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Effects of lake morphometry, emergent vegetation and shore habitat on breeding bird communities

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Abstract. The aim of this study was to investigate the role of lake morphometry, emergent vegetation and the surrounding habitat on breeding bird communities. The analysis was based on the published data covering breeding bird communities of 18 lakes in Western Poland. Seven habitat variables were used in the analysis: lake area, length of shore line, maximum depth, area of rushes, length of shoreline covered by emergent vegetation, length of shoreline covered by forest and presence of islands. A stepwise multiple regression analysis revealed that most of the variation in the total bird species richness was explained by the length of shoreline covered by emergent vegetation. The number of water bird species was predicted by the lake area, since the number of reed and bush birds was dependent on the area of rushes. The most important factors determining the total number of pairs were the lake area and the area of rushes. The number of pairs of water birds was dependent on the lake area and the maximum depth. The density of water birds was negatively correlated with the area of rushes and positively with the lake area. The number of pairs of water birds was statistically higher on lakes with islands than on those without. The abundance of reed and bush birds correlated positively with the area of rushes, hence the density was dependent on the maximum depth and the area of rushes. There was no effect of shoreline covered by forest on the abundance of studied groups of birds.

Key words: water birds, reed and bush birds, lake morphometry, island presence, shore habitat

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INTRODUCTION

The previous studies (Ås et al. 1992, Nudds 1992, Elmberg et al. 1993, 1994) revealed that the area as well as habitat diversity and diversity of prey appear to be important to the species richness of the waterfowl community. Numerous studies indicate that some physiognomic properties of lakes as well as the amount and structure of coverage vegetation, the coverage of vegetation, stands of certain plant species, the depth and general status of the landscape affect the inhabiting of a lake by particular species (Nummi 1992, Kauppinen & Väisänen 1993, Kauppinen 1997).

The benefits of the lake marshes for birds could be explained in terms of reduced nest predation. Such factors as nest concealment, water depth, breeding bird density and the number of predators can influence nest predation in marshes (Dyrcz 1981, Burger 1985, Picman et al. 1993, Jobin & Picman 1997). However, although nesting in marshes reduces the likelihood of mammalian predators it does not offer protection from avian predators and nest parasitism (Øien et al. 1996, Schulze-Hagen et al. 1996). It is known, that some *Passerine* species avoid the afforested shoreline of water reservoirs (Kostyrko 1989, Øien et al. 1996). However, in order to reduce the predation risk, some waterfowl species, mainly ducks, prefer nesting on islands, reaching higher densities compared to dry land (Bengston 1970, Amat 1982, Hill 1984, Stawarczyk 1995).

The aim of this study was to investigate the role of lake morphometry, area of emergent vegetation and surrounding habitat (open/closed) in determining variation in the number of species and abundance of breeding bird species. As different taxonomical or ecological groups of birds may vary in their response to habitat variables (Wiens 1989), patterns of species richness and number of pairs were analysed separately for two morpho-ecological groups: species depending on open water (here called "water birds") and species of reed and bush. Specifically, two predictions were tested:

1) how the presence of islands determines the number of water bird pairs,

2) how the number of species and pairs decreases with an increase in shoreline covered by forest.

STUDY AREA

The lakes studied are all situated in the Wielkopolska region (western Poland) within the area delineated by 16°30'1'', 18°22'1'' E and 52°40'7'', 51°59'0'' N. An attribute of this area is the presence of lakes of post-glacial origin, especially the tunnel-valley lakes. During the breeding season (April–July), mean monthly temperature increases from +7° to +18°C (Kotońska & Tamulewicz 1990). Because the lakes are ice-covered in winter, they are inhabited by migratory bird populations. Most of the lakes studied are situated in agricultural landscape and surrounded by arable land. They are classified as eutrophic lakes. Their emergent vegetation consists mainly of *Phragmites* stands.

