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# Synusial assemblages of pleustonic plants of the genera Lemna, Spirodela, Wolffia, Salvinia, Hydrocharis, Riccia and Ricciocarpus

Jerzy WOŁEK

# 1. INTRODUCTION

As often demonstrated, assemblages of free floating water plants (= pleustonic plants) establish their synusiae within rush and aquatic vegetation (PANKIN 1947, LOHAMMAR 1965, HEJNY 1971, KEPCZYNSKI 1972, REJMANKOVA 1975, PASSARGE 1978, FINTHA 1979, OCHYRA and TOMASZEWICZ 1979 and others). Besides a few scarce and general remarks, however, no more detailed data on the subject have as yet been published.

In this paper, the results of studies are represented on the occurrence of individual pleustonic plant species and their assemblages within different plant communities occurring in aquatic habitats.

## 2. MATERIAL AND METHODS

Nine pleustonic species were considered, including Lemna minor L., L. trisulca L., L. gibba L., Spirodela polyrrhiza (L.) Schleid., Wolffia arrhiza (L.) Wimm., Salvinia natans (L.) All., Riccia fluitans L., Ricciocarpus natans (L.) Corda and Hydrocharis morsus-ranae L. All but the last species are unanimously regarded as characteristic of the class Lemnetea. As to Hydrocharis morsus-ranae, opinions are divided, and more relevant information is to be found in WOŁEK (1983). The study in question was carried out with phytosociological data which had already been used to study determinants of species composition in pleustonic assemblages (WOLEK 1983). In addition, use was made of synthetic tables worked out by TOMASZEWICZ (1980). Of the relevés collected by the present author, only those with a clearly defined syntaxonomic position were taken into account. In general, this study does not include relevés which are classed in the Myriophyllo-Nupharetum W. Koch 1926 and Scirpo-Phragmitetum W. Koch 1926 associations because latest findings show that phytocoenoses, included until recently in the two syntaxons mentioned above, represent different associations which often belong to separate alliances (TOMASZEWICZ 1973, 1977). Likewise, for obvious reasons, pleustonic associations, as well as Hydrocharitetum morsus-ranae van Langendonck 1935, were not considered in this paper. On the whole, 738 phytosociological records, selected from the author's collection, were used. This selection as well as the data taken from TOMASZEWICZ (1980) served as the basis for an inventory of all plant associations occurring in the aquatic habitats. All associations were registered in which even one of the above mentioned pleustonic species was found, regardless of its degree of abundance.

# 3. RESULTS

Based on the author's material, individual pleustonic species were found in 42 associations assembled in 12 alliances. These associations embrace aquatic and rush phytocoenoses as well as phytocoenoses of wet alderwood, therophytes, minor amphibian perennials and phytocoenoses which develop in both oligotrophic waters of fens and dystrophic waters of fens and raised bogs. On the basis of synthetic tables provided by TOMASZEWICZ (1980) the presence of pleustonic plants was demonstrated in 54 aquatic and rush associations classed into nine alliances. Considering 34 associations common in both cases, the total number of plant associations penetrated by pleustonic species amount to 64 associations assembled in 14 alliances. These associations are listed in Table 1 along with an indication of those pleustonic plant species that are encountered in them.

At first sight two distinct groups of species are easily recognizable, one including *Lemna minor*, *L. trisulca*, *Spirodela polyrrhiza* and *Hydrocharis morsus-ranae* and the other comprised of *Wolffia arrhiza*, *L. gibba*, *Salvinia natans*, *Riccia fluitans* and *Ricciocarpus natans*. Species of the first group recur fairly regularly in all associations of the aquatic and rush plants, while species of the second group occur mainly in the associations of the alliances Nymphaeion, Phragmition and Magnocaricion. The latter species are missing entirely in associations of the alliance Charion fragilis. L. minor, L. trisulca, S. polyrrhiza and Hydrocharis morsus-ranae penetrate, respectively, 49, 50, 36 and 43 plant associations, on average 44.5 associations. On the other hand, W. arrhiza, L. gibba, S. natans, R. fluitans and R. natans penetrate, respectively, 7, 8, 8, 12 and 8 plant associations, on the average 8.6 associations. In sum, species of the first group penetrate five times as many associations as do species of the second group. What is surprising here, is how negligible the differences are between species within each group in regards to the penetrated associations as shown in Table 1, and in this respect, how the boundary is marked between species belonging to separate groups.

