purposes (including power boating), but also the succession on native plant species such as *Ceratophyllum demersum* (L.) or *Myriophyllum spicatum* (L.), characteristic of eutrophic lakes (eg. ALAHUHTA et al. 2012, KOLADA et al. 2014). The wastewater treatment plant for the town of Olecko was put into operation relatively late, in 1995 (RÓŻAŃSKI et al. 2004). The decline of *Charophyte* species may also be associated with specific fishery management, e.g. the use of bottom dragging equipment (own study – unpublished).

With reference to aquatic mosses, the decline of *Eurhynchium riparioides* [(Hedw.) Richards] sites was observed. In recent years, sites of this species have not been recorded, but the distribution range of *Fontinalis antipyretica* (L.) has clearly increased. The decline of sites was also observed for *Elodea canadensis* (Michx.), *Polygonum amphibium* f. *natans* (Michx.), *Potamogeton friesii* (Rupr.) and *Potamogeton trichoides* (Cham. et Schldl.).

In the 1980s no sites of *Nuphar x intermedia* (Ledeb.) or *Nymphaea alba* (L.) were recorded, but in 2009 they form their own communities. *Ceratophyllum submersum* (L.), a species indicating improved water quality, was recorded on several sites. This ephemeral species occurs in lakes where trophic conditions have improved. However, its regression occurs after some time, until complete decline (TOMASZEWICZ 1979).

In 2009 communities formed by *Potamogeton crispus* (L.), *Potamogeton praelongus* (Wulfen), *Stratiotes aloides* (L.) and *Eleocharis acicularis* (L.) were found (not recorded previously). However, sites of *Potamogeton friesii* and *Potamogeton trichoides* have declined.

Characteristics of individual plant formations found in Olecko Wielkie Lake in 2009 are presented below.

Aquatic plants – hydrophytes

Most of the 23 aquatic taxa found in Olecko Wielkie Lake in 2009 were represented by plants rooted in the lake bottom (Table 1 – *R*), followed by semi-rooted plant species (Table 1 – *S*) and plants submerged in water or floating on its surface (Table 1 – *F*).

Helophytes

The shoreline of Olecko Wielkie Lake was a habitat for 26 helophytic species (Table 2), and 14 co-existing terrestrial plant species encroaching on the helophytic communities (Table 3).

Table 3
Plants co-existing with helophytic communities in Olecko Wielkie Lake in 2009

<p>Division: <i>Telomophyta</i> Subdivision: <i>Magnoliophytina (Angiospermae)</i> Class: <i>Magnoliopsida (Dicotyledones)</i></p>
<p>(1.) Family: <i>Cannabaceae</i> 1. <i>Humulus lupulus</i> L.</p>
<p>(2.) Family: <i>Urticaceae</i> 2. <i>Urtica dioica</i> L.</p>
<p>(3.) Family: <i>Polygonaceae</i> 3. <i>Rumex obtusifolius</i> L. 4. <i>Polygonum amphibium</i> L. f. <i>terrestre</i> Leyss</p>
<p>(4.) Family: <i>Rosaceae</i> 5. <i>Filipendula ulmaria</i> (L.) Maxim.</p>
<p>(5.) Family: <i>Lythraceae</i> 6. <i>Lythrum salicaria</i> L.</p>
<p>(6.) Family: <i>Onargaceae (Oenotheraceae)</i> 7. <i>Epilobium hirsutum</i> L.</p>
<p>(7.) Family: <i>Primulaceae</i> 8. <i>Lysimachia vulgaris</i> L.</p>
<p>(8.) Family: <i>Convolvulaceae</i> 9. <i>Calystegia sepium</i> (L.) R. Br.</p>
<p>(9.) Family: <i>Boraginaceae</i> 10. <i>Symphytum officinale</i> L.</p>
<p>(10.) Family: <i>Solanaceae</i> 11. <i>Solanum dulcamara</i> L.</p>
<p>(11.) Family: <i>Asteroideae (Tubiflorae)</i> 12. <i>Bidens tripartita</i> L. 13. <i>Eupatorium cannabinum</i> L.</p>
<p>Division: <i>Magnoliophytina (Angiospermae)</i> Class: <i>Liliopsida (Monocotyledones)</i></p>
<p>(12.) Family: <i>Orchidaceae</i> 14. <i>Dactylorhiza incarnata</i> (L.) Soósubsp. <i>incarnata</i></p>

Sites of protected species in Poland

Species under legal protection up to 2014 (under legal protection in 2009, currently not protected)

Species: *Utricularia vulgaris* (L.)

