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# Resources of *Nuphar lutea* (L.) Sibth. & Sm. in mid-eastern Poland as a potential source of herbal raw material

Zasoby *Nuphar lutea* (L.) Sibth. & Sm. w Polsce środkowowschodniej jako potencjalne źródło surowca zielarskiego

**Summary.** The aim of this study was to characterize the phytocoenoses with a share of *Nuphar lutea* (L.) Sibth. & Sm. and to evaluate the area of patches of *Nupharo-Nymphaeetum albae* Tomaszewicz 1977 as well as resources of the yellow water lily that can be used as a source of valuable medicinal raw material. The field investigations were carried out in the summer seasons of 2009–2018, and fifty-eight lakes were included in this study. *Nuphar lutea* is a very interesting plant species due to considerable concentration of secondary metabolites and their biological activity. Therefore, under conditions of eastern Poland, it can be a valuable raw material for pharmaceutical purposes. The largest *Nupharo-Nymphaeetum albae* phytocoenoses with *N. lutea* as the main floristic component are localized especially in retention reservoirs connected with the Wieprz-Krzna Canal and other lakes of a natural character. They are often very shallow basins. Therefore, removal of a biomass, especially in the case of small lakes that overgrow at a very rapid rate, can significantly slow down their shallowing and they will remain and function in the landscape over a longer time. Harvesting the *N. lutea* leaves can decelerate the process of shallowing of water bodies, especially in the case of retention reservoirs, and may contribute to their better functioning. Collected raw material can be a source of valuable secondary metabolites suitable for the pharmaceutical industry.

**Key words:** *Nuphar lutea*, *Nupharo-Nymphaeetum albae*, raw material, secondary metabolites, biological activity, Łęczna-Włodawa Lake District

## INTRODUCTION

Macrophytes serve some important functions in water ecosystems i.e. in preserving the clear water state [Scheffer and Nes 2007]. Many aquatic plant species can reduce the growth of cyanobacteria by producing active substances that inhibit phytoplankton photosynthesis or suppress algal growth, consequently lowering phytoplankton biomass. This process is known as allelopathy, and a great number of allelopathic interactions between macrophytes and phytoplankton have been described [Gross 2003, Erhard and Gross 2006, Zhu et al. 2020]. Aquatic allelochemicals have been identified in some aquatic plants. They exhibit a broad spectrum of different chemical characteristics and often target multiple physiological processes [Gross 2003]. The biological activities of the secondary metabolites of aquatic macrophytes suggest that some of these compounds seem to be involved in chemical defense of plants against pathogens and herbivorous invertebrates and fishes [Cespedes et al. 2015]. They include sulfur compounds, fatty acid derivatives, polyacetylenes, and polyphenols [Gross 2003].

Aquatic plants have many unique biological features and potential agricultural, nutraceutical, and medicinal importance. Many plant species of aquatic origin are extensively used in traditional medicine, and various investigations have been done to investigate their bioactivity and their phytochemical constituents [Yildirim et al. 2012, Zhang et al. 2014, Khan et al. 2018]. Literature reviews have revealed different pharmacological activities of aquatic species, including antimicrobial, antidiabetic, antiprotozoal, antioxidant, cytotoxic, and anti-proliferative effects. Aquatic herbs are traditionally used for the treatment of injuries, snakebites, jaundice, dysentery, convulsion etc. and as a constituent of well-known ayurvedic drug formulations, e.g. Tagara [Khan et al. 2018].

*Nuphar* is a genus of aquatic plants belonging to the family Nymphaeaceae. It comprises at least 18 species [The Plant List 2013] occurring in the northern hemisphere. It is most diverse in North America but less widely represented in Europe and Asia. There are two species in Poland – the yellow water lily *Nuphar lutea* (L.) Sibth. & Sm. and the small water lily *Nuphar pumila* (Timm) DC. [Mirek et al. 2002]. Natural products of *N. lutea* have been widely used for treating inflammatory conditions in ethnic medicine. The aboriginal peoples of the Canadian boreal forest used *N. lutea* extracts for medicinal purposes [Uprety et al. 2016]. Leaf extracts of this species were used against rheumatism [El Beyrouthy et al. 2008], and a herbal mixture with *Nuphar* rhizome powder was used to treat swelling and pain in traditional Japanese medicine [Nakae et al. 2012]. A systematic review of early studies has revealed that the full therapeutic potential of *Nuphar* products is still largely unexplored by modern research [Padgett 2007]. Nevertheless, recent reports on the medicinal properties of *Nuphar* extracts have indicated potential applications as antibacterial [Turker et al. 2009, Yildirim et al. 2012], anti-viral [Winer et al. 2020], anti-inflammatory [Ozer et al. 2015], anticancer [Matsuda et al. 2006, Yildirim et al. 2012], and anti-metastatic properties [Ozer et al. 2017].

