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Factors influencing habitat choice of bird species: a comparison of a natural and an artificial wetland

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abstract

Between 2019 and 2022, we studied the avifauna and environmental conditions of two wetland habitats located in close proximity to each other in Transcarpathia (nearby to the village of Dyida, Zakarpatska Oblast, Ukraine) — one being a natural, currently protected but drying and highly degraded former bog (Tóvár Ornithological Reserve), whereas the other one being an artificial pit lake (Lake Dyida). Lake Dyida is used as recreation area during the summer nesting season of birds. Both of these wetlands border with agricultural lands. Bird species that occur in both of the investigated habitats are affected by severe anthropogenic disturbances. A total of 27 795 individuals of 58 bird species were observed in the two areas over the four study years. Results indicate that the species composition of the two study sites differed considerably, both on annual and seasonal basis. Seasonal precipitation totals strongly influence the current spatial ratios of terrestrial and waterbird species, and show a strong positive correlation with the seasonal total number of bird species. Maximum numbers of birds are recorded in spring and summer at Tóvár and in autumn and winter at Lake Dyida. In the case of Lake Dyida, these could partly be due to the autumn–winter appearance of migratory waterbirds and the end of the beach season. Despite the impact of numerous anthropogenic factors and habitat distrubances, the natural wetland is much more species-rich even in its degraded condition than the artificial wetland, which has been confirmed not only for bird species but also for plant species in the two areas. Duck species consider the deep-water pit lake as an alternative habitat during periods of drought, but for waders the great water depth makes this site less exploitable. In Europe, too, drying out due to seasonal precipitation shortages is an issue of increasing concern, especially for wetlands beacuse artificially maintained lakes and reservoirs cannot fully take over the role of natural lakes, marshes and bogs, which will have severe consequences in the future.

Фактори, які впливають на вибір оселища видами птахів: порівняння природного та штучного водно-болотного угіддя

Степан Коложварі, Сілард Серені, Федір Молнар, Ержебет Когут

Резюме. У період з 2019 по 2022 рр. нами досліджено орнітофауну та природні умови двох розташованих поруч водно-болотних угідь Закарпаття (с. Дийда, Україна), одне з яких — висихаюче, сильно деградоване, колишнє болото природного походження, яке зараз перебуває під охороною (Орнітологічний заказник «То́вар»), а друге — штучно створене кар'єрне озеро (озеро Дийда). У літній сезон озеро Дийда використовується як зона відпочинку. Обидва водно-болотні угіддя межують із сільськогосподарськими угіддями. Обидва досліджені ділянки перебувають під значним антропогеннім впливом. За чотири роки досліджень у цих двох оселищах спостережено 27 795 екз. 58 видів. Показано, що видовий склад птахів двох територій суттєво відрізняється у різні роки та різні сезони. Сезонна кількість опадів значною мірою впливає на актуальне просторове співвідношення наземних і водних видів птахів та демонструє сильну позитивну кореляцію із сезонною загальною кількістю видів птахів. Максимальна кількість особин навесні та влітку спостерігається на озері То́вар, а восени та взимку — на озері Дийда. У випадку з озером Дийда — це, ймовірно, частково є наслідком осінньо-зимової появи мігруючих водоплавних птахів і закінчення пляжного сезону. Разом із багатьма антропогенними факторами порушення середовища існування, оселище природного походження, навіть у його деградованому стані, має набагато вищий показник видового багатства порівняно зі штучно створеним оселищем. Це підтверджено не тільки кількістю видів птахів, але й видів рослин обох територій. У періоди посухи глибоководне кар'єрне озеро розглядається представниками родини качкових як альтернативне оселище, проте воно є менш привабливим для куликів через велику глибину води. Висихання внаслідок періодичної відсутності опадів стає дедалі серйознішою проблемою і в Європі, особливо для водно-болотних угідь, оскільки, озера і водосховища, що підтримуються штучним водозаміщенням, не можуть повністю взяти на себе роль природних озер та боліт, що матиме серйозні наслідки у майбутньому.

Ключові слова: водоплавні птахи, водно-болотне угіддя, висихання, Закарпаття.

