Habitat conditions of the *Nymphaeetum candidae* Miljan 1958 and *Nupharo-Nymphaeetum albae* Tomaszewicz 1977 dominated by *Nymphaea alba*

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Abstract

The paper presents comparative analysis of habitats of 19 phytocoenoses of the *Nymphaeetum candidae* and 21 phytocoenoses of the *Nupharo-Nymphaeetum albae* dominated by *N. alba* from the lakes of north-eastern Poland. The differences in ecological amplitudes and optima of occurrence between two phytocoenose types were pronounced. The *N. candida* phytocoenoses had narrower amplitudes both regarding the properties of water and substrate and required higher minimum nutrient contents as compared to the *N. alba* phytocoenoses. Habitat distinction of phytocoenoses dominated by *N. candida* expressed in a relatively narrow trophic amplitude totally justifies to distinguish *Nymphaeetum candidae* as a separate syntaxon.

Key words: *Nymphaea candida*, *N. alba*, phytocoenoses, habitats, water and substrate properties

INTRODUCTION

Nymphaea alba L. and *N. candida* Presl. are typical aquatic plants with floating leaves that occur within Europe in various standing waters and those with only a slight current (Casper and Krausch 1981). In Poland *Nymphaea alba*

is one of the commonest flora elements, while *N. candida* is a rare species with dispersed localities (Tomaszewicz 1979). Both species are components of various aquatic communities, but mostly form independent phytocoenoses. So far, they have been considered as characteristic of *Myriophyllo-Nupharetum* W. Koch 1926 association, while the phytocoenoses with their domination have been treated as facies, or variants of this association (Podbielkowski 1968, Kraska 1971, Krzywański 1974, Dąbska and Kraska 1976, Michna 1976, Tomaszewicz 1977a, Noryśkiewicz 1978). Recently, in Poland, after Tomaszewicz (1977b) the stands dominated by *Nymphaea alba* are classified to *Nupharo-Nymphaetum albae* Tomaszewicz 1977, while those with *N. candida* – to *Nymphaetum candidae* Miljan 1958 (Matuszkiewicz 1981, Rejewski 1981, Tomaszewicz and Kłosowski 1985, Samosiej 1987). For Europe two more associations have been recorded, *Nymphaetum albo-candidae* (Hejný 1948) Pass. 1957 (e.g. Schrott 1974, Oberdorfer 1981) and *Potamogetoneto natantis-Nymphaetum candidae* Hejný and Husák 1978 (Cernohous and Husák 1986). The associations *Nymphaetum albae* Vollmar 1947, and *Nymphaetum albo-luteae* Nowiński 1930 are also often mentioned (e.g. Hilbig 1971, Oberdorfer 1981, Otahelová 1980). The latter is actually a counterpart to *Nupharo-Nymphaetum albae*. However, although there are lots of phytosociological data on the phytocoenoses dominated by *N. alba* or *N. candida*, the data on their habitats (water and substrate analyses) are rather scarce. Otahelová (1980) gives some fragmentary information on *Nymphaetum albo-luteae nymphaetosum*, while Cernohous and Hušák (1986) – on *Potamogetoneto natantis-Nymphaetum candidae*. Meriaux (1978) and Gołdyn (1984) present some water properties for a number of phytocoenoses dominated by *N. alba*. One can find more autecological data concerning *Nymphaea candida* and/or *N. alba* e.g. Lohammar 1938, Iversen and Olsen 1946, Wiegleb 1978, Pietsch 1982, Van der Velde et al. 1986, Smits et al. 1988). Among those the works of Pietsch (1982) and Van der Velde et al. (1986) are worth noticing. The first gives the amplitudes of various water chemical properties, the second also comprises the results of the analysis on amplitudes of some substrate (interstitial waters) properties, based on water and sediment samples taken within the stands dominated by *Nymphaea candida* or *N. alba*. This gives better opportunity to compare these data with the synecological information.

The survey of the material on both phytocoenose types indicates the need for detailed habitat analyses. Such data are necessary for synthetic monographs on ecological amplitude and indicative value of aquatic plant communities. Hence the present work aims to study the habitat conditions of the phytocoenoses composed of *Nymphaea candida* and *N. alba* in north-eastern Poland, the area subjected since 1978 to the authors' investigations on the ecology of aquatic and swamp vegetation (Kłosowski 1988, Kłosowski and Tomaszewicz 1986, 1989).