The yellow water lily is the only species from the Nymphaeaceae family that is not subject to legal protection. This submerged perennial macrophyte consists of rhizomes and roots under water and floating leaves holding floating flowers above the water surface. This diploid species is pollinated by bees and flies, with frequent reproduction by rhizomes [Padgett 2007]. *Nuphar lutea* in Poland occurs mainly in lowland areas, where it is a common plant. It grows at a depth of 50 to 200 cm in water bodies and river waters that are abundant in organic substances and in places with a sandy-silty or muddy bottom of the riverbed [Szoszkiewicz et al. 2010]. The yellow water lily is a permanent component of the *Nupharo-Nymphaeetum albae* Tomaszewicz 1977 phytocoenoses, which are commonly found in various types of water bodies, and is very common in the water bodies of central-eastern Poland [Sugier et al. 2010]. It is placed on the European Red List of Medicinal Plants with the Least Concern category [Allen et al. 2014] but not on the list of pharmacopoeial species. Nevertheless, as mentioned above, *N. lutea* is a source of many valuable secondary metabolites characterized by diverse biological activities that can be used by humans, especially as natural products and their derivatives are important sources of novel therapeutic molecules [Clardy and Walsh 2004]. Therefore, the aim of this study is to characterize phytocoenoses with a share of *N. lutea* and to evaluate the area of patches of *Nupharo-Nymphaeetum albae* and resources of *N. lutea* as a raw material, which can be used in Poland. The paper presents *N. lutea* resources to highlight the importance of Nymphaeaceae plant species as a source of valuable medicinal raw material.

## MATERIALS AND METHODS

### Site description

This study is based on our own field investigation conducted in the Łęczna--Włodawa Lake District and Pagóry Chełmskie located in mid-eastern Poland. The area belongs to the Polesie Zachodnie sub-region [Kondracki 2002]. The lakes constitute of a group of Polish lakes located outside the extent of the last glaciation [Wilgat 1954]. The processes of ground-ice melting (thermokarst) and karst phenomena contributed to the formation of lake basins [Harasimiuk and Wojtanowicz 1998]. The studied lake group includes both polymictic and dimictic reservoirs. The polymictic lakes are eutrophic, while the dimictic ones are both eutrophic and mesotrophic. Some of them were transformed into retention reservoirs connected with the Wieprz-Krzna Canal. The oxbow lakes located in the Bug River Valley are another specific group of the studied lakes.

### Sampling method

The field investigations were carried out in the summer seasons of 2009-2018, and fifty-eight lakes were surveyed in this study. All lakes located in protected areas (Poleski National Park, reserves) were excluded. Such lakes as Biesiadki, Karaśne near Urszulin, Laskie, Orzechówek, and Maczółki were also excluded from the analyses due to shallowing and total overgrowth by vegetation. The occurrence of aquatic plant communities and aquatic plants was analyzed. Macrophytes were searched from an anchored boat or pontoon. The range limits of macrophyte plant communities in each lake were established along transects using a GPS device to record the location. The number of transects (from 6 to 42) was correlated with the area of a given lake and depended on the degree of the structural-spatial plant diversity. Additionally, bathymetric maps, aerial photographs, and satellite photomaps were used for preparation of vegetation maps. This paper present only the area of *Nupharo-Nymphaeetum albae* patches. The macrophyte vegetation was studied with the use of the commonly applied mid-European phytosociological method, which is based on phytosociological data recorded from representative patches of vegetation by means of phytosociological relevés [Braun-Blanquet 1964]. Phytosociological relevés (62) representing *Nupharo-Nymphaeetum albae* phytocoenoses were made using an eleven-degree scale, with + symbol for species coverage less than 5%, 1 – for coverage of 5–10%, 2 – for 11–20%, …, 10 – for 91–100%.