MATERIAL AND METHODS

Source of data and census methods

The analysis was based on the published data on the breeding bird communities of 18 lakes (Table 1), collected between 1972 and 1995, mainly during the last seven years. Most of the data were obtained by uniform field methods described by Borowiec et al. (1982) and Ranoszek (1983). This method is appropriate for censusing the whole breeding avifauna of selected reservoirs or their complexes. To avoid pseudoreplication (Hurlbert 1984), in the case of the lakes studied during two years only one was randomly selected for the analysis. In the case of Lednica Lake, when the increase in the water level and reconstruction of emergent vegetation was observed, the data from 1995 were included (Kosiński 1997).

Species belonging to three morpho-ecological groups of birds were considered as breeding bird communities (Jakubiec 1978, Kauppinen 1993):

1) water birds (*Anas* spp., *Aythya* spp., *Fulica atra*, *Cygnus olor*, *Podiceps* spp.),

2) birds of reed and bush (*Botaurus stellaris*, *Ixobrychus minutus*, *Rallus aquaticus*, *Gallinula chloropus*,

Table 1. Data used in the study; Sp — number of species, P — number of pairs.

Lake	Year	All birds		Water birds		Reed and bush birds		Source
		Sp	P	Sp	P	Sp	P	
Bytyńskie	1973	19	517	9	164	8	331	Wesołowski 1973
Swarzędzkie	1979	15	263	4	93	9	167	Kupczyk 1987
Bnińskie	1989	14	584	6	308	6	273	Giertych 1997
Borówieckie	1989	9	75	2	10	7	65	—"—
Jeziory Małe	1989	8	80	5	73	3	7	—"—
Jeziory Wielkie	1989	8	60	3	50	5	10	—"—
Kórnickie	1989	12	195	6	101	6	94	—"—
Łękno	1989	10	69	5	56	5	13	—"—
Skrzyneckie Duże	1989	9	104	4	53	5	51	—"—
Czartowo	1989	14	111	6	62	7	47	Kupczyk 1997
Skulska Wieś	1989	11	195	3	63	7	131	—"—
Skulskie	1989	16	346	7	188	6	155	—"—
Staw Deszna	1989	7	30	2	5	5	25	—"—
Tryszczyn	1991	10	65	5	45	4	19	—"—
Dolskie Małe	1988	15	125	4	16	8	105	Łucka 1997
Dolskie Wielkie	1989	18	419	5	86	9	318	—"—
Popielewskie	1993	18	430	6	242	10	188	Dzięgielewski 1995
Lednica	1995	19	548	7	232	10	308	Kosiński 1997

Porzana spp., *Acrocephalus* spp., *Locustella* spp., *Emberiza schoeniclus, Panurus biarmicus*),

3) flight feeders (*Circus aeruginosus, Chlidonias niger, Larus ridibundus, Sterna hirundo*).

Additionally *A. anser* and *G. grus* were included into the bird communities because they nested in rushes. On the other hand, typical shore bush insectivores (*Remiz pendulinus, Luscinia* spp., *Carpodacus erythrinus*) were excluded from the analysis because of their dependence on dry land vegetation. From the total number of pairs, pairs of terns and gulls were excluded because their presence was limited only to a few lakes and the abundance sometimes exceeded the total number of other species. The number of species and pairs of breeding bird community, water birds and birds of reed and bush were treated as single variables (Table 1). In the case of each group of birds density was calculated using three calculation units: 10 ha of lake area (LA), km of shoreline covered by emergent vegetation (SV) and 10 ha of rushes (AR).

Description of lakes

Six habitat variables and separately the presence of islands were used in the analysis (Table 2). The main sources of data were: The Atlas of Polish Lakes (Jańczak 1996) and the bathymetric plans of the Institute of Inland Fishing in Olsztyn. Some data were obtained from original ornithological papers and maps. The maximum depth was used as a proper habitat characteristic because data on mean depths of the lakes were incomplete, and these factors were strongly correlated ($r = 0.98$, $p < 0.05$, $N = 15$). Since only 5 of the lakes studied had islands, the analysis considered information only about presence or absence of this element. Islands were mostly afforested except the islands on Bytyńskie Lake.