STUDY AREA, MATERIAL AND METHODS

The data was collected mainly in the growing season of 1988 in the Sejny, Suwałki, and Elk Lake Districts, and at Great Mazurian Lakes. For the phytocoenoses with *N. alba* also samples collected in growing seasons of 1978-1980 and 1983 were used. Totally 19 phytocoenoses with *Nymphaea candida* located in 6 lakes, and 21 phytocoenoses with *N. alba* located in 17 lakes were studied. For each phytocoenose one relevé was recorded, and water and substrate samples were taken for further physical-chemical analyses. Water was sampled directly to plastic containers at the mean stand depth (water for oxygen content and BOD₅ determination was taken in 250 ml glass-bottles). The substrates were sampled from the rhizome-root layer by means of tubular bottom sampler. Each substrate sample was a mixture of three taken within one phytocoenose. Both water and substrate samples were driven directly to laboratory and placed in fridges at 4°C, then immediately analysed. They were not stored for more than a few days. All properties that change quickly with time were analysed at the sampling day (Hermanowicz et al. 1976).

In hydrochemical analyses the following determinations were carried out: oxygen saturation and BOD₅ by Winkler's method, pH in N-517 pH-meter, NH₄-N by direct Nessler's reaction, NO₃-N colorimetrically with phenoldisulphonic acid, oxidability as potassium permanganate consumption in acid medium, carbonate and total hardness — using methylorange and Warthy-Pfeifer's sodium mixture, chloride by Mohr's argentometric method, dissolved SiO₂ by colorimetric molybdate method, total iron by colorimetric rhodante method, phosphate colorimetrically by blue molybdate method, calcium, sodium and potassium by flame photometry on a Flapho 4 flame photometer, sulphate by nephelometric method, magnesium was estimated with ASS 1N Atomic Absorption Spectrophotometer, colour according to the platinum-cobalt scale.

In substrate samples the following properties were assessed directly: pH, hydration, oxidability and organic matter content. Other assays were determined after the samples were mineralized (total nitrogen), acid extracts were done in HCl 1 + 1 (Fe, Ca, Mg, SO₄, PO₄-P), or water extracts were conducted (Cl; NO₃-N, dissolved SiO₂). Sodium and potassium were assessed from ignited sediment after hydration and organic matter content were determined. The analyses from acid and water extracts, determinations of sodium, potassium, oxidability and pH were conducted by the methods described above. Hydration was determined by drying substrate samples at 105°C to constant weight, organic matter content by ignition of dry samples at 550°C for 1.5 h and total nitrogen by Kjeldahl's method.

Numerical data were evaluated statistically. For each component and property, both of water and substrate, mean values and confidence intervals

were calculated. Values of pH were recalculated so as to obtain specific acidity according to Wherry (1922). Next the mean values and ranges of all properties of substrate and water of the communities studied were compared. The significance of differences between means was determined by t-test at $P = 0.05$.

RESULTS

PHYTOSOCIOLOGICAL AND ECOLOGICAL CHARACTERISTICS OF THE PHYTOCOENOSES STUDIED

In north-eastern Poland the phytocoenoses dominated by *Nymphaea candida*, or *N. alba* have been so far encountered only in lakes. Such phytocoenoses are mostly compact two-, three-layered. Besides the dominants other species with floating leaves occur, like *Potamogeton natans* L. and *Nuphar lutea* (L.) Sm., and plants with their leaves submerged as *Ceratophyllum demersum* L. and *Potamogeton lucens* L. (Table 1). It seems surprising that

Table 1

Basic phytosociological data on the *Nymphaetum candidae* (Nc) and *Nupharo-Nymphaetum albae* (NNa) phytocoenoses