The occurrence of pleustonic assemblages in plant associations occurring in aquatic habitats was determined on the basis of the author's relevés (Table 2), because synthetic tables prepared by TOMASZEWICZ (1980) were not appropriate for this purpose. Individual associations in the sample were, for the most part, represented in a small number of relevés, they were therefore presented in the form of plant alliances.

In Table 2, the fractions of relevés containing 1 to 7 pleustonic species as related to plant alliances are presented. The fractions are not given in the form of relative numbers because of the generally small size of samples (N<50). For the same reason, distributions shown in Table 2 are not quite suitable for a detailed statistical analysis. Fairly credible conclusions concerning the occurrence frequency of k-species combinations can be made in the cases of Magnocaricion and Phragmition because only in these cases sufficient numbers of relevés exist (Table 2). Since the observed distributions of relevés, characteristic of both these alliances, show a fairly good agreement, both samples of relevés were combined and the fractions of relevés that fall into each category of random variable, k, were calculated for such a general sample. The greatest number of relevés, i.e. 46.6%, contained one-species pleustonic assemblages. Two-species assemblages were found in 32.8% of the relevés, those of 3-species in 15.8%, 4-species assemblages were present in 3.7%, and 5-species in 1% of the relevés. Consistently, in the alliances Magnocaricion and Phragmition there occur mainly assemblages composed of a small number of pleustonic species, multi-species assemblages being extremely rare. It is supposed that the frequency distribution of k-species pleustonic assemblages in the remaining alliances is probably the same as in the case of Magnocaricion and Phragmition alliances. It is probably possible to

**Table 1.** Occurrence of Lemna minor (1), L. trisulca (2), Spirodela polyrrhiza (3), Hydrocharis morsus-ranae (4), Wolffia arrhiza (5), Lemna gibba (6), Salvinia natans (7), Riccia fluitans (8), and Ricciocarpus natans (9) in plant associations occurring in aquatic habitats. Syntaxonomy of the associations according to TOMASZEWICZ (1980) and MATUSZ-KIEWICZ (1981).

Class Order				S	pe	cie	s			
Alliance					1					
Association	1	2	3	L,	5	6	7	8	9	
Association					-		÷			
Charetea Fukarek 1961										
Charetalia Sauer 1937										
Charion fragilis Krausch 1964										
Nitellopsidetum obtusae (Sauer 1937) Dambska 1961		х								
Charetum fragilis Fijałkowski 1960	x		х							
Charetum contrariae Corillion 1957	x	х								
Charetum jubatae Krausch 1964		х								
Charetum rudia Dąmbska 1966		х								
Charetum aculeolatae (Corillion 1957) Dąmbska 1966	x			х						
Charetum vulgaris Corillion 1957	x	х								
Charetum coronatae Corillion 1957		х	х							
Charetum hispidae Corillion 1957	x	х		х						
Charetum strigosae Dąmbska 1966	x									
Nitellion Dambaka 1966										
zbiorowisko z Nitella mucronata	x									
Potamogetonetea R. Tx. et Preisg. 1942										
Potamogetonalia W. Koch 1926										
Potamogetonion (W. Koch 1926) Oberd. 1957										
Potamogetonetum lucentis Hueck 1931	x	х	х	х						
Potamogetonetum perfoliati (W. Koch 1926) Pass. 1964			х							
Potamogetonetum pectinati Carstensen 1955 .	x	х		х						
Myriophylletum verticillati Soó 1927	x	х	х	х			х			
Myriophylletum spicati Soó 1927	x			х						
Ranunculetum circinati (Bennema et Westh. 1943) Segal 1965	x	х								
Elodeetum canadensis (Pign. 1953) Pass. 1964	x	х	х	х		х	х			
Ceratophylletum demersi Hild 1965	x	х	х	х						
Potamogetonetum obtusifolii (Carstensen 1954) Segal 1965		x	х	х						
Parvopotamogetoneto-Zannichelietum W. Koch 1926		х								
Potamogetonetum filliormis W, Koch 1920		~		×						
Numberton W. Kash 1026		x								
Numberato-Numphasetum albas (Comparautor 1977	l v	×	~	Y						
Numphasetum candidae Milian 1958	Î.	Ŷ	Ŷ	Ŷ						
Nunharetum numili Oberd. 1957		Ŷ	^	^						
Tranetum netantis Müller et CMrs 1960	×	x	Y	x	Y	Y	¥	×		
Nymphoidetum peltatae (All, 1922) Oberd, et MAller 1960	×	x	Ŷ	Ŷ	^	^	Ŷ	Ŷ	¥	
Potemogetonetum natantis Soó 1927	x	Ŷ	x	x		¥	Ŷ	Ŷ	^	
Polygonetum natentis Soó 1927		Ŷ	^	^		^	~	~		
Hottonion Segal 1964		^								
Hottonietum palustris R. Tx. 1937	x	x	x	x				x	Y	
								~	~	
Phragmitetea R. Tx. et Preisg. 1942										
Phragmitetalia W. Koch 1926										
Phragmition W. Koch 1926										
Scirpetum lacustris (All. 1922) Chouard 1924	x	х	х	х						
Typhetum angustifoliae (All. 1922) Soó 1927	х	х	х	x	x					
Phragmitetum (Gams 1927) Schmale 1939	x	х	х	x						
Equisetum limosi Steffen 1931	х	x	х	х				х	х	