### Cartographic and statistical analysis

For each lake, the vegetation map was made and the area of the *Nupharo--Nymphaeetum albae* patches was calculated using the ArcMap 10.1 programme. The percent share of the *Nupharo-Nymphaeetum albae* association was calculated. The lake areas were taken from publications by Michalczyk et al. [1998] and Dawidek and Turczyński [2006]. The variation of the phytosociological relevés with lake characteristics as response variables and the variation of the studied lakes were explored using Principal Component Analysis (PCA) [Jongman et al. 1987]. The PCA analyses were conducted using MVSP [Kovach 1999].

## RESULTS

The *Nupharo-Nymphaeetum albae* association is represented mainly by two and three layers of plant communities, with floating leaf plants and varying proportions of submerged species, and sometimes with helophytes. The coverage and frequency of plant species registered in the 62 phytosociological relevés in the *Nupharo--Nymphaeetum albae* phytocoenoses are presented in table 1. The coverage of the dominant plant species in the studied phytocoenoses varied from 40 to 80% with a mean value of 55% in the case of *N. lutea* and from 5 to 50% with a mean value of 26% in the case of *Nymphaea alba* L. A majority of the *Nupharo-Nymphaeetum albae* phytocoenoses were dominated by *N. lutea* and *N. alba*; however, some of the analyzed communities were also characterized by quite high frequency of elodeids: *Ceratophyllum demersum* L. s. s. (38.7%) and *Potamogeton lucens* L. (35.5%) and lemnids: *Lemna minor* L. (59.7%), *L. trisulca* L. (51.6%), *Spirodela polyrhiza* (L.) Schleid (29%), and *Hydrocharis morsus-ranae* L. (38.7%).

The specific appearance of the phytocoenoses of this community is ascribed to the abundance of the characteristic species *N. lutea* and *N. alba*, as evidenced by the close location of most points in the phytosociological relevés along vectors representing these two species (Fig. 1). However, the opposite direction of the vectors indicates that an increase in the coverage of individuals of one species results in a decrease in the coverage of individuals of another species.

The largest area of the *Nupharo-Nymphaeetum albae* patches was shown in Lake Wytyckie – 374990 $m^2$ (Tab. 2, Fig. 2). It is several times larger than that in the other water bodies. Lakes with a ca. 4–6 ha area of *Nupharo-Nymphaeetum albae* were represented by Ciesacin (60800 $m^2$), Białe Sosnowickie (44888 $m^2$), and Skomielno (66750 $m^2$). The next lake group with a *Nupharo-Nymphaeetum albae* area in the range of ca. 2–3 ha comprised Łukcze (28815 $m^2$), Dubeczyńskie (21692 $m^2$), Głębokie Cycowskie (23712 $m^2$), Uchańka (21280 $m^2$), and Wilgocha (20894 $m^2$). *Nupharo-Nymphaeetum albae* phytocoenoses with an area between 1 and 2 ha were noted in Czarne Uścimowskie (19344 $m^2$), Czarne Włodawskie (19116 $m^2$), Ściegienne (19454 $m^2$), Płotycze (16748 $m^2$), Cycowe (14577 $m^2$), Hańskie (12528 $m^2$), Wola Uhruska (11083 $m^2$), and Tomaszne (10260 $m^2$) (Tab. 2).

Table 1. Coverage (mean, min value, max value) and frequency (F) of particular plant species registered in 62 phytosociological relevés in *Npharo-Nymphaeetum albae* phytocoenoses

