ABSTRACT

The paper presents results of geobotanical and taxonomic studies on the distribution and habitat requirements of *Nymphaea candida* in southern Poland. The researches were conducted in southern Poland in 2003-2009, in the provinces of Lower Silesia, Lublin, Małopolska, Opole, Silesian province as well as, in southern parts of Mazowieckie and Lubuskie. Flowers, leaves and fruits of *Nymphaea* species were collected from 27 locations. Altogether pollens from 73 populations of *N. candida* and 18 of *N. alba* from all the researched area were measured. The trophic level of an ecosystem was evaluated according to the results of the total nitrogen, total phosphorus, chlorophyll *a*, transparency and biological parameters.

As the result of the studies of more than 200 water bodies, 57 localities of *N. candida* were documented within the investigation area. The populations of *N. candida* occupy mid-forest water bodies and river ox-bow lakes. A
significant number of populations was also found in artificial reservoirs – fish ponds. The most suitable habitat conditions for *N. candida* occur in shallow waters in the shore zone with the amplitude of the water column vary from 0.5 to 2 m. Regarding the trophy level, *N. candida* occupies different habitats, mainly mesotrophic and also eutrophic with high content of organic matters. Considering the 15 checked morphological parameters, especially the stigma diameter, the number of carpellar teeth, flower and pollen diameters, the found and collected specimens of *N. candida* significantly differ from *N. alba*.

The study confirms that *N. candida* occurs in whole lowland Poland without any regional distribution gaps. According to the IUCN guidelines to species assessment the data gathered during the presented study do not allow to classify *N. candida* as a vulnerable species in Poland. Still existing populations for more than 150 years, numerous stable locations, abundant populations, a habitat accessibility, a biotope extent, an ecological amplitude against the trophy level and direct human impacts suggest, that the species should be regarded as a least concern (LC) taxon.

KEY WORDS: *Nymphaea candida*, distribution, ponds, aquatic vegetation, habitat, range.

INTRODUCTION

*Nymphaea candida* C. Presl. is an Euro-Siberian element of aquatic flora with the western range limit on the line of the Rhine (Hegi 1965; Meussel et al. 1965; Hulten and Fries 1986; Muntendam et al. 1996). According to Wayda (2000), *N. candida* occurs in Poland only in the northern part of the country reaching there the southern limit of its general continuous range. However, the species was also reported from the Czech Republic (Hejný and Slavík 1997), southern regions of Germany (Benkert et al. 1996), eastern France, Switzerland, south-western Romania, Austria, Hungary and former Yugoslavia (Tutin et al. 2002; Muntendam et al. 1996). The general distribution map of the species in Europe is presented in Fig. 1. Considering the fact that aquatic plants are distributed widely and limited mostly by climatic zones, a distribution gap in southern Poland is hardly possible to really exist. Moreover, *N. candida* was reported from southern Poland by Polish and German botanists in the 19th and early 20th centuries (detailed list of papers cited in Results). Unfortunately, the herbarium materials documented these localities and deposited in WRSL were destroyed during the Second World War, so they could not be re-examined. It is worth mentioning that the data published by German botanists were based on careful plant examinations. Moreover, most of their floristic reports have been later confirmed, so they are regarded as a credible source of botanical information. Nevertheless, these data were questioned by Wayda (2000), and in result not included in the “Atlas of Vascular Plants of Poland” (Zając and Zając 2001). On the other hand, the occurrence of *N. candida* in the area of Silesia and the Pojezierze Łęczyńsko-Włodawskie Lakeland was mentioned by Kłosowski (2001) in the “Polish Red Data Book of Plants”. Localities of the species were also reported from the southern part of Lubuskie province by Kujawa-Pawlaczyk and Pawlaczyk (2003) and from Lower Silesia by Bobrowicz and Koniecny (2000). Authors of the present paper have found the individuals of water lily in southern Poland, identified in the field as *N. candida*, based on the botanical key of Rutkowski (1998) or Kubiat (2002). Further investigations proved, that *N. candida* occurs also in other regions of central and southern Poland (Nobis 2007; Nowak and Nowak 2007).

*N. candida* is closely related to *N. alba* L., with many varieties and subspecies described (Glück 1924; Heukels and Van der Meijden 1990). Despite the fact that the species has been extensively investigated (Glück 1924; Neuhaus and Tomšovic 1957; Radics 1967; Casper and Krausch 1981; Jones and Clarke 1981; Muntendam et al. 1996), its identification still brings confusions. Most useful for identification both of the species during the field studies is the number of stigma rays. In the case of *N. candida*, the stigma consists of 9-14 rays, whereas in the case of *N. alba* between 15 and 25 (Muntendam et al. 1996). Several specimens with 12-13 stigma rays were hardly possible to determine according to pollen diameter or exine shape. Surely these cases are rather hybrids of both species. The individuals collected by the authors of this paper in southern Poland have usually had 9 or even 7 carpellar teeth in stigma. Also the equatorial diameter of pollen grains seems to be a comfortable feature in some cases, however these analyses are possible only in the laboratory. The highest values of the equatorial length of *N. alba* pollen do not exceed 42 µm. The pollen of *N. candida* are in general larger than those of *N. alba* (Muntendam et al. 1996).