Data analysis

To meet the requirements of parametric analyses all variables were log-transformed according to the formula $y = \log(x + 1)$. After transformation, distributions of all variables did not differ from the normal distribution (Kolmogorov-Smirnov test: $p > 0.05$ in all cases). The data were analysed by pairwise correlation and stepwise multiple regression (Sokal & Rohlf 1995). Because most of the habitat variables were strongly intercorrelated (Table 3) and some of them could be redundant in contribution to the final model of regression, the tolerance of variables was defined as 0.6. In this way reliability of regression coefficients increases. The relationships between the species number and the abundance of waterfowl were examined using analysis of covariance (ANCOVA) to investigate the effect of island presence. As covariates, the habitat variables, which significantly explained variation of species richness and number of pairs, were used. All statistics were performed on the basis of statistical software package STATISTICA (StatSoft, Inc. 1997).

RESULTS AND DISCUSSION

Bird–habitat relationships

A pairwise correlation analysis indicated that the number of species and pairs in the community of two

Table 2. Habitat variables of 18 lakes studied.

Habitat variable	Mean (Min–Max)	SD
Lake area (ha) — LA	117.2 (2–339)	107.9
Length of shoreline (m) — LS	7707.8 (550–26680)	7257.5
Maximum depth (m) — MaxD	9.9 (0.4–46)	10.2
Area of rushes (ha) — AR	12.4 (0.4–36)	12.8
Shoreline covered by emergent vegetation (m) — SV	5458.2 (494–18501)	5144.5
Shoreline covered by forest (m) — SF	1224.4 (0–2825)	938.1

Table 3. Intercorrelation between habitat variables (symbols see Table 2); * P < 0.05, ** P < 0.01.

Habitat variable	LS	MaxD	AR	SV	SF
LA	0.959**	0.638**	0.562*	0.771**	0.054 NS
LS	–	0.646**	0.597**	0.821**	0.070 NS
MaxD		–	0.083 NS	0.386 NS	0.361 NS
AR			–	0.876**	–0.188 NS
SV				–	–0.167 NS

morpho-ecological groups of birds correlated positively with most of the habitat variables (Table 4). The reason for this was the strong multicollinearity of morphometric measures. Hence, to find the best predictors of species and pair numbers, the stepwise multiple regression was used.

The species number of water birds and birds of reed and bush varied in their response to habitat variables (Table 5). This was a consequence of the occupation of different parts of lakes by both groups of birds. In spite of nesting in the rushes, water birds depend on the open water surface where they feed, since the birds of reed and bush depend on emergent vegetation in relation both to nest site and feeding location. The relatively low share of the lake area influencing changes in the number of water bird species as well as reed and bush birds indicated that other factors, not included in this analysis, seem to be of importance in forming the species number of this group of birds, e.g. habitat diversity and/or abundance and diversity of prey (Elmberg et al. 1994). On the other hand some other results suggested that the lake area must have been important in the habitat selection and in forming waterfowl bird assemblages (Sillen & Solbreck 1977, DesGranges & Darveau 1985, Kauppinen & Väisänen 1993, cf. Nudds 1992).

Table 4. Pairwise correlation between species (Sp) and pair numbers (P) in different groups of birds and habitat variables (symbols see Table 2); *p < 0.05, **p < 0.01.

Habitat variable	All birds		Water birds		Reed and bush birds	
	Sp	P	Sp	P	Sp	P
LA	0.760**	0.891**	0.721**	0.892**	0.505*	0.664**
LS	0.788**	0.881**	0.704**	0.864**	0.584*	0.681**
MaxD	0.436 NS	0.481*	0.708**	0.792**	0.065 NS	0.144 NS
AR	0.814**	0.751**	0.409 NS	0.342 NS	0.762**	0.897**
SV	0.852**	0.835**	0.606**	0.620**	0.746**	0.835**
SF	0.010 NS	0.006 NS	0.209 NS	0.253 NS	–0.184 NS	–0.205 NS

Table 5. Factors affecting variation in number of species in different groups of birds. Adjusted R^2 are given; *P < 0.01.