| Plant species | Mean | Min | Max | F | Plant species | Mean | Min | Max | F |
|---|---|---|---|---|---|---|---|---|---|
| *Aldrovanda vesiculosa* | 0.5 | 0.5 | 0.5 | 1.6 | *Nuphar lutea* | 5.5 | 4.0 | 8.0 | 100.0 |
| *Batrachium circinatum* | 0.8 | 0.5 | 1.0 | 9.7 | *Nymphaea alba* | 2.6 | 0.5 | 5.0 | 90.3 |
| *Bidens tripartita* | 0.5 | 0.5 | 0.5 | 3.2 | *Oenanthe aquatica* | 0.5 | 0.5 | 0.5 | 8.1 |
| *Carex rostrata* | 0.5 | 0.5 | 0.5 | 1.6 | *Phalaris arundinacea* | 0.5 | 0.5 | 0.5 | 1.6 |
| *Ceratophyllum demersum* | 1.5 | 0.5 | 4.0 | 38.7 | *Phragmites australis* | 0.6 | 0.5 | 1.0 | 12.9 |
| *Chara globularis* | 0.5 | 0.5 | 0.5 | 1.6 | *Polygonum amphibium* | 0.5 | 0.5 | 0.5 | 3.2 |
| *Chara intermedia* | 0.5 | 0.5 | 0.5 | 9.7 | *Potamogeton crispus* | 0.5 | 0.5 | 0.5 | 4.8 |
| *Chara vulgaris* | 0.5 | 0.5 | 0.5 | 1.6 | *Potamogeton lucens* | 1.2 | 0.5 | 3.0 | 35.5 |
| *Elodea canadensis* | 0.7 | 0.5 | 1.0 | 21.0 | *Potamogeton natans* | 1.4 | 0.5 | 3.0 | 21.0 |
| *Equisetum fluviatile* | 0.6 | 0.5 | 1.0 | 6.5 | *Potamogeton pectinatus* | 0.5 | 0.5 | 0.5 | 6.5 |
| *Fontinalis antipyretica* | 0.5 | 0.5 | 0.5 | 3.2 | *Potamogeton perfoliatus* | 1.0 | 1.0 | 1.0 | 3.2 |
| *Glyceria maxima* | 0.6 | 0.5 | 1.0 | 6.5 | *Potamogeton compressus* | 0.8 | 0.5 | 1.0 | 3.2 |
| *Hydrocharis morsus-ranae* | 1.2 | 0.5 | 3.0 | 38.7 | *Rorippa amphibia* | 0.5 | 0.5 | 0.5 | 11.3 |
| *Lemna gibba* | 0.8 | 0.5 | 1.0 | 3.2 | *Rumex hydrolapathum* | 0.5 | 0.5 | 0.5 | 3.2 |
| *Lemna minor* | 1.0 | 0.5 | 4.0 | 59.7 | *Sagittaria sagittifolia* | 0.6 | 0.5 | 1.0 | 11.3 |
| *Lemna trisulca* | 1.6 | 0.5 | 4.0 | 51.6 | *Schoenoplectus lacustris* | 0.5 | 0.5 | 0.5 | 3.2 |
| *Lychnothamnus barbatus* | 1.0 | 1.0 | 1.0 | 1.6 | *Sium latifolium* | 0.5 | 0.5 | 0.5 | 1.6 |
| *Mentha aquatica* | 0.7 | 0.5 | 1.0 | 4.8 | *Sparganium erectum* | 0.5 | 0.5 | 0.5 | 8.1 |
| *Myriophyllum spicatum* | 1.0 | 0.5 | 4.0 | 16.1 | *Spirodela polyrhiza* | 1.2 | 0.5 | 3.0 | 29.0 |
| *Myriophyllum verticillatum* | 1.1 | 0.5 | 3.0 | 12.9 | *Stratiotes aloides* | 1.0 | 0.5 | 3.0 | 27.4 |
| *Najas minor* | 0.5 | 0.5 | 0.5 | 3.2 | *Typha angustifolia* | 0.7 | 0.5 | 1.0 | 9.7 |
| *Nitellopsis obtusa* | 0.5 | 0.5 | 0.5 | 6.5 | *Utricularia vulgaris* | 0.8 | 0.5 | 3.0 | 14.5 |