The morphologically closest to *N. candida* is *N. alba* var. minor DC. It is a starvation form differing from typical specimens of *Nymphaea alba* only in size. Recently, this form has been reported from Opole Silesia (Spalek 2007), but with no taxonomical evidences and herbarium documentation. According to Oberdorfer (1994) and Muntendam et al. (1996), the occurrence of *N. alba* var. minor is restricted to colder, northern regions of Europe.

A separate taxonomical problem related with *Nymphaea candida* is the possible hybridisation with *N. alba*. Morphologically intermediate forms between these two species are known for a quite long time (e.g. Conard 1905; Glück 1924). Also during *N. candida* survey in southern Poland such intermediate forms were collected. Molecular studies on hybrid specimens of *N. alba* and *N. candida* are planed in the future.

The *Nymphaea* genus is also of considerable importance from the conservation point of view. Both species are legally protected in Poland (Rozporządzenie Ministra Środowiska 2004). As a taxon with restricted range in
Poland *N. candida* was categorised as a vulnerable species in the Polish Red Data Book of Vascular Plants (Kłosowski 2001). So, it is important to have precise information about the distribution of both species to conduct the effective management and conservation.

The successive aims of the present study were: 1) to provide old, published floristic data on the distribution of *N. candida* in southern Poland; 2) to present the current distribution of the species in the discussed area; 3) to stimulate further molecular researches on infraspecific hybridisation in the genus in the area of co-occurrence of the two species representing the genus *Nymphaea*; 4) to provide data on habitat preferences of *N. candida* from selected localities, and finally 5) to discuss the present threat status of *N. candida* in Poland.

**MATERIALS AND METHODS**

The field studies were conducted in southern Poland in 2003-2009 (Figs 1 and 2). Flowers, leaves and fruits of the *Nymphaea* species were collected from 27 locations, mainly in Opole Silesia in July and September 2008 on the allowance DKFOPPogiz-4211/I-62/1887/08/ep issued by the Polish Minister of Environment. The plants were collected during warm days between 10 am. and 6 pm. The fresh material was identified and described in the field using the botanical key of Rutkowski (1998).

On the basis of botanical keys by Rutkowski (1998), Kubát (2002), Oberdorfer (1994), Hejný and Slavík (1997), as well as regarding the research works of Müntendam et al. (1996) and Wayda (2000), the following fifteen features were chosen to describe the specimens: the diameter of the stigma (column 1 in Table 1), the number of carpellary teeth (2), the position of the flower on water (3), the shape of the flower (4), the side view of the flowerbase (5), the underside view of the flowerbase (6), the stigma surface structure and colour (7, 8), the diameter of the flower (9) vertical/erect sepals (10), the colour of the underside leafblade (11), the nervation of the leafblade (12), the direction of the main nerves leafslips (13) and the proportion of the stigma to the width of the ovary (14) and for some specimens also the pollen diameter and pollen exine morphology (values given in the distribution list). All collected individuals were determined in the field with careful measurement of the chosen features. Altogether, 64 flowers, 70 leaves and 15 ovaries belonging to 62 specimens were collected and checked. The average stigma diameters, the number of carpellary teeth and the flower diameter were compared to the values of *N. alba*. Pollen diameter was measured using the Olympus BX41 microscope with objective UPlan SA 100×/0.17/FN 26.5 and photographed by the Olympus Camedia camera C3040 200M. Altogether pollens from 73 populations of *N. candida* and 18 of *N. alba* from all the researched areas were measured. Half of them was sampled from fresh material, another half from herbarium collections (WRSL, KRA). The collected material was stored in the herbarium of the Division of Geobotany and Plant Conservation of the Opole University (OPUN).

The trophic level of an ecosystem is evaluated according to the results of the total nitrogen, total phosphorus, chlorophyll *a*, water transparency and biological parameters (Dodds et al. 1998). However, it is generally admitted that phosphorus plays an important role in the development of aquatic plants and, in most cases, is a limiting factor of eutrophication in temperate lakes (Parinet et al. 2004). In order to estimate the status of investigated water bodies, the Trophic State Index (TSI) was calculated according to Carlson’s equations (Carlson 1977):

\[
TSI = \frac{TSI_{(TP)} + TSI_{(Chl)} + TSI_{(SD)}}{3}
\]

where:

- \( TSI_{(TP)} = 10 \left[ 6 - \ln(48 \cdot TP - 1) \cdot \ln 2 - 1 \right] \)
- \( TSI_{(Chl)} = 10 \left[ 6 - (2.04 - 0.68 \ln Chl) \cdot \ln 2 - 1 \right] \)
- \( TSI_{(SD)} = 10 \left[ 6 - \ln SD \cdot \ln 2 - 1 \right] \)

*TP* – total phosphorus (mg m\(^{-3}\)); *Chl* – chlorophyll *a* (mg m\(^{-3}\)); *SD* – Secchi depth (m).

![Fig. 1. The distribution range of *Nymphaea candida* in Europe with the investigation area.](image-url)
The TSI values, constructed on a scale of 0 to 100, indicate the trophic level of ecosystems from oligotrophic (<40) to eutrophic (60-100). To minimize the sampling mistake the mean value of three indices (TSITP, TSIChl and TSISD) were taken while determining the trophy level (Pełechaty et al. 2007). Also the reference classification adopted by OECD was taken into account (OECD 1982; Solheim 2005).