Variables		B	SE	t	P
All species	$R^2 = 0.71$*				
	SV	0.251	0.038	6.5	< 0.01
Water birds	$R^2 = 0.49$*				
	LA	0.190	0.046	4.2	< 0.01
Reed and bush birds	$R^2 = 0.55$*				
	AR	0.170	0.036	4.7	< 0.01

In opposition to previous studies the shoreline covered by emergent vegetation (SV) was the best single factor explaining the pattern of the total number of species (Table 5). This factor indicates the role of the emergent vegetation as the nest site location for most of the birds breeding on the lakes. It is likely that the increase in shore length covered by emergent vegetation increased the habitat diversity. In this sense, the increase in species number could be affected by increasing spatial heterogeneity. According to the spatial heterogeneity hypothesis (Wiens 1989, Nudds 1992), more-complex environments support more-diverse communities, and more diverse habitats provide more resources. However, data collected in Sweden and Finland showed that the length of shoreline was poorly or not correlated with the habitat diversity (Sillen & Solbreck 1977, Elmberg et al. 1994). It is possible that these differences could have been caused both by lake size effect and the selection of different variables for analysis and/or could have been scale dependent (Sillen & Solbreck 1977, Wiens 1981, 1989).

The lake area (LA) and the area of rushes (AR) were the most important factors in determining the total number of pairs (Table 6). This dependence seemed to be connected with the number of accessible food resources. It concerned mainly waterfowl, which dominated in the biomass over the reed and bush birds. Because marshes are thus characterised by the variety and renewed source of food, food accessibility should not limit the number of birds inhabiting this area (Burger 1985). In the case of water birds the increase in the lake area and its depth may cause the occurrence of new feeding niches and also extension of the existing areas e.g. for the *P. cristatus* and diving ducks (Giertych 1997). However, the increase in the lake depth may thus restrict the number of species and pairs, mainly dabbling ducks (Kauppinen 1993). The use of maximum depth as an independent variable instead of mean depth (which better describes the depth of whole lake) can be disputable. However, the strong correlation between those two variables (see: Description of lakes) indicates, that in the analysed group of lakes, maximum depth reflects not only the deepest point in each of the lakes but the conditions attributable to the whole area of lake. The close connection between the number of water bird pairs and the lake area is also a result of some water birds becoming the territory species during breeding (e.g. *P. cristatus* and *F. atra*). Spacing mechanisms are probably very important in fertile bodies of water (Kauppinen 1993). The influence of the space isolation mechanism on abundance may also concern the reed and bush birds which strongly depend on the rushes area.

It was found that densities of all species were negatively dependent on a variable which was used to estimate the density measure (Table 7). This clear statistical dependence can be explained as an effect of mathematical calculations (e.g. increase in the lake area

Table 6. Factors affecting variation in number of pairs in different groups of birds. Adjusted R^2 are given; *$p < 0.01$.

Variables		B	SE	t	P
All species	$R^2 = 0.87$*				
	LA	0.495	0.077	6.5	< 0.01
	AR	0.265	0.077	3.4	< 0.01
Water birds	$R^2 = 0.86$*				
	LA	0.553	0.099	5.6	< 0.01
	MaxD	0.376	0.117	3.2	< 0.01
Reed and bush birds	$R^2 = 0.82$*				
	AR	0.749	0.122	4.7	< 0.01

Table 7. Factors affecting variation in densities of pairs in different groups of birds. Adjusted R^2 are given; *$p < 0.05$, **$p < 0.01$.