Association	Nc		NNa	
Number of relevés	19		21	
<i>Ch. Potamogetonetea</i>				
<i>Nymphaea candida</i>	V ⁴⁻⁵	8487	•	
<i>Nymphaea alba</i>	•		V ⁴⁻⁵	8274
<i>Potamogeton natans</i>	IV ⁺⁻¹	58	II ⁺	2
<i>Nuphar lutea</i>	II ⁺⁻¹	56	III ⁺⁻²	134
<i>Ceratophyllum demersum</i>	II ⁺	4	I ⁺	1
<i>Potamogeton lucens</i>	I ⁺	1	II ⁺	2
<i>Ranunculus circinatus</i>	I ⁺	2	I ⁺	1
<i>Elodea canadensis</i>	I ⁺	1	•	
<i>Myriophyllum verticillatum</i>	I ⁺	1	I ⁺	1
<i>Utricularia vulgaris</i>	I ⁺	1	I ⁺	1
<i>Potamogeton friesii</i>	I ⁺	1	•	
Accompanying species				
<i>Lemna trisulca</i>	II ⁺	3	•	
<i>Typha angustifolia</i>	II ⁺	2	•	
<i>Phragmites australis</i>	I ⁺⁻¹	27	II ⁺	3
<i>Schoenoplectus lacustris</i>	I ⁺	1	II ⁺	2
<i>Lemna minor</i>	I ⁺	2	I ⁺	1
<i>Equisetum fluviatile</i>	I ⁺	1	I ⁺	1
<i>Spirodela polyrrhiza</i>	I ⁺	1	I ⁺	1
<i>Fontinalis antipyretica</i>	I ⁺	1	•	
<i>Chara tomentosa</i>	•		I ¹	24
<i>Carex rostrata</i>	•		I ⁺	1

Nymphaea candida does not grow in the *N. alba* phytocoenoses and vice versa, although the association *Nymphaeetum albo-candidae* has been recorded for Europe. Some species, e.g. *Lemna trisulca* L. and *Schoenoplectus lacustris* (L.) Palla accompany only the phytocoenoses dominated by *Nymphaea candida*.

The *Nymphaea alba* phytocoenoses develop in the zone of floating-leaved vegetation, adjacent to the communities with *Nuphar lutea* and *Potamogeton natans*. Often they occupy large areas in shallowed lake bays. The phytocoenoses dominated by *N. candida* as a rule grow only in lake bays or occupy vast areas in the centre of shallowed small lakes (e.g. the Róg, Dubinek, Kołowiek).

The phytocoenoses with *Nymphaea alba* grow at less than 1 m to 3 m but usually their water depth does not exceed 1.5-2 m. They mostly inhabit organic or organic-mineral substrates. Some phytocoenoses develop on detrital-calcareous gyttja, or on clay with slime. No *N. alba* phytocoenoses were found on highly mineral, sandy or gravel substrates.

Water depth in the phytocoenoses with *Nymphaea candida* ranges between 1 and 3 m, mostly exceeds 2 m. The analysed phytocoenoses develop on substrates covered with a layer of organic sediments. However, the layer may be very thin and overlay fine sand. Detrital-calcareous gyttja was found only in 5 phytocoenoses. Single *N. candida* specimens occur on lake margins on mineral-sandy substrates.

Both the phytocoenoses with *Nymphaea alba* and with *N. candida* are within the analysed area confined to lakes or their parts which markedly undergo the ageing process and are late successional stages of water communities.

PHYSICAL AND CHEMICAL PROPERTIES OF WATER AND SUBSTRATES OF THE PHYTOCOENOSES COMPARED

Waters dominated by the phytocoenoses with *Nymphaea candida* were compared to those with *N. alba* regarding the means and ranges of 18 properties (Fig. 1, Table 2). The comparison showed that water habitats of the phytocoenoses studied considerably differed. This concerned minimum, maximum and mean values of all components and factors. Firstly the range of some properties of the *Nymphaea candida* phytocoenoses were essentially narrower, such as total and carbonate hardness, calcium, potassium, sodium, chloride contents, those of dissolved SiO_2 , phosphate, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, magnesium, as well as oxidability and colour. Above properties had higher minimum values (chloride except) and lower maximum values in the phytocoenoses with *Nymphaea candida*, compared to those with *N. alba*. Regarding pH, sulphate, iron contents, oxygen saturation, both minimum and maximum values were higher in waters of *Nymphaea candida* phytocoenoses. The comparison of mean values showed that for total and carbonate hardness, calcium, chloride, and sulphate contents, and colour, the differences were significant statistically.