The endanger status of \textit{N. candida} in southern Poland was evaluated according to the IUCN categorization method (IUCN 2001). All doubtful specimens, probably hybrids, were excluded from the analyses. Only evident individuals of \textit{Nymphaea candida} were taken into account when generating map and listing the location of the species.

The average values of the pollen diameter of both species were compared using the \textit{t} test for independent variables.

**RESULTS**

**THE DISTRIBUTION OF \textit{NYMPHAEA CANDIDA} IN SOUTHERN POLAND**

All localities of \textit{N. candida} from southern Poland published before 2001 are listed below. Additionally, new records as well as old localities which have been confirmed recently (after 2001) in the field are also presented (Fig. 2).

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**Abbreviations (relate to Results):**

GB – dense exine outgrowths; RB – rare exine outgrowths.

By location the position in ATPOL grid 10×10 km (Zając 1978) was given. If the precise localisation of a population in ATPOL grid was impossible, a question-mark (?) was given.

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**Lower Silesian Province**

AE16: Jagodzin (Barber 1937; Schube 1903a), Węgliniec – Dziczy Pond (Schube 1903a), Węgliniec – Wolno Stary Pond (Schube 1903a), Węgliniec – Wolno Nowy Pond (Berdowski and Narkiewicz 1996);

AE25: Zielonka – pond to the NE from the village (Zabawski and Matuła 1973), Zielonka – Krużsa Pond (Berdowski and Narkiewicz 1996), Zielonka – Rygle I Pond – western reservoir (Berdowski and Narkiewicz 1996), Zielonka – Rygle I Pond – eastern reservoir (Berdowski and Narkiewicz 1996), Zielonka – bog to the NE from Rygle I Pond (Berdowski and Narkiewicz 1996), Zielonka – midforest pond to the SE from Rygle II Pond – forest division section 201 (Berdowski and Narkiewicz 1996);

AE26: Zielonka – pond to the NE from the village (Zabawski and Matuła 1973), Zielonka – pond close to the railway, to the NE from Zielonka (Berdowski and Narkiewicz 1996), Węgliniec – bog to the NW from railway station (Schube 1903a; Zabawski and Matuła 1973);

BD62: Radzyń near Sława (leg. E. Kozioł 04.07.1974, WRSL94073, pollen ø 42-45 µm, GB);

BE05: Przechowa near Legnica, Odra river ox-bow lake (leg. E. Kozioł 28.06.1993, WRSL 87085, pollen ø (40)42-43 µm, GB; Przyborów, Odra river ox-bow lake (Macicka and Wilczyńska 1992; Macicka-Pawlik and Wilczyńska 1996, 1998; Bobrowicz and Konieczny 2000);

BE09: Niezgoda (Schube 1903a), Ruda Sulinowska (Schube 1903a), Radziąd (Aniol-Kwiatkowska et al. 1995);

BE10: Nature Reserve “Torfowisko Borówki” (Cieślak and Szlachetka 1987; Szlachetka and Szlachetka 1998, 1999, Bobrowicz and Konieczny 2000);

**TABLE 1. Sampled specimens with their location and morphological characteristic.**

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**TABLE 1. Cont.**

| Location, specimen | Organ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
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| Sowin              |       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |
|                    | L     | 7.5 | 9 |   |   |   |   |   |   |   | 5.5 | ere |    |    | 0.63 |
|                    | O     | 5.5 | 9 | sub | cup | conc | squ | dull | ora | 4.5 | ere | re/gr | pro | par |
|                    | 4     | 6.5 | 9 | sub | cup | conc | squ | dull | ora | 5.5 | ere | re/gr | pro | conv |
|                    | L     | 6 | 9 | sub | cup | conc | squ | dull | ora | 7 | ere | re/gr | pro | conv |
|                    | O     | 5 | 10 | sub | cup | conc | squ | dull | ora | 5.5 | ere | re/gr | pro | conv |
|                    | 7     | 5 | 8 | sub | cup | str | squ | dull | ora | 8 | ere | re/gr | pro | conv |
|                    | O     | 7 | 11 | sub | cup | conc | squ | dull | ora | 5 | ere | re/gr | pro | conv |
|                    | 8     | 5.5 | 12 | sub | cup | conc | squ | dull | ora | 5 | ere | re/gr | pro | conv |
|                    | O     | 6.5 | 9 | sub | cup | conc | squ | dull | ora | 5 | ere | re/gr | pro | par |
|                    | 9     | 5 | 9 | sub | cup | str | squ | dull | ora | 8 | ere | re/gr | pro | conv |
|                    | O     | 6 | 8 | sub | cup | conc | squ | dull | ora | 5 | ere | re/gr | pro | par |
|                    | 10    | 5 | 10 | sub | cup | conc | squ | dull | ora | 4 | ere | re/gr | pro | conv |
|                    | O     | 5.5 | 9 | sub | cup | conc | squ | dull | ora | 5 | ere | re/gr | pro | par |
|                    | 11    | 4.5 | 7 | sub | cup | str | squ | dull | ora | 4.5 | ere | re/gr | pro | conv |
|                    | O     | 7 | 10 | sub | cup | str | squ | dull | ora | 4.5 | ere | re/gr | pro | par |
| Przysiecz         |       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |
|                    | 1     | 7.5 | 11 | sub | cup | str | squ | dull | ora | 8 | ere | re/gr | pro | par |
|                    | L     | 5.5 | 11 | sub | cup | conc | squ | dull | ora | 4 | ere | re/gr | pro | par |
|                    | 2     | 7 | 12 | sub | cup | conc | squ | dull | ora | 7 | ere | re/gr | pro | par |
|                    | L     | 7 | 10 | sub | cup | conc | squ | dull | ora | – | ere | re/gr | pro | par |
|                    | 3     | 6 | 12 | sub | cup | conc | squ | dull | ora | 7 | ere | re/gr | pro | par |
| Kawadałnik        |       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |
|                    | 1     | 6 | 12 | sub | cup | conc | squ | dull | ora | 5 | ere | re/gr | pro | par |
| Sław Nowokaźnicki |       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |
|                    | 1     | 5.5 | 7 | sub | cup | str | squ | dull | ora | 7 | ere | re/gr | pro | par |
|                    | L     | 6 | 10 | sub | cup | conc | squ | dull | ora | 6 | ere | re/gr | pro | par |
|                    | 2     | 4 | 8 | sub | cup | str | squ | dull | ora | 5 | ere | re/gr | pro | par |