Variables		B	SE	t	P
All species					
pairs/10 ha LA	$R^2 = 0.71$**				
	LA	–0.484	0.074	–6.5	< 0.01
	AR	0.255	0.074	3.4	< 0.01
pairs/km SV	$R^2 = 0.17$*				
	SV	–0.257	0.120	–2.1	< 0.05
pairs/10 ha AR	$R^2 = 0.84$**				
	AR	–0.729	0.077	–9.5	< 0.01
	LA	0.497	0.076	6.5	< 0.01
Water birds					
pairs/10 ha LA	$R^2 = 0.31$**				
	AR	–0.238	0.081	–2.9	< 0.01
pairs/km SV	$R^2 = 0.69$**				
	AR	–0.705	0.116	–6.1	< 0.01
	LA	0.534	0.115	4.6	< 0.01
pairs/10 ha AR	$R^2 = 0.89$**				
	AR	–1.184	0.104	–11.3	< 0.01
	LA	0.881	0.104	8.5	< 0.01
Reed and bush birds					
pairs/10 LA	$R^2 = 0.51$*				
	MaxD	–0.577	0.149	–3.9	< 0.01
	AR	0.304	0.126	2.4	< 0.05

causes decrease in density per 10 ha LA). On the other hand, it could be connected with the presence of groups of birds in the whole community which strongly differed in their response to habitat variables. In these cases, the mathematical calculations can not be separated from biological significance of the studied morphometric measures.

There were no such situations in the case of both morpho-ecological groups of birds. The density of water birds was negatively correlated with the area of rushes and positively with the lake area (Table 7).

Table 8. Effect of island presence on species numbers (Sp) and abundance (P) of water birds.

Source of variation	*df*	*MS*	*F*	*P*
Sp				
LA	1	0.181	17.46	< 0.01
Main effect	1	0.012	1.14	< 0.30 NS
P				
LA	1	0.907	41.50	< 0.01
MaxD	1	0.300	13.70	< 0.01
Main effect	1	0.127	5.83	< 0.03

This dependence is connected with a relationship between plant-cover and the percentage of open water table. The increase in the area of rushes (their percentage cover) causes the decrease in the water table and shortening of the border zone rushes-water which was found to be important for the abundance of some water birds (Łucka 1997). Different results were obtained for boreal lakes in Finland, where waterfowl were correlated positively with the percentage of the total plant-cover (Kauppinen 1993), probably as a result of lower vegetation cover which strongly limited nest site locations. The density of reed and bush birds (pair/10 ha LA) was negatively correlated with the maximum depth (MaxD) and positively with the area of rushes (Table 8). In the case of other density measures there were no linear regressions between studied variables. The negative correlation between density of reed and bush birds and the maximum depth was probably connected with the fact that among the studied lakes deeper ones possess a narrow littoral zone and thus a narrow or unequally distributed zone of rushes, which strongly limited the number of pairs of some species (e.g. Kostyrko 1989, Kosiński 1997).

Effect of island presence

The presence of islands affected the differences in the number of water bird pairs independent of the size and depth of the lake, which had a significant influence on their abundance (Table 8). The abundance of water birds was statistically higher on lakes with islands than on those without islands. There was no difference in the species richness of water birds between these two types of lakes. In numerous papers the significance of nesting on islands has been emphasised as being connected with the reduction of nesting predation and increase in breeding success (e.g. Bengston 1979, Amat 1982, Hill 1984, Górski & Wiatr 1986, Stawarczyk 1995, Sikora 1996). Another noteworthy factor is that the presence of islands causes lengthening of the shore line as well as an increase of the littoral area. In this way new nest site locations and new feeding areas for most of the water bird species, mainly for *P. cristatus*, dabbling ducks and *F. atra*, appear.

The effect of landscape on species and pair numbers

Neither pairwise correlation nor stepwise multiple regression showed an effect of the length of shoreline covered by forest on the pair numbers in each group of birds (Table 5 and 6). Because the influence of this variable on the number of pairs may have been concealed by the length of shoreline, the partial correlation was used when variation in the length of shoreline was controlled for. Only pair numbers of reed and bush birds moderated negatively but not statistically significant correlated with the length of the shoreline covered by forest ($r_p = -0.35$, $p = 0.17$).