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Introduction

Between September 2019 and February 2022, ornithological observations were conducted in the Tóvár Ornithotological Reserve nearby to the village of Dyida (Zakarpatska Oblast [=Transcarpathia], Ukraine) and at Lake Dyida. The Tóvár Ornithological Reserve is a wetland of natural origin, which is nowadays highly degraded; it was granted protected status to preserve the rare plant species and waterbirds found in this area [Kovalchuk *et al.* 2006; Marushevsky *et al.* 2006]. The other site — Lake Dyida — is an artificially created pit lake currently used for recreational purposes. More than 200 species of birds are known to occur in Transcarpathia [Potish 1995; 2009; Lugovoy *et al.* 2001; Lugovoy & Potish 2004; Fesenko & Bokotey 2002], although systematic and standardised ornithological monitoring in the two studied habitats, apparently, has not been conducted earlier.

Although Transcarpathia is an affluent area in terms of natural water resources, due to its geological conditions, the vast majority of surface waters are rivers, while the number of lakes is low. This factor also determined previous ornithological research, most of which was carried out in the valleys of the Tisa, Latoritsa, Uzh, and Borzhava rivers. In the past, the lowland areas of the region were interspersed with a number of small watercourses and were characterised by backwaters, bogs, and marshes (e.g. the 'Szernye-mocsár' bog), the natural appearance of which was subsequently strongly altered by land reclamation works. As a result, artificial lakes and reservoirs now exceed natural lakes in both number and size. Lake Dyida is the largest among pit lakes in the region, its surface area being exceeded only by larger reservoirs (e.g. reservoir of Fornosh 285 ha, hydroelectric power plant reservoir Tereblya-Rika 155 ha) [Molnár 2009].

In the absence of regular monitoring studies, little is known about the current role of the area for migratory waterbirds and the effects of climate change [IPCC 2021[1]] on the local ornithofauna. It is therefore unclear whether the benefits expected from the state protection status granted to the Tóvár Ornithological Reserve are being realised in practice for the bird fauna. Fluctuations in the recharge of lakes, marshes, bogs, wet meadows can lead to changes in the composition of the former flora and fauna [Fraser & Keddy 2005; Kirby *et al.* 2008; O'Neal *et al.* 2008; Hoover 2009]. Monitoring the migration of waterbirds, studying their seasonal variation of abundance, and understanding their importance in food chains makes are particularly relevant [Van Eerden *et al.* 2005; Malavasi 2009; Gyurácz *et al.* 2011; Pavón-Jordán *et al.* 2019; Keten *et al.* 2020]. Compared to recent decades, most migratory bird species have experienced declines in numbers across Europe (Kirby *et al.* 2008; Dubovyk *et al.* 2020; PECBMS, 2021[2]]. The reasons behind these are complex, but agriculture and aquaculture, biological resource use, natural system modifications, pollution, invasive species and climate change are the most damaging for bird species [Salafsky *et al.* 2008; Reif 2013]. In the light of this, the role of the two studied areas is regionally enhanced for the species of birds that prefer standing water. Therefore, the aim of the study was to reveal the species composition of the bird fauna of the Tóvár Ornithological Reserve and Lake Dyida, as well as to clarify their seasonal characteristics and the relationship, similarities, and differences between the ornithofauna of a natural but highly degraded and an artificial wetland.

Materials and Methods

Fieldwork and study sites

Field studies were conducted for 110 days between September 2019 and February 2022. The duration of ornithological observations was 3 hours at a time. Birds were observed with the naked eye and with binoculars, and counts of individuals flying or swimming in flocks were carried out from photographs taken with a camera equipped with a telephoto lens. During the fieldwork, the animals were not captured and their nests were not disturbed or damaged.

The Tóvár Ornithological Reserve (TOR) is located at the Hungarian–Ukrainian state border in the south-western part of the village of Dyida (Fig. 1). At the beginning of the 20th century, the area was still a complex wetland habitat, part of the 'Szernye-mocsár' bog. This natural ecosystem, however, was disrupted after the land reclamation interventions of the 1930s and 1950s. Today, only parts of the once contiguous marshland can be found, which is now networked by artificial channels, sluices, and pumping stations. In 2002, the Transcarpathian Regional Council declared the following parts of the area as nature reserves of local importance: Tóvár Ornithological Reserve, 49.90 ha (48°13'15.02" N, 22°32'45.34" E); 'Dyida Reservoir' Hydrological Reserve, 18.50 ha (48°12'50.14" N, 22°32'37.76" E); 'Didivs'kij Mits' Hydrological Reserve, 15.40 ha (48°13'12.49" N, 22°32'22.50" E). These three protected areas are closely connected thus they were treated as a single monitoring unit.

Only isolated patches of primary wetland and marsh habitats have remained, with the majority of the formerly contiguous marshland now covered by patches of woodland, scrub, sedge, and reed. The area can dry out completely in drought periods, and the water depth in the drainage channel does not exceed 2 metres in wet periods.