Morphological features (according to the text)

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NYMPHAEA CANDIDA IN SOUTH POLAND

TABLE 1. Cont.

<table>
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<th>Location, specimen</th>
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<th>Location, specimen</th>
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<td>Kościerzyce</td>
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|                   | 1     | Misleading locations: Klosterteich pond by Lubomierz (Schall 1935) – according to the author comment it was an anthropogenic population.

Lublin Province

FD78: Mizak Lake, 04.07.1964, rev. M. Kucharczyk 1995; pollen ø 40-45 µm, GB; Fijalkowski 1962; Świerże, Tyśmienica river (Fijalkowski 1962);

FD86: Gżyce by Kock, Wieprz river (Fijalkowski 1964);

FD78: Skoki by Czemiernik, Tyśmienica river (Fijalkowski 1964);

FD89: Siemięc, fish ponds (Fijalkowski 1962);

FD99: Kleszczów Lake, Łęczyński-Włodawskie Lakeland (Fijalkowski 1959a; Popiołek 1971; Sugier and Czarnecka 1998); Czarne Gościnieckie Lake (Fijalkowski 1959a; Popiołek 1974; Sugier 1998); peat-bog depressions by Miejskie Lake (Popiołek 1973; Czarnecka and Sugier 1998);

FE06: Samoklęski, fish ponds (Fijalkowski 1962);
FE09: Rudka Kijawska, ditches (Fijalkowski 1962); FE43: Lezioro Bartków (Fijalkowski 1961); FE62: Popów, Bliskowice, Święciechów Duży, Wisła river (Fijalkowski 1960); FE84: Zaklików, Stawy (Fijalkowski 1960); FE95: Nature Reserve “Stawy Wilezowskie” (Fijalkowski 1997); Nature Reserve “Imiety Lug” (Fijalkowski et al. 1992; Fijalkowski 1997); Nature Reserve “Las Janowskie” (Fijalkowski 1997);

GD64: Holeszów by Sławatycz, meadow ditch (Fijalkowski 1963);

GD84: Dolnobrody by Włodawa, Bug river (Fijalkowski 1963);

GD95: Surroundings of Sobibor by Włodawa, Bug river (Fijalkowski 1964);

GD90: Skomielno Lake, Łęczyńsko-Włodawskie Lakeland (leg. D. Fijalkowski 01.08.1957, pollen ø 48 µm, GB; Fijalkowski 1959a);

Hańskie Lake, Pojezierze Łęczyńsko-Włodawskie (leg. D. Fijalkowski 26.08.1960, pollen ø 40-41 µm, R-GB; Fijalkowski 1959a);

GE04: Spino Lake (Fijalkowski et al. 1994a); Perespolno Lake (Fijalkowski 1959a; Fijalkowski et al. 1994a);

GE05: Płotycze Lake, Sobiborskie Forests, Łęczyńsko-Włodawskie Lakeland (Fijalkowski 1959a; Fijalkowski et al. 1993); Brudno Lake, Sobiborskie Forest, Łęczyńsko-Włodawskie Lakeland (Fijalkowski 1959a; Fijalkowski et al. 1993);

GE11: Eastern shore of Uściewir Lake, Grabniak by Łężna, Łęczyńsko-Włodawskie Lakeland (Fijalkowski 1959a; Popiołek 1988); Rotce Lake (Fijalkowski 1959a; Popiołek 1988); Sumin Lake (Fijalkowski 1959a; Popiołek 1988); Bikece Lake (Fijalkowski 1959a; Popiołek 1988); Nadyrie Lake (Fijalkowski 1959a; Popiołek 1988);

GE12: Świerszczów Lake (Fijalkowski 1959a, 1965; Karczmarz and Malicki 1971);

GE13: Slone Lake (Fijalkowski 1959a);

GE25: Hniszów, in Bug river (Fijalkowski 1964);

GE34: Kol. Rudka, Kamień, Strupie, peat-bog depressions in calcareous moors (Fijalkowski 1959a);

GE36: Drohousk by Cheln, Bug river (Fijalkowski 1964);

GE47: Uchańka by Dubienka, Bug river (Fijalkowski 1964);

GE57: Matece by Horodla, Bug river (Fijalkowski 1964);

GE62: Strżyjów, Orlów Murowany, ponds (Fijalkowski 1960);

GE82: Sitaniec, Łabuńka river (Fijalkowski 1959b);

GE84: Miączyn, peat-bog depressions (Fijalkowski 1959b);

GE92: Lipsko, peat-bog depressions (Fijalkowski 1959b);

GF15: Chodwyńce by Tomaszów Lubelski, peat-bog depressions (Fijalkowski 1962).