Previous studies have shown that avoidance of the afforested shoreline by birds may be a consequence of the following factors: the higher level of predation compared to open landscape, greater risk of nesting parasitism, restricted food accessibility and space structure of rushes (Dyrcz 1981, Kostyrko 1989, Picman et al. 1993, Øien et al. 1996, Jobin & Picman 1997). It is supposed that the main reason for the avoidance afforested shorelines by some *Passerine* was the restriction of the frequency of nest parasitism which results in even greater selective pressure than predation e.g. in

Acrocephalus scirpaceus (Øien et al. 1996, Schulze-Hagen et al. 1996). On the other hand, cuckoo brood parasitism did not affect nesting mortality in other species e.g. in *Acrocephalus arundinaceus* (Dyrcz 1981). The lack of a statistically significant correlation in the case of the analysed lakes, together with the negative trend of correlation, may be caused by two factors. Among them there is a different reaction of species to various degrees of the afforested shoreline. It was found that the presence of woodland around the lake strongly limited the occurrence of *Acrocephalus scirpaceus*, *A. schoenobaenus* and *Emberiza schoeniclus* (Kostyrko 1989, Giertych 1997, Kosiński 1997). The second reason may be connected with the presence of well developed, often of a considerable width, emergent vegetation zone, on most of the examined lakes in Wielkopolska. It is likely that the number of reed and bush birds is more dependent on the area and spatial structure of emergent vegetation compared to the degree of a shoreline covered by forest.

CONCLUSIONS

1. The shoreline covered by emergent vegetation (SV) was found to be the single factor determining the variation of the total number of species (R^2 = 71%). The species number of water birds was predicted by the lake area (R^2 = 49%), since the number of reed and bush species was dependent on the area of rushes (R^2 = 55%).

2. The total number of pairs was determined by the lake area and the area of rushes (R^2 = 87%). The abundance of water birds was dependent on the lake area and its maximum depth (R^2 = 86%), since the area of rushes was found to be a factor determining the pairs number of reed and bush birds (R^2 = 82%).

3. The density of water birds, independent of a density measure, was negatively correlated with the area of rushes and positively with the lake area. The density of reed and bush birds (pair/10 ha of lake area) was negatively correlated with the maximum depth and positively with the area of rushes (R^2 = 0.51).

4. The number of pairs of water birds was statistically higher on lakes with islands than on those without, independent of the size and depth of the lake.

5. There was no relationship between the shoreline covered by forest and all the studied groups of birds.

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STRESZCZENIE

[Wpływ morfometrii jezior, roślinności wynurzonej i charakteru pobrzeży na zgrupowania ptaków lęgowych]

Badano wpływ rozmiarów jeziora, powierzchni roślinności wynurzonej, zalesienia brzegów oraz obecności wysp na bogactwo gatunkowe, liczebność i zagęszczenie ptaków lęgowych. Niezależnie rozpatrywano dwie ekologiczno-morfologiczne grupy ptaków: ptaki pływające i ptaki oczeretów i zarośli (Jakubiec 1978).

Materiał stanowiły opublikowane dane różnych autorów dotyczące zgrupowań ptaków lęgowych 18 jezior z terenu Wielkopolski (tab. 1). Awifauna większości jezior (16) była badana w latach 1988–1995, przy użyciu tzw. metody kompleksowej (Borowiec et al. 1982, Ranoszek 1983). W skład zgrupowania ptaków lęgowych włączono: ptaki pływające, ptaki oczeretów i zarośli (z wyłączeniem typowych entomofagów zaroślowych), ptaki polujące z lotu oraz gnieżdżące się w szuwarach gęgawę i żurawia. W całkowitej liczebności zgrupowania nie uwzględniono mew i rybitw. W analizie wykorzystano następujące zmienne środowiskowe: powierzchnię jeziora (LA), długość linii brzegowej (LS), maksymalną głębokość (MaxD), powierzchnię szuwarów (AR), długość linii brzegowej zarośniętej szuwarami (SV), długość linii brzegowej zarośniętej lasem (SF) (tab. 2) oraz niezależnie — obecność lub brak wysp na jeziorze. Podstawową metodą analizy danych była krokowa regresja wielokrotna. Wpływ obecności wysp na liczbę gatunków i par ptaków pływających zbadano wykorzystując analizę kowariancji. Większość analizowanych parametrów środowiska wykazała znaczny stopień współzależności (tab. 3).