The flora of the area is unique and species-rich, with 70 plant species found during our field surveys and 31 species known by previous references in the literature [Margittai 1933; Andriyenko *et al.* 1999; Felbaba-Klushyna 2015]. The area covered with reeds, bulrush, and sedge species can be estimated at around 16.9 ha, the wooded and shrubby parts 49.2 ha, the grassland 15.8 ha, and the built-in/concrete paved areas 0.1 ha. The extent of the open water surface fluctuates strongly during dry and wet periods. During the wet season, up to 30 ha of water is spread over reed, rush, sedge, and shrubby

[1] IPCC, AR6. Sixth Assessment Report, Climate Change 2021 — The Physical Science Basis.
[2] PECBMS 2021 — The State of Europe's Common Birds 2019. CSO/RSPB, Prague, Czech Republic.

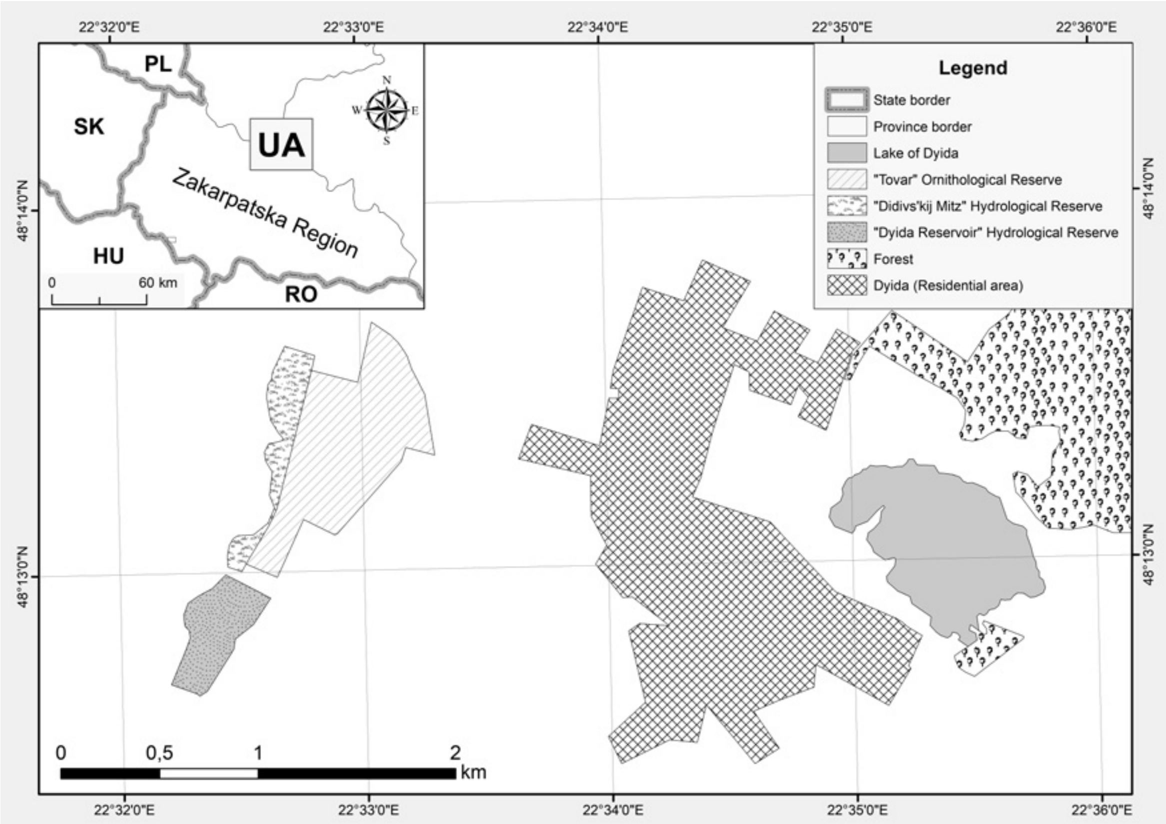

Fig. 1. Map of the two wetlands studied.
Рис. 1. Мапа двох досліджених водно-болотних угідь.

areas. During dry periods, water remains only in the canals, which cover a total area of approximately 1.8 ha and a total length of 8200 m. Within a 1 km radius of the protected area complex, about 10% of the territory is wooded and shrubby, 2% is a built-in area or backyard gardens and roads, and 88% is arable land, where maise and wheat are grown. Between September and February, small game hunting occasionally occurs in the agricultural areas adjacent to the Tóvár Ornithological Reserve.