Malopolska Province

DF69: Kraków – Dębinki, data ?, leg. ?; KRA 11471; pollen ø 42-46 µm, GB);

DF78: Tyniec near Kraków – pond, leg. H. Błaszyck may 1938, KRA 89674; ø pyłku 41-43 µm GB);

EF62: Puszcza Niepolomicka, Ispina, ox-bow lake “Wiśliško Kobyłne” in Myriophyllum-Nupharum association, leg. E. Dubiel 5.08.1968, KRA 98181; pollen ø 42-45 µm GB);

DF69: Kraków – Dębinki, leg. F. Berdau 1854, KRA 11470; pollen ø 42,5-47,5 µm, GB);

DF79: Kraków – Kobierzyn, leg. F. Berdau 1854, KRA 11470; pollen ø 42,5-47,5 µm, GB).

Mazowsze Province

EE38: Pakosławskie bog (Mlyn Bagno) in Pakosław near Iłża (Szafran 1925);

FE60: Puszcza Koziienicka, bog near Anielin; leg. H. Błaszyck 07.1939, KRA89676; pollen ø 38-40 µm, GB);

?: Puszcza Koziienicka, bog near Laskowoła, drainage ditch (leg. H. Błaszyck 6.07.1939, KRA 89677; pollen ø 42 µm, GB).

Opole Province

CE67: Kluczborz (Fiek 1887; Schube 1903a);

CE73: Nowe Kolnie (Kuźniewski 1964);

CE77: Szumirad near Olesno, pond (Fiek 1888; Schube 1903a);

CE79: Borki Wielkie (Schube 1903b);

CE83: Buszycy near Lewin Brzeski (Schube 1908);

CE84: Chroćcice (Wimmer 1844; Schube 1903a);

CE85: Kop (Schube 1903a);

CE98: Mid forest pond in Staniszewo Male (Dajdok et al. 1998);

CF03: Tułowice Male, Grodziec (Wimmer 1844; Schube 1903a), Tułowice (Schube 1910);

CF04: Przyjescie (Fiek, Schube 1893; Schube 1903a);

CF05: Staw Nowokuźnicki (Michalak 1963);

CF09: Zawadzkie (Dajdok et al. 1998);

CF13: Stara Jamka (Schube 1910);

CF25: Dobra (Schube 1906);

CF48: Stara Kuźnia (Wimmer 1844; Schube 1903a);

DE50: Dalachów, pond in forest sect. No. 96 (Fojcik 1997).

Misleading locations: Lewin Brzeski (Kuczyńska 1974 – data from before 1939) – data refers undoubtedly to Stara Jamka near Korfantów (Schube 1910);

Buszycy near Lewin Brzeski (Schube 1908) not to Lewin Brzeski itself; Chróścina (Kuczyńska 1974 – data from before 1939) – data refers undoubtedly to Stara Jamka near Korfantów (Schube 1910);

Podkarpacie Province

FF24: Plaskowyż Kolbuszowski, Brzóza (S. Loster, E. U. Zając, E. Dubiel, A. Zając 17.06.1975, KRA11735; pollen ø 43-45 µm, RB).

Silesian Province

CF38: Rudziniec (Schube 1903a);

CF57: Nature Reserve “Łężczok” (Fiek 1881; Sendek 1986); Grabowiec Pond in Nature Reserve “Łężczok” (leg.
The list of new localities found or confirmed by authors:

Lower Silesian Province


BE10: “Sześci Stawów” (obs. Z. Dajdok, A. Nowak, W. Bena 22.08.2009; pollen ø 42-45 µm, GB), between Krzyżowa and Borówki – fish pond in forest (Szlathecka 2007a, 2008).

BE15: Malowice – large ox-bow lake to the W from Malowice (Ruszwlewicz and Szlathecka 2007), Dziewin – ox-bow lake to the S from village (Szlathecka 2007b).

BE25: Grzybów – ox-bow lake ca. 300 m to the SE from village (Szlathecka 2007b), Jurcz – ox-bow lake ca. 2500 m to the SW from village (Szlathecka 2007b), Jurcz – four small ox-bow lakes, ca. 1300 m to the E from village (Szlathecka 2007b), Jurcz – ca. 1200 m to the SE from village (A. Szlathecka 2007 npbl.), Kwiatkowice – ox-bow lake ca. 1200 m to the NE from village (Szlathecka 2007b).