Fig. 1. Ranges of chemical and physical properties of waters of the *Nymphaeetum candidae* and *Nupharo-Nymphaeetum albae* phytocoenoses. All values in $\text{mg} \cdot \text{dm}^{-3}$, except: total and carbonate hardness ($\text{mval} \cdot \text{dm}^{-3}$), colour ($\text{mg Pt} \cdot \text{dm}^{-3}$), oxidability and BOD_5 ($\text{mg O}_2 \cdot \text{dm}^{-3}$), oxygen saturation (%), pH

Mean sulphate content was higher in the *Nymphaea candida* phytocoenoses, while those of all the other properties lower. No statistically significant differences were found regarding other properties. However, it is worth noticing that mean phosphate, $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ contents were also lower in waters dominated by *Nymphaea candida*. This concerned also the contents of sodium, potassium and dissolved SiO_2 , although to a lesser extent.

The sediments in the phytocoenoses compared were similarly differentiated (Fig. 2, Table 3). The sediments in the *Nymphaea candida* phytocoenoses had narrower ranges of the following properties: the contents of organic matter, total nitrogen, iron, $\text{NH}_4\text{-N}$, potassium, sodium, dissolved SiO_2 , chloride,

Table 2

Chemical and physical properties of waters of the *Nymphaeetum candida** (Nc) and *Nupharo-Nymphaeetum albae* (NNa) phytocoenoses (means and their 95% confidence limits)

Properties	Unit	Nc n = 19	NNa n = 21	Significance Nc>NNa
pH		7.95	7.75	—
Total hardness		3.38 ± 0.27	3.85 ± 0.32	+
Carbonate hardness	mval · dm ⁻³	2.86 ± 0.27	3.24 ± 0.26	+
Ca	mg · dm ⁻³	29.58 ± 1.95	40.66 ± 8.32	+
Mg	mg · dm ⁻³	13.80 ± 0.93	16.05 ± 3.46	—
K	mg · dm ⁻³	1.56 ± 0.21	1.83 ± 0.46	—
Na	mg · dm ⁻³	3.53 ± 0.31	4.03 ± 0.77	—
Cl	mg · dm ⁻³	9.91 ± 1.91	12.82 ± 1.94	+
SO ₄	mg · dm ⁻³	33.47 ± 4.89	25.24 ± 5.31	+
Dissolved SiO ₂	mg · dm ⁻³	5.25 ± 1.84	5.68 ± 1.94	—
Fe	mg · dm ⁻³	0.122 ± 0.059	0.110 ± 0.048	—
Colour	mg Pt · dm ⁻³	18 ± 2	24 ± 5	+
PO ₄ -P	mg · dm ⁻³	0.032 ± 0.025	0.082 ± 0.061	—
NO ₃ -N	mg · dm ⁻³	0.038 ± 0.008	0.061 ± 0.030	—
NH ₄ -N	mg · dm ⁻³	0.26 ± 0.06	0.33 ± 0.10	—
Oxidability	mg O ₂ · dm ⁻³	10.09 ± 1.18	9.29 ± 1.95	—
BOD ₅	mg O ₂ · dm ⁻³	4.00 ± 0.88	3.30 ± 0.70	—
Oxygen saturation	%	112.0 ± 11.13	108.24 ± 10.19	—

+ = significant at P=0.05; — = not significant at P=0.05

Table 3

Chemical and physical properties of substrates of the *Nymphaeetum candida* (Nc) and *Nupharo-Nymphaeetum albae* (NNa) phytocoenoses (means and their 95% confidence limits)