Among the bird species, the white stork (*Ciconia ciconia* (Linnaeus 1758)), black stork (*Ciconia nigra* (Linnaeus 1758)), grey heron (*Ardea cinerea* Linnaeus 1758), Eurasian bittern (*Botaurus stellaris* (Linnaeus 1758)), mute swan (*Cygnus olor* (Gmelin, 1789)), common crane (*Grus grus* Linnaeus 1758), graylag goose (*Anser anser* Linnaeus 1758), Eurasian teal (*Anas crecca* Linnaeus (1758)), and northern lapwing (*Vanellus vanellus* Linnaeus 1754) were previously reported [Kállai 2004; Kovalchuk *et al*. 2006[3]; Marushevsky *et al.* 2006[4]], and an earlier occurrence of the great white pelican (*Pelecanus onocrotalus* Linnaeus 1758) is known by personal communication.

Lake Dyida (LD) is an artificial standing water near the village of Dyida (48°13'03.65" N, 22°35'22.86" E; Fig 1). Its origins date back to 1963, when significant sand layers were found in the area and were mined on an industrial scale. The lake basin currently covers 53.20 ha, has a depth of up to 16 m, and the water surface does not vary significantly seasonally. A fenced area of 25.30 ha borders the lake bed. Intensive mining was suspended in 1990, and later only small-scale mining was carried

[3] Kovalchuk, A. A., L. M. Felbaba-Klushina, N. E. Kovalchuk, I. M. Horbany, L. I. Horbany, [et al.]. 2006. Swamp ecosystems of the East Carpathians in Ukraine. Uzhhorod National University, Uzhhorod, 1–242. [In Ukrainian]
[4] Marushevsky, G. B., I. S. Zharuk, G. B. Fesenko, A. A. Didukh, T. P. Dzyuba. 2006. Directory of Ukraine's Wetlands. Wetlands International Black Sea Programme, Kyiv, 1–310. [In Ukrainian]

out here, which is now used as a holiday resort in summer. It is bordered by fenced parcels of private housing and agricultural land.

No published ornithological data based on systematic observations are known for Lake Dyida. Its narrow shoreline and the shoreside are partly covered with reed and rush. During our botanical surveys, specimens of 36 plant species were recorded in the area, but no floristic data were found in the scientific literature. The stretches used as a beach in summer mostly lack vegetation and, in some places, have been built in. The areas covered with reeds, rushes, and sedges cover 1.30 ha, 12.6 ha of wooded and shrubby areas, 12.7 ha of grassland, 10.8 ha of built-up/concrete paved areas, and 51.90 ha of open water. Within a 1 km radius of the lake, the area is about 20% forest, 15% built-up residential area, road, railway, or backyard garden, 65% arable land with maise, wheat, and barley.

Data analysis

Land use, vegetation cover, and seasonal water cover conditions of the two study areas were determined by field surveys and field measurements and by using Google Earth satellite images and multispectral satellite images from the Sentinel-2B satellite available from the Copernicus Open Access Hub (Copernicus Sentinel Data 2022). Twelve channels were used to create the multi-channel satellite image. The satellite images were processed using ArcGIS 10.1 software. After unifying the spatial resolution of each channel, the separate single-band images were merged into one multispectral raster dataset. Principal component analysis (PCA) was used to linearly transform each spectral band to minimise the correlation between the bands so that the raster image could be used to distinguish those areas currently covered by water.

Annual ornithological data from the two habitats were compared using hierarchical cluster analysis (paired group, Morisita index) and principal coordinates analysis (PCoA, Morisita index). The similarity of the species composition of each year was analysed using the SIMPER method (Similarity Percentage) [Clarke 1993].

The annual and seasonal diversity ratios for bird species in the two areas for 2021–2022 were characterised by calculating the Shannon diversity index, H [Shannon-Weaver 1949; Pielou 1975]; and Buzas and Gibson's evenness values (eH/S, where H is the Shannon index, and S is the number of species) were also determined for the same periods.