Liczba gatunków i par obu rozpatrywanych grup ptaków była pozytywnie skorelowana z większością analizowanych parametrów środowiska (tab. 4).

Długość linii brzegowej zarośniętej szuwarami w 71% wyjaśniała zmienność całkowitej liczby gatunków. Zależność ta odzwierciedla znaczenie roślinności wynurzonej jako miejsca umieszczania gniazd przez większość gatunków ptaków. Bogactwo gatunkowe ptaków pływających zależało w 49% od powierzchni jeziora, a ptaków oczeretów i zarośli w 55% od powierzchni szuwarów (tab. 5). Stosunkowo niewielki wpływ wielkości jeziora na liczbę gatunków wskazuje na oddziaływanie innych czynników w kształtowaniu bogactwa gatunkowego obu grup ptaków np.: zróżnicowania środowiska i/lub liczebności oraz różnorodności pokarmu (Elmberg et al. 1994). Powierzchnia jeziora i powierzchnia szuwarów wyjaśniały 87% całkowitej zmienności liczby par w zgrupowaniu. Liczba par ptaków pływających była zależna w 86% od powierzchni i maksymalnej głębokości jeziora, podczas gdy liczebność ptaków trzcin i zarośli w 82% od powierzchni szuwarów (tab. 6).

Zagęszczenie par w obrębie zgrupowania ptaków było negatywnie skorelowane ze zmienną objaśniającą, której użyto do obliczenia wartości zagęszczenia (tab. 7). Prawdopodobną przyczyną takiego zjawiska, poza zależnością czysto statystyczną, była obecność w zgrupowaniu grup gatunków w odmienny sposób reagujących na analizowane zmienne środowiskowe. Zagęszczenie ptaków pływających, niezależnie od miary zagęszczenia, było ujemnie skorelowane z powierzchnią szuwarów i dodatnio z powierzchnią jeziora (tab. 7). Zależność ta jest efektem ujemnej korelacji pomiędzy udziałem roślinności wynurzonej a powierzchnią lustra wody i co za tym idzie skracaniem długości linii styku szuwary/lustro wody (Giertych 1997, Łucka 1997). Zagęszczenie ptaków oczeretów i zarośli (par/10 ha powierzchni jeziora) było ujemnie związane z maksymalną głębokością zbiornika i dodatnio z powierzchnią szuwarów (tab. 7). W przypadku pozostałych miar zagęszczeń nie stwierdzono liniowej zależności pomiędzy zmiennymi. Negatywny związek między zagęszczeniem tej grupy ptaków a maksymalną głębokością i dodatnią zależnością z powierzchnią szuwarów wynikał prawdopodobnie z faktu, że głębsze jeziora mają węższą strefę litoralu i tym samym węższy lub nierównomiernie rozmieszczony pas szuwarów, który nie odpowiada wymaganiom większości gatunków ptaków (Kostyrko 1989, Kosiński 1997).

Wykazano, że obecność wysp na jeziorze w istotnym stopniu zwiększa liczebność par ptaków pływających w porównaniu z jeziorami pozbawionymi wysp (tab. 8). Jest to związane z bezpieczeństwem gniazd oraz zwiększeniem powierzchni litoralu.

Długość linii brzegowej zarośniętej lasem nie wpływała istotnie na liczebność żadnej z analizowanych grup ptaków. W przypadku ptaków oczeretów i zarośli zauważalna jest jednak umiarkowana tendencja do zmniejszania się liczebności wraz ze wzrostem zalesienia linii brzegowej. Jest prawdopodobne, że liczebność ptaków oczeretów i zarośli jest bardziej zależna od powierzchni i struktury przestrzennej szuwarów niż sąsiedztwa zalesionego brzegu.

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