Family: *Lentibulariaceae*

Class: *Magnoliopsida (Dicotyledones)*

Utricularia vulgaris had been under strict protection in Poland since 2004, together with other species from the genus *Utricularia* (O.J. 2004, No. 168, item 1764). However, it is not listed in the recent Regulation of the Minister of the Environment (O.J. 2014, item 1409) on protected plant species in Poland. *U. vulgaris* is common in Poland and found mainly in nutrient-rich stagnating waters (RUTKOWSKI 2011, KŁOSOWSKI and KŁOSOWSKI 2012). The plant is carnivorous (insectivorous), like all representatives of the genus *Utricularia*. Small aquatic animals are captured by leaves transformed into bladder-like traps, closed with a trapdoor which allows entry but cannot be open from within the bladder. The bladderwort is an aquatic and marshland plant, rootless, with creeping or free floating stems. The leaves are finely innately divided, and some are transformed into bladder-like traps. The major threat to this species results from the decline of natural habitats.

In Olecko Wielkie Lake it was recorded infrequently near reeds at a depth of 1.3 m, and in *Fontinalis antipyretica* communities at a depth of 1.9 m, in phytocenoses with dominant *Potamogeton pectinatus* at a depth of 0.5 m, in patches with dominant *Potamogeton lucens* at a depth of 0.5 to 1.2 m and in communities with dominant *Batrachium circinatum* (Sibth.) at a depth of 0.7 to 1.9 m. Single specimens were found rarely at depths of 1.4 to 2.8 m. This species was found in littoral zone in the central and northern parts of the lake (Figures 2–4)

Species: *Nuphar lutea* [(L.) Sibth.]

Family: *Nymphaeaceae*

Class: *Magnoliopsida (Dicotyledones)*

Nuphar lutea had been under strict protection in Poland since 1983 (O.J. 1983, No. 27, item 134). In the Regulation of the Minister of the Environment of 2001 it was still listed as a strictly protected species (O.J. 2001, No. 106, item 1167). Since 2004 it had been under partial protection (O.J. 2004, No. 168, item 1764). However, it is not listed in the recent Regulation of the Minister of the Environment (O.J. 2014, item 1409).

Nuphar lutea is a common hydrophyte with floating leaves. It is found in natural and man-made reservoirs, and in slowly flowing rivers. It forms phytocenoses of the *Nupharo-Nymphaeetum albae* association. In the vegeta-

tion of Olecko Wielkie Lake phytocenoses dominated by *Nuphar lutea* covered 1.178 ha, versus 3.859 ha covered by all identified hydrophytic communities (DZIEDZIC and DYNOWSKI 2009). Patches of the *Nupharo-Nymphaetum albae* association with dominant *Nuphar lutea* were found along the whole lake shoreline (Figures 2–5).

Species under legal protection according to the recent Regulation of the Minister of the Environment (O.J. 2014, item 1409)

Species: *Dactylorhiza incarnata* [(L.) Soó] subsp. *incarnata*

Family: *Orchidaceae*

Class: *Liliopsida* (*Monocotyledones*)

The family *Orchidaceae* is represented in the flora of Poland by 46 species (SZLACHETKO 2014). Plants with colourful flowers are at risk of being collected or dug out. Generally, threats to these species are associated with the transformation of natural habitats caused by human activity.

All orchid species in Poland were covered by protection relatively early, in 1983 (O.J. 1983, no. 27, item 134). Currently, *Dactylorhiza incarnata* is under partial protection (O.J. 2014, item 1409). This orchid was found on two sites near the eastern shoreline of Oleckie Wielkie Lake, in the southern part (Figure 2 and Figure 5). In Poland *Dactylorhiza incarnata* occurs in a number of varieties and subspecies. Specimens found near the lake had characteristics of a typical subspecies, *Dactylorhiza incarnata* subsp. *incarnata*, most common in the southern part of Poland (SZLACHETKO 2014).