Seasonal differences in the species composition of the study years were also analysed using hierarchical cluster analysis (paired group, Jaccard index). The seasonal averages of the number of individuals from the two study habitats for the study years 2021–2022 were compared using a one-way analysis of variance (one-way ANOVA). Welch's F-test was used to assess differences in means, depending if variances were equal or unequal. For the same period, Pearson's linear correlation was used to examine the relationship between seasonal mean individual counts, seasonal species counts, seasonal Shannon diversity and evenness values, seasonal precipitation totals, and seasonal mean water surface. The relationship between the seasonal species composition of the two study sites for 2021–2022 and seven habitat variables (extent of woodland/shrubland, extent of reed–sedge area, extent of grassland, extent of built-in or paved areas, extent of water surface, seasonal precipitaton, and vegetation species number) was assessed using canonical correspondence analysis (CCA).

For precipitation data, data from Station 12786: Záhony (Hungary) were used [OGIMET[5]] and processed in Microsoft Excel 2019 and PAST 4.50 [Hammer *et al.* 2001] software.

Results and Discussion

A year-to-year comparison of the ornithofauna of the two study areas

The ornithological observations confirmed the occurrence of 58 bird species of 32 families in the two habitats:

[5] OGIMET. Weather Information Service. 2786: Záhony (Hungary). Accessed on 10.04.2022. https://www.ogimet.com

Podicipedidae [*Podiceps cristatus* (Linnaeus, 1758), *Tachybaptus ruficollis* (Pallas, 1764)], Phalacrocoracidae [*Phalacrocorax carbo* (Linnaeus, 1758)], Ardeidae [*Ardea alba* Linnaeus, 1758, *Ardea cinerea* Linnaeus, 1758, *Egretta garzetta* (Linnaeus, 1766), *Nycticorax nycticorax* (Linnaeus, 1758), *Botaurus stellaris* (Linnaeus, 1758)], Ciconiidae [*Ciconia ciconia* (Linnaeus, 1758), *Ciconia nigra* (Linnaeus, 1758)], Anatidae [*Cygnus olor* (Gmelin, 1789), *Anser albifrons* (Scopoli, 1769), *Anas querquedula* Linnaeus, 1758, *Anas acuta* Linnaeus, 1758, *Anas platyrhynchos* Linnaeus, 1758], Accipitridae [*Circus aeruginosus* (Linnaeus, 1758), *Accipiter nisus* (Linnaeus, 1758), *Buteo buteo* (Linnaeus, 1758)], Phasianidae [*Phasianus colchicus* Linnaeus, 1758, *Coturnix coturnix* (Linnaeus, 1758)], Rallidae [*Rallus aquaticus* Linnaeus, 1758, *Fulica atra* Linnaeus, 1758, *Gallinula chloropus* (Linnaeus, 1758)], Laridae [*Chroicocephalus ridibundus* (Jerdon, 1840), *Sterna hirundo* Linnaeus, 1758], Columbidae [*Streptopelia turtur* (Linnaeus, 1758)], Cuculidae [*Cuculus canorus* Linnaeus, 1758], Strigidae [*Athene noctua* (Scopoli, 1769)], Alcedinidae [*Alcedo atthis* (Linnaeus, 1758)], Meropidae [*Merops apiaster* Linnaeus, 1758], Upupidae [*Upupa epops* Linnaeus, 1758], Picidae [*Dendrocopos major* (Linnaeus, 1758)], Alaudidae [*Alauda arvensis* Linnaeus, 1758], Hirundinidae [*Delichon urbicum* (Linnaeus, 1758)], Motacillidae [*Motacilla alba* Linnaeus, 1758, *Motacilla flava* Linnaeus, 1758], Muscicapidae [*Erithacus rubecula* (Linnaeus, 1758), *Luscinia megarhynchos* C.L. Brehm, 1831, *Muscicapa striata* (Pallas, 1764)], Turdidae [*Turdus pilaris* Linnaeus, 1758, *Turdus merula* Linnaeus, 1758], Sylviidae [*Sylvia borin* (Boddaert, 1783), *Sylvia atricapilla* (Linnaeus, 1758), *Sylvia communis* Latham, 1787], Phylloscopidae [*Phylloscopus collybita* (Vieillot, 1817)], Acrocephalidae [*Acrocephalus arundinaceus* (Linnaeus, 1758), *Acrocephalus schoenobaenus* (Linnaeus, 1758)], Paridae [*Cyanistes caeruleus* (Linnaeus, 1758), *Parus major* Linnaeus, 1758)], Sittidae (*Sitta europaea* Linnaeus, 1758), Remizidae [*Remiz pendulinus* (Linnaeus, 1758)], Oriolidae [*Oriolus oriolus* (Linnaeus, 1758)], Laniidae [*Lanius collurio* Linnaeus, 1758], Corvidae [*Garrulus glandarius* (Linnaeus, 1758), *Pica pica* (Linnaeus, 1758)], Sturnidae [*Sturnus vulgaris* Linnaeus, 1758], Fringillidae [*Carduelis carduelis* (Linnaeus, 1758), *Linaria cannabina* (Linnaeus, 1758)].