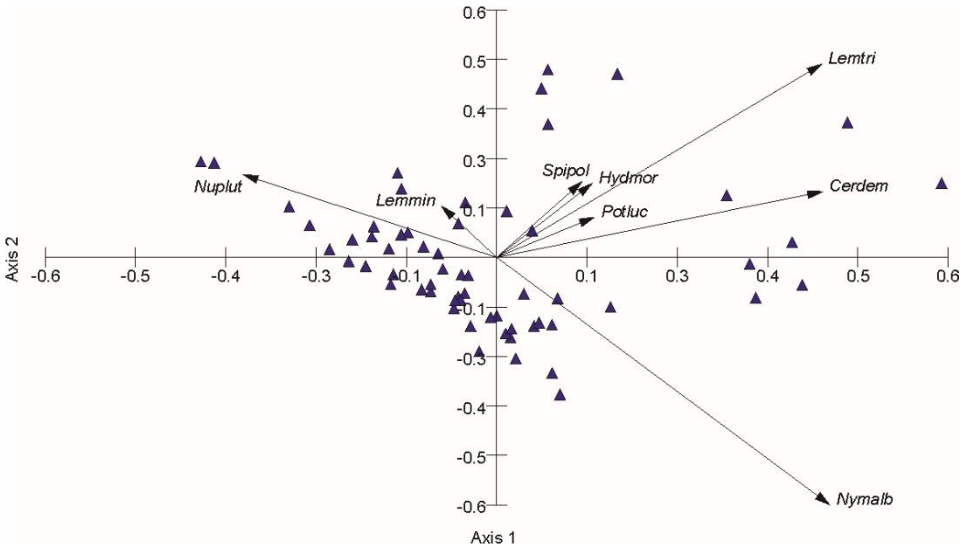


Fig. 1. PCA ordination diagram of the studied *Nupharo-Nymphaeetum albae* phytocoenoses on the basis of phytosociological relevés; Nuplut – *Nuphar lutea*, Nymalb – *Nymphaea alba*, Lemmin – *Lemna minor*, Spipol – *Spirodela polyrhiza*, Hydmor – *Hydrocharis morsus-ranae*, Potluc – *Potamogeton lucens*, Lemtri – *Lemna trisulca*, Cerdem – *Ceratophyllum demersum*

On the right side of the PCA diagram ordination space (Fig. 2), there is a group lakes characterized by a very high percent share of NNA, i.e. Lake Ciesacin (79.5%) Uchańka (60.8%), Hańskie (43.2%), Wilgocha (33.7%), Lubowierz (33.5%), and Wola Uhruska (26.2%). In turn, the bottom left side of the PCA diagram presents a group of lakes characterized by a very small *Nupharo-Nymphaeetum albae* area and those devoid of phytocoenoses of this type (Dratów, Krzczeń, Mytycze, Syczyńskie, Rogóźno Włodawskie, Piaseczno, Orzechówek, Maśluchowskie).

## DISCUSSION

The *Nupharo-Nymphaeetum albae* phytocoenoses are common in Polish lakes. The optimum development of this plant community is observed in shallow eutrophic lakes, oxbow lakes with organic sediments, and in various artificial reservoirs. These phytocoenoses can also be found in mesotrophic and even dystrophic waters. The bottom in these reservoirs is different – from purely mineral to extremely peaty. The depth of water varies greatly but does not exceed 2 m in most phytocoenoses [Lorens and Sugier 2000, 2001, Lorens 2006, Sugier et al. 2010, Szoszkiewicz et al. 2010, Jabłońska and Kłosowski 2012]. The physiognomy and floristic composition of the studied plant communities is similar to phytocoenoses of this type described from other regions of Poland [Kłosowski and Tomaszewicz 1989, Tomaszewicz and Ciecierska 2009, Jabłońska and Kłosowski 2012]. During eutrophication, emergent macrophytes, especially those in shallow lakes, are less sensitive to changes in habitat conditions than submerged species

Table 2. Characteristics of the studied lakes; A – natural lakes used for recreation and fishing, B – lakes transformed into retention reservoirs connected with the Wieprz-Krzna Canal, C – oxbow lakes located in the Bug River Valley; NNA – *Nupharo-Nymphaeetum albae* phytocoenoses