Species: *Nymphaea alba* (L.)

Family: *Nymphaeaceae*

Class: *Magnoliopsida* (*Dicotyledones*)

Nymphaea alba was covered for the first time by partial protection in 1957 (O.J. 1957, No. 15, item 78). In 1995, this status was changed to strict protection, which was reflected in the regulation of 2001 (O.J. 2001, no. 106, item 1167). Since 2004 *Nymphaea alba* has been under partial protection (O.J. 2004, no. 168, item 1764, O.J. 2014, item 1409).

Nymphaea alba and *Nuphar lutea* are species characteristic of the *Nupharo-Nymphaetum albae* association (MATUSZKIEWICZ 2012). In Olecko Wielkie Lake one large patch (0.148 ha) of the association formed by *Nymphaea alba* was found in the northern part of the lake, on the western side of the Lega river mouth (Figure 3). *Nymphaea alba* was recorded at a depth of 0.9 to 2.4 m (DZIEDZIC and DYNOWSKI 2009). Other rare and single sites of the white water lily were recorded only in the northern part of the lake, in the north-western bay, and one separate site in the north-eastern bay.

Occurrence of threatened, rare and protected charophyte species in Poland

Charophytes, known as sensitive indicators of water quality, were found in the studied lake. These plants are also attributed with habitat- and environment-forming functions, associated with the intake of biogenic compounds and water decalcification, as well as effects on other aquatic organisms (CIECIERSKA et al. 2003, GĄBKA et al. 2007, URBANIAK and GĄBKA 2014).

Species: *Chara fragilis* (Desvaux) = *Chara globularis* (Thuillier)

Family: *Characeae*

Class: *Charophyceae*

According to the Red List of Algae in Poland (SIEMIŃSKA et al. 2006) *Chara fragilis* is classified as a vulnerable species. During the carried out study no phytocenoses of *Charetum fragilis* association were found (DZIEDZIC and DYNOWSKI 2009). A few sites were recorded in the northern and southern parts of Olecko Wielkie Lake (Figures 2, 3 and 5). In the northern part of the lake *Chara fragilis* was found in a phytocenosis with dominant *Nuphar lutea* near a tributary of the Lega river, at a depth of 1.2 m, and near the western shoreline, northwards from the public beach, near a patch with dominant *Nuphar x intermedia* at a depth of 0.6 m. In the southern part of the lake (southern bay), *Chara fragilis* was a component of a phytocenosis with dominant *Chara tomentosa* at a depth of 1.4 m. Separate single sites were recorded near the eastern shoreline at depths of 0.7 to 0.9 m.

Species: *Chara contraria* (Braun ex Kützing)

Family: *Characeae*

Class: *Charophyceae*

Chara contraria is classified as a vulnerable species (SIEMIŃSKA et al. 2006). In Olecko Wielkie Lake it was found only in the bay near the outflow of the Lega river by the western shoreline, in the central part of the lake (Figure 2 and Figure 4). In the central part of the bay, at a depth of 2.5 m, *Chara contraria* formed a patch with the dominant *Fontinalis antipyretica*, and at a depth of 0.9 m it was found in a phytocenosis with the dominant *Potamogeton lucens*. It also grew near the southern tip of the bay, at a depth of 0.6 m, in a community with the dominant *Fontinalis antipyretica*.

Species: *Nitella flexilis* [(L.) Agardh]

Family: *Characeae*

Class: *Charophyceae*

Nitella flexilis is classified as a vulnerable species (SIEMIŃSKA et al. 2006). In Olecko Wielkie Lake it was recorded only on one site, in the northern part of the lake near a tributary of the Lega river, at depths of 1.0 and 1.2 m, in a community with the dominant *Nuphar lutea* (Figure 3). In a recent Regula-

tion of the Minister of the Environment (O.J. 2014, item 1409) *Nitella flexilis* is listed as a partly protected species.

Species: *Chara tomentosa* (L.)