Lublin Province


Małopolska Province


Mazowsze Province


Opole Province

CE62: Ox-bow lake in Blota (obs. A. Nowak 16.07.2008);
CE64: Krogólna, fish ponds (Nowak and Nowak 2007; leg. A. Nowak 08.07.2007; pollen ø 35-43 µm, GB); CE72: Ox-bow to the S from Lubusa and to the SW and NE from Kościerycz (obs. A. Nowak 14.07.2008); CE73: Odra river ox-bow lake in Stare Kolnie (Nowak and Nowak 2007; leg. A. Nowak 08.07.2007, pollen ø 43-46 µm, GB); Odra river ox-bow lake in Stobrawa (Nowak and Nowak 2007, leg. A. Nowak 08.07.2007; pollen ø 44-49 µm, GB); CE75: Winna Góra, fish ponds (Nowak and Nowak 2007, leg. A. Nowak 08.08.2007; pollen ø of 2 specimens, each 46 µm, GB); CE77: Szumirad near Olesno, pond (Nowak and Nowak 2007; leg. A. Nowak 08.07.2007; 1 specimen pollen ø 43-46 µm, GB; 2 specimens pollen ø 48-49 µm, GB; 3 specimens pollen ø 46-50 µm, GB); between Lasowice Male and Lasowice Wielkie, pond (Nowak and Nowak 2007); Lasowice Male – village pond, leg. A. Nowak 08.07.2007, 1 specimen KRA 358250; pollen ø 46-48 µm, GB; 2 specimens KRA 358006, pollen ø (4445-48 µm, GB); CE83: Odra river ox-bow lake in Wronów (leg. A. Nowak 09.08.2007; pollen ø 42-43 µm, GB) Nysa Kłodzka µm, GB); CE85: Winna Góra, fish ponds (Nowak and Nowak 2007; leg. A. Nowak 08.07.2007; pollen ø 43 µm, GB); CE84: Wielopole by Popielów, Odra river ox-bow lake (Nowak and Nowak 2007; leg. A. Nowak 12.08.2007; pollen ø 41 µm, GB), Odra river ox-bow lake to the N from Narok and in Kopanie (obs. A. Nowak 14.07.2008); CE94: Odra river ox-bow lake between Niewodniki and Żelazna (obs. A. Nowak 14.07.2008); CE95: Odra river ox-bow lake in Żelazna (obs. A. Nowak 14.07.2008); CE97: Poliwoda, ponds (Nowak and Nowak 2007); CE98: Mid forest pond in Staniszcze Male (Nowak and Nowak 2007; leg. A. Nowak 08.07.2007; pollen ø 43-46 µm, GB); CF03: Pustelnik and Loża ponds by Lipno, Ławnik pond by Tulowice (Nowak and Nowak 2007); CF04: Przysiecz (Nowak and Nowak 2007; leg. A. Nowak 23.08.2007; 1 specimen pollen ø 40-43 µm, GB; 2 specimens, pollen ø 40-43 µm, GB); CF05: Nature Reserve “Staw Nowokuźnicki” (Nowak and Nowak 2007; leg. A. Nowak 08.07.2007, 1 specimen pollen ø 46 µm, GB; 2 specimens pollen ø 40-43 µm, GB; 3 specimens pollen ø (38)40-43; µm, GB); Opole-Groszowice, pond (Nowak and Nowak 2007); CF07: Utrata, pond (Nowak and Nowak 2007); CF13: Mid forest pond to the S from Sowin (leg. A. Nowak 08.07.2007, Nowak and Nowak 2007; 1 specimen pollen ø 43-46 µm, GB; 2 specimens pollen ø 46-48 µm, GB). Podkarpackie Province

FF16: Pond in Tanew river valley, to the N from Nadtamy settlements by Ulanów (A. Nobis 2005 npbl); FE84: Jan Pond by Zaklików in Sandomierska Basin (leg. R. Krawczyk, 07.08.2003, KRA 357977; pollen ø 42-45 µm, GB); FE95: Świdry in Sandomierska Basin, Oleńka pond (leg. R. Krawczyk 07.08.2003, KRA 357638; ø of pollen, 42-43 µm, GB). Silesian Province


Świętokrzyskie Province

EE25: Mid forest lake on Jablonica river in Rzuców near Chlewiska (obs. M. Nobis 26.08.2003, KRA 265084; pollen ø 42-45 µm, GB); Rzuców – mesotrophic pond (obs. M. Nobis 26.08.2003, KRA 357971; pollen ø 40-43 µm, GB); EE32: Mesotrophic pond by Barycz near Końskie (A. Trojeka 2007 npbl); EE33: Mesotrophic pond by Stary Młyn near Końskie (A. Trojeka 2007 npbl); EE57: Pasternik reservoir on Kamienna river in Starachowice (obs. M. Nobis 08.09.2003, KRA 265037; Nobis 2007; M. Nobis 2008 npbl.; pollen ø 45, 50 µm, GB); Pasternik reservoir on Kamienna river in Starachowice (obs. M. Nobis 08.09.2003, KRA 265085; pollen ø 40, 43, 45, 48 µm, GB); Pasternik reservoir on Kamienna river in Starachowice (M. Nobis 08.09.2003, KRA 265619, 265622; pollen ø 42, 45 µm, GB); EE60: Peat-bog pond near Skape village (Lopuszańskie Hills), (obs. A. Adamiec, R. Piwowarczyk 12.08.2008); EE61: Peat-bog pond near Mokre village (Lopuszańskie Hills; obs. A. Adamiec 12.08.2008 npbl); EE72: Lake within transitional bogs “Żarnowski Ług” by Gnieździska (Lopuszańskie Hills; obs. 14.08.2008 A. Adamiec, R. Piwowarczyk npbl); EF08: Lakes in karst sink, to the E from Golejów near Staszów (M. Nobis 2006, 2008 npbl).