| Group of lakes | Lakes | Lake area (ha) | NNA area ($m^2$) | Share of NNA in the lake area (%) |
|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* |
| A | Bialskie | 31.7 | 317 | 0.1 |
| | Białe Włodawskie | 106.4 | 745 | 0.1 |
| | Białe Sosnowickie | 144.8 | 44888 | 3.1 |
| | Bikcze | 85 | 850 | 0.1 |
| | Ciesacin | 7.6 | 60420 | 79.5 |
| | Cycowe | 11.3 | 14577 | 12.9 |
| | Czarne Gościnieckie | 11.6 | 116 | 0.1 |
| | Czarne Sosnowickie | 38.8 | 6208 | 1.6 |
| | Czarne Uścimowskie | 24.8 | 19344 | 7.8 |
| | Czarne Włodawskie | 23.6 | 19116 | 8.1 |
| | Dubeczyńskie | 11.6 | 21692 | 18.7 |
| | Glinki | 46.9 | 14539 | 3.1 |
| | Głębokie Cycowskie | 11.4 | 23712 | 20.8 |
| | Głębokie Uścimowskie | 20.5 | 7790 | 3.8 |
| | Gumienek | 8.1 | 6237 | 7.7 |
| | Gumienko | 4.5 | 1305 | 2.9 |
| | Hańskie | 2.9 | 12528 | 43.2 |
| | Kleszczów | 53.9 | 11319 | 2.1 |
| | Krasne | 75.9 | 911 | 0.1 |
| | Lipiniec | 4.1 | 5576 | 13.6 |
| | Lubowierz | 2.7 | 9045 | 33.5 |
| | Łukcze | 56.5 | 28815 | 5.1 |
| | Łukietek | 3.5 | 1330 | 3.8 |
| | Maśluchowskie | 26.7 | 0 | 0 |
| | Miejskie | 45.3 | 45 | <0.1 |
| | Nadrybie | 46.8 | 2340 | 0.5 |
| | Orzechówek | 6.3 | 0 | 0 |
| | Piaseczno | 84.7 | 0 | 0 |
| | Płotycze | 10.6 | 16748 | 15.8 |
| | Rogóźno | 57.1 | 286 | <0.1 |
| | Rogóźno near Włodawa | 2.5 | 0 | 0 |
| | Rotcze | 42.7 | 939 | 0.2 |
| | Sumin | 91.5 | 915 | 0.1 |
| | Ściegienne | 27.4 | 19454 | 7.1 |
| | Święte | 5.7 | 171 | 0.3 |
| | Turowolskie | 3.1 | 62 | 0.2 |
| | Uścimowskie | 66.7 | 8671 | 1.3 |
| | Uściwierz | 284.1 | 5682 | 0.2 |
| | Zagłębocze | 59.0 | 3540 | 0.6 |

| *1* | *2* | *3* | *4* | *5* |
|---|---|---|---|---|
| A | Zienkowskie | 7.6 | 5776 | 7.6 |
| | Pniówno | 7.7 | 15 | <0.1 |
| | Syczyńskie | 6.0 | 0 | 0 |
| | Słone | 4.6 | 14 | <0.1 |
| | Tarnowskie | 2.2 | 29 | 0.1 |
| | Wereszczyńskie | 5.2 | 52 | 0.1 |
| B | Dratów | 107 | 0 | 0 |
| | Krzczeń | 175 | 0 | 0 |
| | Mytycze | 202.3 | 0 | 0 |
| | Skomielno | 75 | 66750 | 8.9 |
| | Tomaszne | 85.5 | 10260 | 1.2 |
| | Wytyckie | 487 | 374990 | 7.7 |
| C | Bawole Rogi | 2.36 | 24 | 0.1 |
| | Hniszów | 0.28 | 566 | 20.2 |
| | Jama Roma | 2.68 | 27 | 0.1 |
| | Orchówek | 8.17 | 82 | 0.1 |
| | Uchańka | 3.5 | 21280 | 60.8 |
| | Wilgocha | 6.2 | 20894 | 33.7 |
| | Wola Uhruska | 4.23 | 11083 | 26.2 |