Family: *Characeae*

Class: *Charophyceae*

According to the Red List of Algae in Poland (SIEMIŃSKA et al. 2006) *Chara tomentosa* is a rare species. Two patches of the *Charetum tomentosae* association were found in Olecko Wielkie Lake (DZIEDZIC and DYNOWSKI 2009). The first patch was identified in the northern part of the lake, in the eastern bay within a swimming sector (Figure 2 and Figure 3). *Chara tomentosa* formed a phytocenosis of the *Charetum tomentosae* association, 180 m² of surface area at depths of 0.7 to 1.4 m. In this part of the lake, near the north-western shoreline, it was found in a patch of the *Nupharo-Nymphaeetum albae* association, at a depth of 0.7 m.

Chara tomentosa also grew in the southern part of the lake (Figure 2 and Figure 5), in the southern bay. It dominated in an area of 228 m², at depths of 0.7 to 1.9 m. Currently, *Chara tomentosa* is under partial protection (O.J. 2014, item 1409).

Species: *Nitellopsis obtusa* (Groves)

Family: *Characeae*

Class: *Charophyceae*

Nitellopsis obtusa is a rare species (SIEMIŃSKA et al. 2006). In the northern part of the surveyed lake it formed a patch of the *Nitellopsidetum obtusae* association at a single site (Figure 2 and Figure 3). This phytocenosis was formed in the eastern bay within the swimming sector, next to a patch of the *Charetum tomentosae* association. *Nitellopsis obtusa* dominated in an area of 100 m² and penetrated the littoral zone at depths of 0.4 to 0.9 m. The recent Regulation of the Minister of the Environment (O.J. 2014, item 1409) established partial protection of this species.

Rare and declining species in Poland

Taxon: *Nuphar x intermedia* [Ledeb.] (= *N x spenneriana* [Gaudin])

Family: *Nymphaeaceae*

Class: *Magnoliopsida* (*Dicotyledones*)

Nuphar x intermedia is a hybrid of *Nuphar pumila* and *Nuphar lutea*, with distinct morphological features (RUTKOWSKI 2011, KŁOSOWSKI 2014). *Nuphar pumila* is a glacial relic, a rare and vulnerable species, listed in the Polish Red Data Book of Vascular Plants (KŁOSOWSKI 2014). *Nuphar lutea* is classified as

a frequent (RUTKOWSKI 2011) or common species (KŁOSOWSKI and KŁOSOWSKI 2012). The most serious threats to the sites of *Nuphar pumila* are posed by the increase in water hardness, but also *Nuphar lutea*, which as a result of cross-breeding produces hybrids and gradually becomes the dominant species (KŁOSOWSKI 2014).

In Olecko Wielkie Lake *Nuphar lutea* and *Nuphar x intermedia* formed distinct plant communities (DZIEDZIC and DYNOWSKI 2009). The presence of this hybrid indicates that *Nuphar pumila* occurred initially in the lake flora. *Nuphar x intermedia* was recorded in the northern and central parts of the lake (Figure 2–4). It formed its own community or separate single sites at depths of 0.4 to 1.8 m. In the northern part of the lake phytocenoses with dominant *Nuphar x intermedia* occupied mainly the western shoreline, and in the central part of the lake the northern part of the eastern shoreline.

Species: *Ceratophyllum submersum* (L.)

Family: *Ceratophyllaceae*

Class: *Magnoliopsida (Dicotyledones)*

Ceratophyllum submersum, with leaves branched dichotomously three times, is considered a rare species, unlike the common *Ceratophyllum demersum*, with leaves branched once or twice or classified as quite frequent in some regions (RUTKOWSKI 2011).

In Olecko Wielkie Lake it was recorded only at a single site, in the northern part of the lake (Figure 2 and Figure 3). *Ceratophyllum submersum*, at a depth of 1.2 m, formed a phytocenosis of the *Nupharo-Nymphaeetum albae* association with the dominant white water lily, in a patch near the mouth of the Lega river.

Species: *Alisma gramineum* (Lej.)