Properties	Unit	Nc n = 19	NNa n = 21	Significance Nc>NNa
Hydration	%	78.46 ± 5.69	82.42 ± 5.13	—
Organic matter	%	27.02 ± 6.65	36.87 ± 11.04	—
Oxidability	g O ₂ · kg ⁻¹ dry wt.	79.17 ± 31.43	133.71 ± 67.53	—
N-tot	g · kg ⁻¹ dry wt.	7.86 ± 2.19	11.08 ± 4.76	—
PO ₄ -P	g · kg ⁻¹ dry wt.	0.783 ± 0.332	0.473 ± 0.219	—
Fe	g · kg ⁻¹ dry wt.	3.66 ± 1.34	3.96 ± 1.53	—
NO ₃ -N	g · kg ⁻¹ dry wt.	0.0042 ± 0.0010	0.0196 ± 0.0099	+
K	g · kg ⁻¹ dry wt.	0.80 ± 0.42	0.93 ± 1.06	—
Na	g · kg ⁻¹ dry wt.	0.46 ± 0.13	0.99 ± 0.42	+
Dissolved SiO ₂	g · kg ⁻¹ dry wt.	0.66 ± 0.16	0.77 ± 0.44	—
Cl	g · kg ⁻¹ dry wt.	0.34 ± 0.10	1.35 ± 0.80	+
SO ₄	g · kg ⁻¹ dry wt.	2.42 ± 0.65	6.24 ± 4.79	—
Ca	g · kg ⁻¹ dry wt.	98.08 ± 66.86	148.54 ± 42.00	—
Mg	g · kg ⁻¹ dry wt.	3.20 ± 0.90	7.31 ± 2.17	+
pH		6.7	6.7	—

+ = significant at P=0.05; — = not significant at P=0.05

sulphate, magnesium, oxidability and pH. Most had higher minimum and lower maximum values than those in *Nymphaea alba* phytocoenoses. Only the ranges of phosphate and calcium contents were slightly wider in *N. candida* phytocoenoses. Also the comparison of mean values of sediment properties between the phytocoenoses studied seems interesting. It showed that among 15 analysed properties as many as 13 had lower mean values in the phytocoenoses with *Nymphaea candida*. Only mean value of phosphate content was slightly higher. The statistical analysis, however, proved the differences to be significant only for the contents of nitrate, chloride, sodium and magnesium.

Fig. 2. Ranges of chemical and physical properties of substrates of the *Nymphaetum candidae* and *Nupharo-Nymphaetum albae* phytocoenoses. All values in $\text{g}\cdot\text{kg}^{-1}$ dry weight, except: hydration and organic matter (%), oxidability ($\text{g O}_2\cdot\text{kg}^{-1}$ dry weight), pH

DISCUSSION

The habitat differences between *Nymphaetum candidae* and *Nupharo-Nymphaetum albae* have been often emphasized. For instance, Matuszkiewicz (1981) has showed that the phytocoenoses with *Nymphaea candida*

often inhabit water bodies poorer in nutrients and always very shallow, as compared to those occupied by the communities with *N. alba* and *Nuphar lutea*. This has been confirmed by Rejewski (1981) for *N. candida* phytocoenoses in the Tuchola Primeval Forests, that were confined to poor *Lobelia* lakes, and also in autecological studies of Casper and Krausch (1981). The latter have emphasized that *Nymphaea candida* occurs mainly in meso- and dystrophic waters, whereas in eutrophic bodies it is a less vital and weak competitor. To the contrary, *N. alba* grows mainly in the latter. However, all these remarks were based only on field observations, and not on the habitat analysis. Hence, the obtained results provide new data on the habitats of the phytocoenoses studied. The data indicate marked differences in ecological amplitudes and the optima of occurrence between both phytocoenose types. It seems that the phytocoenoses with *Nymphaea candida* have narrower amplitudes with respect to water and substrate than those with *N. alba*. Narrower amplitudes are also accompanied by lower mean property values. This indicates that the optimal stands of these phytocoenoses are located in fairly soft, poor-in-nutrients waters, on substrates also poor (except phosphate content). On the other hand, the phytocoenoses with *Nymphaea candida* require for their development higher minimum nutrient content than those with *N. alba*. Hence, one may assume that the phytocoenoses with *Nymphaea candida* have narrower, more strict habitat requirements.

The results from north-eastern Poland presented here are possibly of a wider, above-regional value, as they confirm autecological Pietsch's (1982) data and also those of Van der Velde et al. (1986).