Table 1 (continued)

Class Order				S	Spe	ec	ie	S				
Alliance								_	-	0	0	
Association	1	2	2	3	4	-	2	6	1	8	9	
Typhetum latifoliae Soó 1927	x	)	¢	х	x	>	x.	x		х	х	
Sparganietum erecti Roll 1938	x	)	¢	x	х					~	~	
Glycerietum maximae Hueck 1931	x	2	¢	х	x			x		~	~	
Acoretum calami Kobendza 1948	×	2	¢	x	х			х				
Scirpetum maritimi (Christ. 1934) R. Tx. 1937	×	3	ĸ	x	12.2							
Oenantho-Rorippetum Lohm. 1950	x		ĸ	х	×		x					
Cladietum marisci (All. 1922) Zobr. 1935					×							
Thelypteridi-Phragmitetum Kuiper 1957	x		x		*							
Eleocharido-Sagittarion Pass. 1964					~							
Eleocharitetum palustris Schennikow 1919	x		x	x	x				~			
Sagittario-Sparganietum R. Tx. 1953	x		x	x	×				~			
Hippuridetum vulgaris Pass. 1955			x		X							
Sparganio-Glycerion BrBl. et Siss. 1942				~								
Sparganio-Glycerietum fluitantis BrBl. 1925			~	x								
Glvcerietum plicatae Oberd. 1957	^		x									
Magnocaricetalla Pign. 1953												
Magnocaricion W. Koch 1926												
Phalaridetum arundinaceae Libb, 1951		c .	х	x	x			х	x		х	
Caricetum gracilis (Graebn, et nueck 1991) N. IX. 1991		Ϋ́	x	x	x							
Caricetum acutiformis Sauer 1997		x	x	x	x							
Caricetum ripariae Soo 1928		x	x	x	x					х	х	
Caricetum elatoe W. Koch 1920		x	x	x	x					x	х	
Carleetum rostratae Ruber 1912		x	x	x	x	2	х		х	х		
Cartestum vasioonise Br -Hi et Denis 1926		x	х	х	x	c						
Laricetum vesicariae BrBi. et Denis ().co		х	x	x	x	c	х	x				
Ciente Caricotum pseudocuperi de Boer 1942		х	х	х	2	c	х					
Caricetum distichae (Nowiński 1928) Jonas 1933					>	c						
Ridentates trippytiti R. Ty. John, et Preise, 1950												
Bidentetelia tripertiti Br -Bl. et B. Tx. 1943												
Bidention tripartiti Nordh, 1940												
Polygono-Bidentetum (W. Koch 1926) Lohm. 1950		х	x									
Utricularietea intermedio-minoris Den Hartog et Segal 1964 em. Pie	etsch	19	65									
Utricularietalia intermedio-minoris Pietsch 1965												
Sphagno-Utricularion Hüller at CBrs 1960												
Sparganietum minimi Schaaf 1925		х	х		2	x				3	C	
Littorelletca uniflorae BrBl. et R. Tx. 1943												
Littorelletalia uniflorae W. Koch 1926												
Eleocharition acicularis Pietsch 1966 em. Dierss. 1975 Eleocharitetum acicularis (Baumann 1911) W. Koch 1926											ĸ	
Scheuchzerio-Caricetea (Nordh. 1937) R. Tx. 1937												
Caricetalia fuscae W. Koch 1926 em. Nordh. 1937												
Caricion fuscae W. Koch 1926 em Klika 1934												
Carici-Agrostietum caninae R. Tx. 1937						х						
Almoston glut(nonco $Bp = B$ ) at $B = \frac{m}{2} = \frac{10/3}{2}$												
Almotalia glutinosae B. Tx. 1047												
Ainecaira giucinosae N. IX. 1991												
Alphon alutinaceo inela servici nel per la												
Alnion glutinosae (Maic, 1929) Meijer Drees 1950						х						

**Table 2.** Occurrence of pleustonic assemblages in different alliances of plant associations of aquatic habitats. The Table was prepared on the basis of 738 relevés selected from the author's collection.