Family: *Alismataceae*

Class: *Liliopsida (Monocotyledones)*

Alisma gramineum, in the Polish Red List of Vascular Plants (ZARZYCKI and SZELĄG 2006), is classified as a vulnerable species.

In Olecko Wielkie Lake it was recorded only on a single site, in the central part of the lake at a depth of 0.6 m, near the southern tip closing the bay near the outflow of the Lega river (Figure 2 and Figure 4).

Species: *Potamogeton praelongus* (Wulfen)

Family: *Potamogetonaceae*

Class: *Liliopsida (Monocotyledones)*

Potamogeton praelongus is found most frequently in north-western Poland, but much less in the Masurian Lake District (ZALEWSKA-GAŁOZ 2008). It has also been reported as a rare and declining species (RUTKOWSKI 2011).

In Olecko Wielkie Lake it was found only on a single site, in the southern part of the lake, in the bay near the western shoreline (Figure 2 and Figure 5), at a depth of 1.4 m next to a *Phragmitetum australis* association.

Changes in the flora of Olecko Wielkie Lake in 1983–2009

The first preliminary floristic surveys of Olecko Wielkie Lake were carried out in 1983 and 1986 (DZIEDZIC 2004 a, b). After over 25 years, changes in the lake flora can be identified in the case of 11 species, of which at 9 species (43% of all species) *in plus* and in 3 (11% of all species) *in minus*, with the specification of declined and vulnerable species (Table 4).

Table 4
Registry of hydrophytes species found in the years 1983–1986 and in 2009 in Olecko Wielkie Lake

Species		1983–1986		2009	
		occurrence	creating community	occurrence	creating community
<i>Charophyta</i>	<i>Chara globularis</i>	+	+	+	–
	<i>Chara rudis</i>	+	+	–	–
	<i>Chara contraria</i>	+	+	+	–
	<i>Nitellopsis obtusa</i>	+	+	+	+
	<i>Chara tomentosa</i>	–	–	+	+
<i>Bryophyta</i>	<i>Fontinalis antipyretica</i>	+	+	+	+
	<i>Eurhynchium riparioides</i>	+	+	–	–
<i>Magnoliopsida</i>	<i>Batrachium circinatum</i>	+	+	+	+
	<i>Nuphar lutea</i>	+	+	+	+
	<i>Nuphar x intermedia</i>	–	–	+	+
	<i>Nymphaea alba</i>	–	–	+	+
	<i>Elodea canadensis</i>	+	+	+	–
	<i>Ceratophyllum demersum</i>	+	+	+	+
	<i>Ceratophyllum submersum</i>	–	–	+	–
	<i>Myriophyllum spicatum</i>	+	+	+	+
	<i>Polygonum amphibium</i> f. <i>natans</i>	+	+	+	–
<i>Utricularia vulgaris</i>	–	–	+	–	
<i>Liliopsida</i>	<i>Potamogeton pectinatus</i>	+	+	+	+
	<i>Potamogeton lucens</i>	+	+	+	+
	<i>Potamogeton crispus</i>	–	–	+	+
	<i>Potamogeton perfoliatus</i>	+	+	+	+
	<i>Potamogeton friesii</i>	+	+	–	–
	<i>Potamogeton trichoides</i>	+	–	–	–
	<i>Potamogeton praelongus</i>	–	–	+	+
	<i>Stratiotes aloides</i>	–	–	+	+
	<i>Lemna minor</i>	+	–	+	–
	<i>Lemnatisulca</i>	+	–	+	–
	<i>Eleocharis acicularis</i>	–	–	+	+
	<i>Alisma gramineum</i>	+	–	+	–

+ the occurrence of a species or communities, – no occurrence of a species or communities

Declined species are represented by:

Species: *Chara rudis* [(Braun) von Leonhardi]

Family: *Characeae*

Class: *Charophyceae*

Chara rudis is classified as a vulnerable species (SIEMIŃSKA et al. 2006). In the past, a single patch of plant association formed by *Charetum rudis* was found in the southern part of the lake, near the eastern shoreline, in its southern part, northwards from the southern tip. The community with the dominant *Chara rudis* covered an area of 75 m² at depths of 0.5 to 0.8 m (DZIEDZIC 2004 a, b). In 2009, this species has not been found. The recent Regulation of the Minister of the Environment (O.J. 2014, item 1409) established strict protection of this species.