MORPHOLOGICAL FEATURES OF THE COLLECTED SPECIMENS

The field and laboratory measurements of the collected flowers and ovaries is ca. 5.87 mm ranging from 4 to 13 (Table 2, Fig. 4). Also the flowers of the verified specimens were small with the diameter restricted to the 33.63 µm (Table 2, Figs 6-8). The average value of this characteristic was 5.95 cm ranging from 4 to 13 (Fig. 8). The mean value of the stigma diameter for the collected flowers and ovaries is ca. 5.87 mm ranging from 4 to 13 (Table 2, Fig. 3). The average number of carpellary teeth meets perfectly the strict N. alba (Table 2, Fig. 4). Also the flowers of the verified specimens were small with the diameter restricted to the N. candida profile. The average value of this characteristic was 5.95 cm ranging from 4 to 8.5 (Table 2, Fig. 5).

The pollen diameter was measured for 98 specimens representing 73 populations of N. candida and for 31 specimens representing 18 populations of N. alba. The average value of the parameter was for N. candida 43.95 µm and for N. alba 33.63 µm (Table 2, Figs 6-8). The pollen diameter for both species has statistically different values (p<0.001; Fig. 8).
HABITAT PREFERENCES
OF NYMPHAEA CANDIDA C. PRESL IN SOUTHERN POLAND

The populations of *N. candida* in southern Poland occupy mainly water bodies especially surrounded by forests, but in some cases also river ox-bow lakes within the meadow-field landscapes. The most suitable habitat conditions for this species occur in shallow waters in the shore zone with the amplitude of the water column fluctuating from 0.5 to 2 m. Populations of *N. candida* develop on open water or close to the rushes with high insolation rate. Higher shading influences directly on the decrease of density and cover rate of the species. In thick reeds or high rushes the species occurs sporadically with a low population size.

The significant number of these populations were found in artificial reservoirs – fish ponds or forest ponds. Regarding the trophy level *N. candida* occupies different habitats, mainly mesotrophic but also eutrophic with high content of organic matters (Table 3).

**TABLE 2. Mean values of quantitative features for *Nymphaea candida* and *N. alba*.

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<th><em>N. candida</em></th>
<th><em>N. alba</em></th>
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<tr>
<td>Stigma diameter [mm]</td>
<td>5.87</td>
<td>13.4*</td>
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<td>Number of carpellary teeth</td>
<td>9.29</td>
<td>16.1*</td>
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<td>Flower diameter [cm]</td>
<td>5.95</td>
<td>11.2*</td>
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<td>Pollen diameter [µm]</td>
<td>43.95</td>
<td>33.63</td>
</tr>
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</table>

* according to Nowak and Nowak (2007)

Fig. 3. Values of stigma diameter of *N. candida* specimens.

Fig. 4. Number of carpellary teeth of *N. candida* specimens.

Fig. 5. Flower diameter of *N. candida* specimens.

THE STATE OF THREAT
OF NYMPHAEA CANDIDA IN SOUTHERN POLAND

To show the conservation state of *N. candida* in southern Poland, the number of localities for separate regions were compared (Table 4).

DISCUSSION

During the present studies the extent area of southern Poland was surveyed aiming to solve the distribution problem of *N. candida* and *N. alba*. Both species of water lily are closely related and many morphological features overlap without any distinct differences. However, the number of carpellary teeth and the pollen diameter seems to be the most useful characteristic features for recognition of the two species as it hardly overlaps (Muntendam et al. 1996). The most useful diagnostic feature, even during the field studies, is the number of carpellary teeth, which is countable in flower as well as in the ovary.

Using the current botanical keys we come to the conclusion that, with no doubts, *Nymphaea candida* occurs in south Poland. Moreover, the preliminary analyses of the rarity of both species show, that *N. candida* is quite frequent. The number of carpellary teeth, which should not exceed 14, was often below 10. The mean value for the examined specimens was 9.29 (from 7 to 12). The mean value of pollen diameter was 43.95 µm (the maximum value for *N. alba* doesn’t exceed 42 µm) and in some cases even more than 50 µm (see the distribution list and Figures 6 and 7). Thus, all the individuals suited the range designated for *N. candida* by Muntendam et al. (1996), Wayda (2000), Rutkowski (1998) and others. Also the other countable features, like the diameter of the flowers (5.95 in average) or the proportion of the stigma diameter to the ovary one (mean value 0.6) evidently indicated *N. candida* (Table 1 and 2). Almost all plants had cup-shaped flowers, the
square-shaped flower base (sometimes with a rough edge), the orange stigma, and the flower partially submerged in the water with erected sepals. Leaves were in the majority red or red-green on the bottom side with converging nerves of leafslips.