	N				k			
Alliance		1	2	3	4	5	6	7
Eleocharis acicularis	1	1						
Caricion fuscae	1	1						
Alnion glutinosae	2	2						
Bidention tripartiti	6	4	2					
Charion fragilis	7	5	1	1				
Eleocharido-Saggitarion	19	4	6	8	1			
Sphagno-Utricularion	22	12	7	2	1			
Hottonion	47	12	13	10	12			
Potamogetion	43	20	10	6	6	1		
Magnocaricion	234	117	73	34	9	1		
Phragmition	302	133	103	51	11	4		
Nymphaeion	51	10	8	7	13	11	1	1

N = number of relevés in a sample, k = number of pleustonic species in a relevé

demonstrate this thesis by means of an adequately large sample of relevés. As it follows from Table 2, the plant alliances in question my be ordered in regards to the maximal number of pleustonic species observed in an assemblage in a given alliance. As it may be seen, one-species pleustonic assemblages occur in the associations of the alliances Eleocharition acicularis, Caricion fuscae and Alnion glutinosae, those of 1-2-species occur in associations of the alliance Bidention tripartiti, those of 1-3-species in associations of the alliance Charion fragilis, those of 1-4-species in associations of the alliances Eleocharido-Sagittarion, Sphagno-Utricularion and Hottonion, 1-5-species in associations of the alliances Potamogetonion, Magnocaricion and Phragmition, and 1-7-species in associations of the alliance Nymphaeion. Thus it may seem that when passing from the habitats of the alliance *Eleocharition* acicularis to those of the alliance Nymphaeion, the pleustonic assemblages find increasingly more suitable living conditions. However, there is an obvious correlation between the maximal number of species in a pleustonic assemblage and the sample size: the more numerous the relevés representing a given alliance, the higher the number of pleustonic species that are encountered in them. The foregoing methodical consideration should be taken into account when examining the influence that different habitats (symbolized by the individual alliances) may exert on the formation of a definite pleustonic assemblage. On the other hand, it cannot be excluded that the small number

of species in a pleustonic assemblage may result from the habitat influence. At the moment, it would be difficult to resolve these doubts due to a scarcity of factographical material.

# 4. DISCUSSION

The results obtained so far suggest that the species under study may be divided into two groups. Species of the first group (*L. minor, L. trisulca, S. polyrrh*iza and *H. morsus-ranae*) penetrate 5 times as many plant associations occurring in aquatic habitats as do the remaining species that belong to the second group. Such an effect could be explained based on the following hypotheses: 1) the null hypothesis assuming that species have identical habitat requirements and that they are dispersed independently of each other (= randomly); 2) the hypothesis assuming that species composition of pleustonic synusium depends mainly on the abiotic factors of habitat (species have different requirements as to the abiotic conditions of habitat and are independent of each other); 3) the hypothesis that species composition of pleustonic synusium depends on biotic factors, mainly on competition between the pleustonic species (species are not independent of each other).

In support of the first hypothesis the fact may be quoted that species of the first group are more common (= more probable) than the species of the second group (Table 3). The occurrence probabilities of the species belonging to the first group are markedly higher than those of the species belonging to the second group, but within each group the occurrence probabilities are very

Species	Frequency	Fraction
Lemna minor	1424	0.293
Lemna trisulca	1080	0.223
Spirodela polyrrhiza	879	0.181
Hydrocharis morsus-ranae	820	0.169
Wolffia arrhiza	221	0.046
Lemna oibha	154	0.032
Salvinia natans	137	0.028
Riccia fluitans	97	0.020
Ricciocarpus natans	41	0.008
Total	4853	1.000

Table 3. Occurrence probabilities of spec	es unde	r study,	estimated	on	the	basis	of	1945
relevés (according to WOLEK 1983).								

similar. If only to assume that the species in question disperse independently of each other (= randomly), that very fact may cause the natural isolation of both groups, i.e. species of the first group will be encountered in a greater number of plant associations than species of the second group. On the other hand, it may as well be admitted that the results obtained testify to the similar habitat requirements shown by the species within each of the distinguished groups, and testify to the fact that species of the first group have a broader ecological scale as compared with that of species of the second group. As frequently demonstrated (LANDOLT 1986), however, the observed differences in species composition of pleustonic synusiae may be sufficiently explained by the varying requirements of the studied species as to the habitat abiotic conditions. Therefore, in the present author's opinion, there is no need for interpreting the analysed data in terms of an interspecific competition. According to the author's opinion, the null hypothesis and the one stressing role of the habitat abiotic conditions do not necessarily exclude each other but may be of a complementary character.