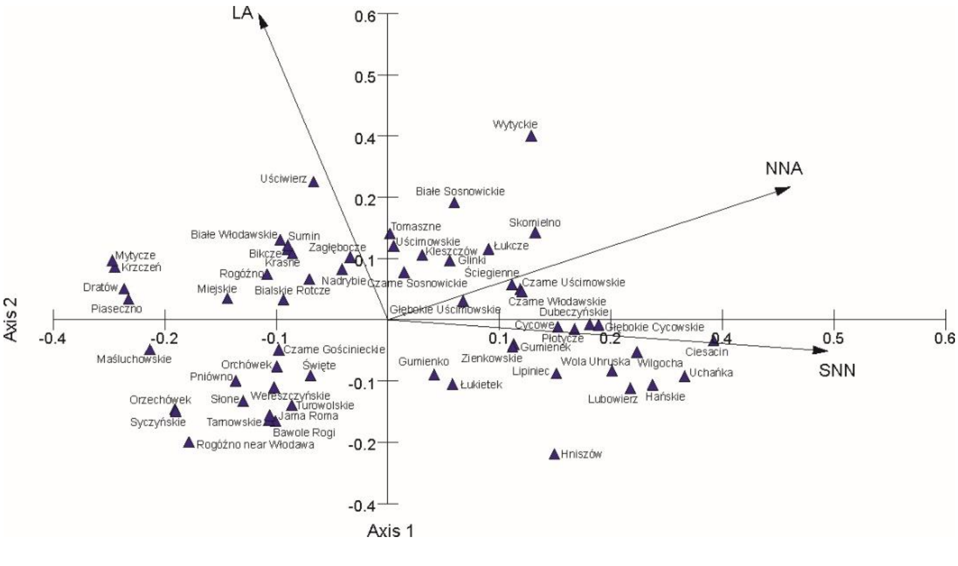


Fig. 2. PCA ordination diagram of the studied lakes; LA – lake area,
NNA – the area of *Nupharo-Nymphaeetum albae* phytocoenoses,
SNN – share of *Nupharo-Nymphaeetum albae* phytocoenoses in the lake area

[Scheffer and van Nes 2007]. The *Nuphar lutea* nympheid is a dominant macrophyte in a large number of the lakes of the Łęczna-Włodawa Lake District and other shallow waters in Poland [Lorens and Sugier 2000, 2001, Lorens 2006, Sugier et al. 2010, Szoszkiewicz et al. 2010]. This is also shown in the results of our study presented in this paper.

Especially in shallow and small lakes, vascular plants are major producers of organic matter, contributing to an increase in bottom sediments in lakes [Bernatowicz and Radziej 1960, Choiński 2010]. Lawniczak-Malińska et al. [2018] analyzed 20 lakes and showed that such parameters as the rate of shallowing of the lakes, their depth, and changes in the water volume were most strongly correlated with the share of macrophytes in the lakes. This indicates that the emergent macrophytes produced and deposited biomass and had an impact on shallowing and overgrowing of the lakes. The processes of organogenic accumulation lead to the successive filling of the lake basins, which has recently resulted in a drastic reduction in the surface of many lakes in the Łęczna-Włodawa Lake District: Laskie, Biesiadki, Maczółki, Uściwierzek, and Karaśne near Urszulin. As shown in our study, a significant increase in the area of *Nupharo-Nymphaeetum albae* phytocoenoses with dominance of *N. lutea* was found in many of them, e.g. Nadrybie, Hańskie, Skomielno, Wspólne, Ciesacin, or Księżowskie.

*Nuphar lutea* is a structuring factor for macrozoobenthos and selected abiotic parameters of water and bottom sediments [Zbikowski et al. 2010]. The floating leaf blades of water lilies fulfill several functions in wetland ecosystems via production, decomposition, and turnover as well as exchange processes [Kok et al. 1990, Klok and Van der Velde 2017]. *Nuphar lutea* plants can produce from 108 to 447 g of ash-free dry weight per $m^2$ [Klok and Van der Velde 2017]. Taking into account only the minimum value, the production of ash-free dry weight during one year in the case of lakes Wytyckie can be over 40 tons, Skomielno (over 7 tons), Ciesacin (over 6 tons), Białe Sosnowickie (over 4 tons), and Łukcze (over 3 tons), and over 2 tons in the case of lakes Czarne Uścimowskie, Czarne Włodawskie, Dubeczyńskie, Głębokie, Cycowskie, and Ściegienne.

In the littoral zonation of lakes, water lilies usually grow between submerged macrophytes and helophytes. In turn, they can cover large areas in shallow freshwater lakes [Zbikowski et al. 2010]. Good examples in the present study are lakes, where the *Nupharo-Nymphaeetum albae* patches significantly fill the water table: Ciesacin (79.5%), Uchańka (60.8%), Hańskie (43.2%), Wilgocha (33.7%), Lubowierz (33.5%), Wola Uhruska (26.2%), and Dubeczyńskie (18.7%) (Tab. 2). These water bodies are very shallow, with a mean depth of 0.49–1.3 m [Michalczyk et al. 1998, Dawidek and Turczyński 2006]. Therefore, in the near future, very rapid terrestrialization of the lakes is inevitable. In this situation, removal of macrophyte biomass is reasonable. Sediment dredging in shallow lakes has been used for many years worldwide as an important eco-environmental engineering method to remove surface sediments permanently from aquatic ecosystems [Peterson 1982, Yu et al. 2015] and is considered an effective approach to aquatic ecosystem restoration [Jing et al. 2019]. This is very important in the context of overgrowing of the lakes in the Łęczna-Włodawa Lake District, and disappearance in last decades of some water bodies. The extraction of *Nuphar* leaves as a valuable source of secondary metabolites can slow down the production of sediments and exclude the necessity to use this eco-environmental engineering method to remove sediments for a long time.