The results of the study in comparison to the recent research on *N. alba* (Nowak and Nowak 2007) revealed the considerable differentiation among *Nymphaea* species. Remarkable differences were found within some diagnostic features, such as the stigma diameter (5.95 mm for *N. candida* and 13.4 mm for *N. alba*) and the number of carpellary teeth (respectively 9.29 and 16.1). At the same time, the flower diameters also differ significantly reaching 5.95 for *N. candida* and 11.2 for *N. alba* (Table 1). The most important difference is within the value of pollen diameter, which has the average 43.95 for *N. candida* and 33.63 for *N. alba*. These values closely correspond with results of Muntendam et al. (1996) (adequately 43.6 and 34.1).
Former habitat analyses show that *N. candida* prefers mesotrophic, clear waters with mineral-organic substrates (Szańkowski and Klosowski 1999; Klosowski 2001). Some reports conclude that also eutrophic water reservoirs could give suitable conditions for development of *N. candida* populations (Tomaszewicz 1979). In the Czech Republic *N. candida* was found in varied types of water, among others in meso- and oligotrophic fish ponds, ox-bow lakes and bog ponds (Tomšovic 1997). Within the researched area the species were noted in waters of intermediate character in terms of trophy level, between the values for meso- and eutrophy. Only in three sites populations of *N. candida* were found in evidently mesotrophic waters and in two cases in eutrophic. A slight shifting of the trophy level in the mesotrophy direction for the analysed samples is detectable when investigating the chlorophyll *a*. This analyse classifies the waters generally to mesotrophy and in the case of the Staw Nowokuźnicki pond even to oligotrophy (OECD 1982). Thus, we found the species able to thrive in poor waters of small, mid-forest ponds or bog ponds as well as in rich with mineral substances waters of fish ponds or ox-bow lakes. Such adaptation potential significantly broadened the habitat amplitude of *N. candida* in southern Poland.

However, in comparison to *N. alba* habitats, it seems to be sure that *N. candida* occurs in waters of slightly lower trophy level, what was suggested earlier by Tomaszewicz (1979).

The outcomes of the conducted researches have considerable meanings for the phytogeography of the *Nymphaea* genus in Central Europe. They fill up the distribution gap in the southern part of *N. candida* range in Europe and definitely explain and prove the results of former researches. The continuous distribution of *N. candida* in southern Poland is also well-founded in climatic and ecological conditions (see Klosowski 2001). With no doubts the south part of Poland is the transition area where the distribution ranges of both species overlap. Existence of hybrids within the genus could cause the morphological characters very unstable and labile making the easy determination of the species, its hybrids or introgressive forms hardly possible. Further cytological and genetic researches of different specimens of *Nymphaea* genus in southern Poland should be conducted to solve the problem of genetic flow between the populations of both relatives and their hybrids.

The taxonomic and chorological surveys in neighbouring areas should be attentively monitored. Some interesting new data on the distribution of *N. candida* were published for the Saxony region in south-east Germany. The revision of the collected specimens and new field studies changed the regional range of the species, considerably diminishing the distribution acreage and splitting it into some small patches (Otto et al. 2000; Otto 2004). Thus, there is a question whether the natural south-western range of *N. candida* in Germany, Austria, the Czech Republic, Switzerland and Poland is continuous or patchy due to uncomfortable ecological conditions, e.g. too high elevation or a lack of suitable waters. This situation is possible for some areas in south Poland where we found scarce number of the *N. candida* population (e.g. Małopolska).

The detailed study on the taxonomy and distribution of the species within the Nymphaea genus is obviously indispensable tool in proper management and effective conservation of both taxa (comp. Nowak and Nowak 2004). Without precise data relating to chorology, dynamic and range changes of these plants the legal protection of water lilies could be ineffective.

In the neighbouring countries *N. candida* is considered as a taxon with different dynamic and endangerment status. In the Czech Republic it was categorized as a critically endangered (Procházka 2001). Generally, in the area of Germany it is regarded as an endangered but in Bavaria as a critically endangered (Korneck et al. 1996). In the last edition of the Polish Red Data Book of Plant, Klosowski (2001) treats *N. candida* as a vulnerable. Surprisingly, the species has not been red listed in Poland (Zarzycki and Szeląg 2006). In separate regions of southern Poland, *N. candida* was evaluated against criteria of IUCN and was classified as a vulnerable taxon in Opole Province (Nowak et al. 2008). It is hardly possible to precisely determine the real degree of endangerment in the whole country using only informa-
tion from southern regions of Poland. Because of the taxono-

mical discrepancies there is also a lack of credible data in some regions. So, it seems to be indispensable to verify the synanthropodynamic situation of *N. candida* as well as *N. alba* in whole Poland.

The comparative analyses within the different time peri-

ods for separate regions of southern Poland show, that for some provinces *N. candida* increases the number of loca-

tions. Inconsiderable decrease is observed in case of Lower Silesia, much worse is the situation in Upper Silesia (Table 4). Even worse is the situation in Lubelskie voivodeship, however, there are some additional information relating to pollen findings of *N. candida* in several lakes, which were not included in presented assessment (see Balaga et al. 2002; Balaga 2007a, b). In some regions (e.g. Podkarpackie) the species was found for the first time. However it does not prove its expansive properties, but rather reflects the intensification of floristic surveys and shows the potential of *N. candida* to settled in mountainous areas. It is also worth to mention that in some regions (north-eastern part of the Małopolska Upland or Opole Silesia) the species is more frequent than *N. alba* (comp. Nobis 2007).

According to the IUCN guidelines to species assessment (IUCN 2001) the data gathered during the presented study do not allow to consider *N. candida* as a vulnerable species in Poland. Still existing populations known from the XIX century, numerous stable locations and abundant popula-

tions in some regions at present suggest that the species should be regarded as a least concern (LC). Also the analy-

ze of the habitat accessibility, a biotope extent, an eco-

logical amplitude against the trophyleveland direct human

impacts support this categorization. Nevertheless it is prob-

able, that in some regions the species could have the con-

siderable withdrawing tendency and has to be red listed in higher categories.

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