The list of plant associations presented above, providing habitats for pleustonic assemblages, is not yet complete. Further studies will certainly contribute to its completion in many aspects. Among other things, they will enable an explanation of the gaps in the occurrence of certain species in some plant associations occurring in aquatic habitat. For example, it seems hardly probable that the associations, in which one of the following species occurs, could be devoid of the remaining group members: L. minor, L. trisulca, S. polyrrhiza Or H. morsus-ranae. From earlier studies (WOLEK 1983), it follows that combinations of these species are among the most common under natural conditions in Poland. Therefore, it seems that the absence of one of the above species in a given combination within an association of aquatic and rush vegetation is a matter of chance rather than of ecological conditions. However, the latter possibility cannot be entirely excluded. The results of studies by McLAY (1974) attested to this. It also seems possible that further detailed investigations could provide more credible information on the distribution of W. arrhiza, L. gibba, S. natans, R. fluitans and R. natans. In view of their small size (W. arrhiza and R. fluitans) or morphological differentiation (L. gibba and R. natans), some of these species can easily be overlooked, particularly if they are not especially sought after.

It would be interesting to analyse the collected material in detail. Such an analysis should consider the occurrence frequency of individual pleustonic species in different associations, particularly in aquatic and rush associations. It should also consider the occurrence frequency of definite pleustonic assemblages in these associations. Valuable information on ecology of pleustonic plants and of their assemblages could thus be provided. Unfortunately, the available material has so far permitted only the superficial treatment of the subject. It seems, however, that the results obtained constitute a good starting point for further systematic investigations.

## SUMMARY

The paper presents the results of a study on the occurrence of nine pleustonic species in different plant associations growing in aquatic habitats in Poland. Plants of the genera Lemna, Spirodela, Wolffia, Salvinia, Hydrocharis, Riccia and Ricciocarpus were taken into account. The study was based on relevés that already have been applied for studying determinants of species composition in pleustonic assemblages (WOLEK 1983). In addition, use was made of synthetic tables worked out by TOMASZEWICZ (1980). Individual pleustonic species were found in 64 plant associations of aquatic habitats, assembled in 14 alliances (Table 1). Lemna minor; L. trisulca, Spirodela polyrrhiza and Hydrocharis morsus-ranae penetrate respectively, 49, 50, 36 and 43 associations (an average of 44.5 associations), Wolffia arrhiza, L. gibba, Salvinia natans, Riccia fluitans and Ricciocarpus natans were found in respectively, 7, 8, 8, 12 and 8 associations (an average of 8.6 associations). In sum, species of the first group penetrate 5 times as many associations as do species of the second group. The occurrence of pleustonic assemblages in plant communities of aquatic habitats is presented in Table 2. Single-species pleustonic assemblages were found in associations of the alliances Eleocharition acicularis, Caricion fuscae and Alnion glutinosae, those of 1-2 species in association of the alliance Bidention tripartiti, those of 1-3 species in associations of the alliance *Charion fragilis*, those of 1-4 species in associations of the alliances Eleocharido-Sagittarion, Sphagno-Utricularion and Hottonion, those of 1-5 species in associations of the alliances Potamogetonion, Magnocaricion and Phragmition, and assemblages of 1-7 species in associations of the alliance Nymphaeion. The results were interpreted from the viewpoint of three main hypotheses: 1) the null hypothesis (species have identical habitat requirements and disperse independently of each other, i.e. randomly); 2) the hypothesis that species composition of a pleustonic synusium depends on abiotic factors (species have different requirements as to abiotic factors of the habitat and are independent of each other); 3) the hypothesis that species composition of a pleustonic synusium depends on biotic factors, mainly on competition between pleustonic species (species are not independent of each other). According to the author's opinion, differences in species composition of the pleustonic synusiae under study can be sufficiently explained on assuming that species disperse randomly and that their distribution is influenced by the habitat's abiotic factors.

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