In this paper, we focused our attention on the lakes, but *N. lutea* is very common in habitats of agricultural landscape such as fishponds, reservoirs, channels, and peat pits [Kwiatkowska-Farbiś and Wrzesień 1996, Falkowski and Nowicka-Falkowska 2006, Sugier 2014, Bryl et al. 2016]. For proper functioning, these objects are very often conserved by mowing of vegetation and removal of sediments. In such cases, all parts of *N. lutea* plants can be collected as a raw material for the pharmaceutical industry.

Recently, medicinal plant products have gained great importance, as they can be used as natural products in medicine. In Europe, with its long tradition in the use of botanicals, about 2,000 medicinal and aromatic plant species are used on a commercial basis [Lange 1998]. However, aquatic plants containing biologically active substances are often marginalized and are not as popular as for example in Asia [Khan and Sultana 2005, Matsuda et al. 2006], where several plant organs of the yellow water lily have been used in traditional medicine for treatment of arthritis, fever, aches, pains, and inflammation for many decades [Ozer et al. 2009]. The arguments presented in this paper, i.e. the presence of secondary metabolites with high value for humans as well as the easy access to the raw material, support the use of *N. lutea* leaves as a valuable source of raw material suitable for use in the pharmaceutical industry.

## CONCLUSIONS

The yellow water lily is a very interesting plant species due to the concentration of secondary metabolites and their biological activity. Therefore, in the conditions of eastern Poland, it can be a valuable raw material used in pharmacy. The *Nupharo-Nymphaeetum albae* phytocoenoses are the most abundant resources of *N. lutea*, and their large areas are localized especially in retention reservoirs connected with the Wieprz-Krzna Canal network and shallowing lakes. Taking the above into account, the extraction of *N. lutea* leaves can provide valuable secondary metabolites that can be used in the pharmaceutical industry. In turn, removal of biomass, especially in the case of small lakes that overgrow at a very rapid rate, can significantly slow down their terrestrialization and save their function in the landscape over a longer time. Harvesting *N. lutea* plant biomass can decelerate the process of shallowing of retention reservoirs and may contribute to their better function. The use of *Nuphar* leaves should be sustainable, without a negative influence on the plants, habitat quality, ecological processes, and landscape values of the lakes, taking into account their actual protection state as well. During raw material collection, considerable attention should be paid to the availability and quantity of harvested material and harvest time.

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**Streszczenie.** Celem pracy było scharakteryzowanie fitocenoz *Nupharo-Nymphaeetum albae* oraz ocena powierzchni ich płatów, a także zasobów gatunku *N. lutea*, który może stanowić źródło cennego surowca leczniczego. Badania terenowe przeprowadzono na pięćdziesięciu ośmiu jeziorach, w sezonach letnich 2009–2018. Grążel żółty jest bardzo interesującą rośliną z punktu widzenia zawartości metabolitów wtórnych oraz ich aktywności biologicznej, dlatego w warunkach Polski Wschodniej może być cennym surowcem wykorzystywanym w przemyśle farmaceutycznym. *Nuphar lutea* jest zdecydowanym dominantem w fitocenozach *Nupharo-Nymphaeetum albae*, a duże ich powierzchnie zlokalizowane są zwłaszcza w zbiornikach retencyjnych połączonych z Kanałem Wieprz-Krzna oraz w innych jeziorach o charakterze naturalnym. Duże areały badanych fitocenoz bardzo często występują w płytkich zbiornikach, zatem usunięcie biomasy, szczególnie w przypadku małych jezior, które zarastają w bardzo szybkim tempie, może znacznie spowolnić ich wypłycanie, dzięki czemu mogą pozostać i funkcjonować w krajobrazie przez dłuższy czas. Usuwanie liści *N. lutea*, może spowolnić proces wypłycania zbiorników retencyjnych i przyczynić się do ich lepszego funkcjonowania, a jednocześnie mogą one być źródłem cennego surowca zielarskiego, wykorzystywanego w przemyśle farmaceutycznym.

**Słowa kluczowe:** *Nuphar lutea*, *Nupharo-Nymphaeetum albae*, surowiec zielarski, metabolity wtórne, aktywność biologiczna, Pojezierze Łęczyńsko-Włodawskie

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