Pietsch's (1982) and Van der Velde et al. (1986) data indicate that *Nymphaea candida* grows in waters of narrower ranges, regarding many components and factors, than *N. alba*. This concerns: total hardness, the contents of magnesium, potassium, sodium, chloride, phosphate, nitrate (lower maximum values), sulphate, dissolved SiO_2 , iron (higher minimum values) and calcium (higher minimum and lower maximum values) in the former work, and in the latter — the contents of calcium, magnesium, potassium, sodium, $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$ and phosphate (higher minimum and lower maximum values). The waters studied by Van der Velde et al. (1986) were richer in sulphates (higher minimum and maximum values). Their results concerning substrates are similar. The phytocoenoses with *Nymphaea candida* grow on substrates with narrower amplitudes with respect to the contents of $\text{NO}_3\text{-N}$, chloride, magnesium, and pH (higher minimum and lower maximum values), and wider amplitudes regarding phosphate (higher maximum). The data also indicate higher requirements of *Nymphaea candida*, as compared to *N. alba* regarding potassium, iron and sulphate contents in a substrate (higher minimum values).

Irrespective of similar trends, the ranges of habitat properties given by the above authors for *Nymphaea candida* and *N. alba* were much wider than those

obtained for the analysed phytocoenoses built by these species. It has been, however, often encountered that phytocoenoses have generally narrower ecological amplitudes than their component-species (Matuszkiewicz 1981), being better indicators of habitat properties.

Habitat differences found between the phytocoenoses dominated by *Nymphaea candida* and those of *Nupharo-Nymphaeetum albae*, dominated by *N. alba* however, do not explain the lack of their co-occurrence in the analysed lakes. Undoubtly, both narrower ecological amplitude of *Nymphaea candida* phytocoenoses and their confinement to poor-in-nutrients waters, favour their recession from water bodies, especially due to ongoing eutrophication, and replacement by the phytocoenoses with *N. alba* and *Nuphar lutea*. The regression of *Nymphaea candida* phytocoenoses due to the eutrophication was observed in the lakes Szlinokienskie and Kaczan, in north-eastern Poland. As recently as ten years ago, the communities dominated by *Nymphaea candida* occupied large proportion of the area of these water bodies (Tomaszewicz and Kłosowski 1985). Presently, only single specimens have survived, the former phytocoenoses being replaced by those with *Nuphar lutea*. The lakes currently occupied by *Nymphaea candida* phytocoenoses can be classified as weakly eutrophic to mesotrophic, like small, in-forest water bodies (the Dubinek, Kołowinek and Legenda). The obtained results confirm those of Casper and Krausch (1981) on *Nymphaea candida* being weaker and less vital competitor in eutrophic waters.

The obtained results need confirmation on wider data. For instance a revision of the distribution of localities of *Nymphaea candida* and *N. alba* is required due to their often erroneous identification. However, already on the grounds of the present results one should consider the phytocoenoses with *Nymphaea candida* as markedly different regarding their habitats from the phytocoenoses dominated by *N. alba*. The former develop on habitats with fairly narrower ecological amplitudes regarding properties of waters and substrates, and require higher minimum nutrient content. Ecological amplitude of *N. alba* phytocoenoses is considerably wider. Habitat distinction of the *Nymphaea candida* phytocoenoses fully justifies their classification as a separate syntaxon, *Nymphaeetum candidae*.

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Warunki siedliskowe fitocenoz Nymphaeetum candidae Miljan 1958 i Nupharo-Nymphaeetum albae Tomaszewicz 1977 z dominacją Nymphaea alba

Streszczenie

Przeprowadzono fitosocjologiczno-ekologiczną analizę siedlisk 19 fitocenoz *Nymphaeetum candidae* i 21 fitocenoz *Nupharo-Nymphaeetum albae* budowanych przez *N. alba* z jezior północno-wschodniej Polski. Na podstawie badań chemiczno-fizycznych właściwości wód i podłoża w obu typach fitocenoz wykazano wyraźne różnice ich amplitud ekologicznych i optimum występowania. Płaty z *Nymphaea candida* rozwijają się na siedliskach o stosunkowo wąskich zakresach większości analizowanych właściwości wody i podłoża. Optimum rozwoju osiągają one na siedliskach uboższych w substancje pokarmowe, wymagają jednak większych minimalnych zawartości składników pokarmowych. Amplituda troficzna fitocenoz budowanych przez *N. alba* jest zdecydowanie szersza, a optimum ich rozwoju obejmuje wody i podłoża ogólnie żyzniejsze. Siedliskowa odrębność fitocenoz z *Nymphaea candida*, wyrażona stosunkowo wąską amplitudą troficzną, potwierdza słuszność wydzielenia *Nymphaeetum candidae* jako samodzielnego syntaksonu.