Species: *Eurhynchium riparioides* [(Hedw.) Richards] [= *Platyhypnidium rusciforme* (Fleisch.)]

Family: *Brachytheciaceae*

Class: *Bryopsida*

Subdivision: *Bryophytina*

Eurhynchium riparioides is an aquatic moss that used to form a small 10 m² patch of the *Platyhypnidietum rusciformis* association at depths of 3.0 to 3.5 m in the northern part of the lake, near the northern shoreline, in the south-western bay (DZIEDZIC 2004 a, b). This species was not identified during our study.

Species: *Potamogeton trichoides* (Cham. et Schlttdl.)

Family: *Potamogetonaceae*

Class: *Liliopsida* (*Monocotyledones*)

The hairlike pondweed used to form phytocenoses of three associations: *Potametum pectinati* with the dominant *Potamogeton pectinatus*; *Ranunculetum circinati* with the dominant *Batrachium circinatum*, and *Potametum perfoliati* with the dominant *Potamogeton perfoliatus*. In 2009, the patches of these associations do not include *Potamogeton trichoides* (DZIEDZIC and DYNOWSKI 2009), which is considered a rare and declining species (RUTKOWSKI 2011), with very few sites in the Masurian Lake District reported (ZALEWSKA-GAŁOŚZ 2008).

Plants for which single sites were identified in Olecko Wielkie Lake are considered vulnerable species. These include *Nitella flexilis*, *Ceratophyllum submersum*, *Alisma gramineum* and *Potamogeton praelongus*.

Studies carried out in 2009 revealed the occurrence of several taxa which had not been previously reported from Olecko Wielkie Lake. These include *Chara tomentosa*, *Nuphar x intermediata*, *Nymphaea alba*, *Potamogeton crispus*, *Potamogeton praelongus*, *Stratiotes aloides* and *Eleocharis acicularis*.

The reason of decline of some plant species could be a change in the trophic state of the lake. It is known, after the 1950s degradation occurred in many urban lakes. This mainly resulted from the direct or indirect discharge of communal and industrial wastewater (CIECIERSKA 2000, RÓŻAŃSKI et al. 2004, LOSSOW et al. 2005, SUTELA et al. 2013, JUSIK and MACIOŁ 2014). The increasing trophic state and decreasing transparency of lake water resulted in transformation of plant communities, mainly reflected in the shrinking distribution range of hydrophytes. Within this group of plants, the share of *Potamogeton* spp. was increasing, with a decreasing share of *Characeae* species (CIECIERSKA 2000).

In the early 1950s Olecko Wielkie Lake was classified as an α -mesotrophic reservoir, with about a 20% oxygen level measured above the bottom. Water transparency, measured on 16 September 1951, was 3.5 m (OLSZEWSKI and PASCHALSKI 1959). In 1987 the water purity was between the second and third class. Water tests in 1996 revealed that the lake had water purity of the third class. In 1996, a slight deterioration in the quality of the lake water probably resulted from unfavourable weather conditions (IMIELSKI and KOZARKIEWICZ 1997). A wastewater treatment plant, put into operation in 1995, contributed to an improvement in the quality of the lake water, but further actions of public authorities with a focus on environmental policy within the catchment area of Olecko Wielkie Lake are still needed (RÓŻAŃSKI et al. 2004).

The results allow us to conclude that over the last 50 years the Olecko Wielkie Lake was converted from α -mesotrophic type to strongly eutrophic type. Increasing human pressure on the reservoir through the development of a residential and tourist infrastructure directly on the banks undoubtedly contributed to this fact. Changes in the scope of occurrence, appearance and disappearance of macrophyte species presented in this article indicates intensively occurring processes of change of trophic status of the lake water. For this reason, it is advisable to increase the frequency of the surveys the ecological status of the lake for the purposes of monitoring, using all elements of the assessment, in accordance with the Water Framework Directive. This activity will enable the identification of a number of existing threats to the lake and will allow take appropriate measures to protect this reservoir.

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