In 2019, regular surveys were limited to autumn and winter, and in February 2022 observations could not be carried out as the Transcarpathian Regional Council issued a decree banning visits to forests and waterfronts due to the war in Ukraine. Analyses comparing the fauna composition of the two areas were therefore limited to 2020 and 2021, when the data for the whole study year were available.

In the cluster analysis (paired group, Morisita index, cophen. corr.: 0.99) based on the species composition of the habitats recorded in 2020 and 2021, two distinct clusters of species assemblages were identified (group 1: 2020 TOR, 2021 TOR; group 2: 2020 LD, 2021 LD), which basically differed in the two studied habitats, but to a lesser extent, the species composition of the same habitats differed in the same year. The obtained results were also supported by the principal coordinate analysis (Morisita index) (the two axes explain 99.39% of the total variance). The SIMPER results suggest that differences in mallard abundance account for 36.27% of the difference between the two habitats, but the contribution of the great crested grebe (12.59%), common coot (6.39), and common pheasant (5.13%) should also be noted.

In the case of Lake Dyida, waterbird species are more prevalent, while in the Tóvár Ornithological Reserve, waterbirds are primarily represented alongside terrestrial bird species, but mallards were dominant in shaping the bird fauna of both habitats.

Diversity ratios for the 2019 and 2022 survey years differed for the two areas, which may have contributed to their separation from the results of the full-year surveys for both Tóvár and Lake Dyida in 2020 and 2021. Consequently, the lowest species and individual numbers were recorded in both habitats in 2019 and the highest in 2021. For the Tóvár Ornithological Reserve, the lowest diversity values were recorded in 2019 (H = 0.305) and the highest in 2021 (H = 3.148). At Lake Dyida, the lowest values were recorded in 2019 (H = 0) and the highest in 2021 (H = 1.615). In all years, Shannon diversity values sensitive to rare species indicated much higher diversity at the Tóvar Ornithological Reserve than at Lake Dyida. The number of species, number of individuals, diversity and evenness values were highly variable between the two habitat complexes in the different study years (Table 1).

Table 1. **Annual number of species, number of individuals, Shannon's diversity and evenness values of bird species observed in the Tóvár Ornithological Reserve (TOR) and in the area of Lake Dyida (LD)**

Таблиця 1. **Щорічна кількість видів, загальна кількість, індекс різноманітності Шеннона та видова рівність птахів, що спостерігаються в Орнітологічному заказнику То́вар (ОЗК) і на озері Дийда (ОД)**

Parameters	LD				TOR			
	2019	2020	2021	2022	2019	2020	2021	2022
Number of species	1	9	17	7	2	11	49	7
Total number of individuals	137	3668	10558	850	55	589	11405	533
Shannon's index, H	0	1.359	1.615	0.808	0.305	2.009	3.148	1.653
Evenness	1	0.432	0.296	0.320	0.678	0.678	0.475	0.746

In general, in the two habitats studied, terrestrial birds dominated in the Tóvár Ornithological Reserve (waterbirds 40.40%; terrestrial birds 60.60%), while waterbirds dominated in the area of Lake Dyida (waterbirds 91.75%; terrestrial birds 8.25%), which also indicates the impact of the drying out of the Tóvár Ornithological Reserve. In our opinion, environmental variables between the two habitats and anthropogenic disturbance may be responsible for this situation.

The ornithofauna of the Tóvár Ornithological Reserve

During the research, 12 582 specimens of 49 bird species were recorded in the area of the Tóvár Ornithological Reserve (Table 2). Mallards had the highest abundance (13.79%) of all bird species at the reserve, but their higher quantity was concentrated in the period between March and September. Among waterbirds, the Eurasian coot (9.93%) followed in abundance. The common pheasant (10.97%) and Eurasian great tit (6.56%) were the most abundant terrestrial species (Fig. 2). The spring–summer period was characterised by an increase in the number of species, mainly due to the presence of land birds.

In the area of the Tóvár Ornithological Reserve, during the entire observation period, rare and protected bird species included into the IUCN Red List were also recorded: the vulnerable northern pintail, and the near threatened European turtle-dove and common quail. The black stork listed in the Red Data Book of Ukraine also occurred here.

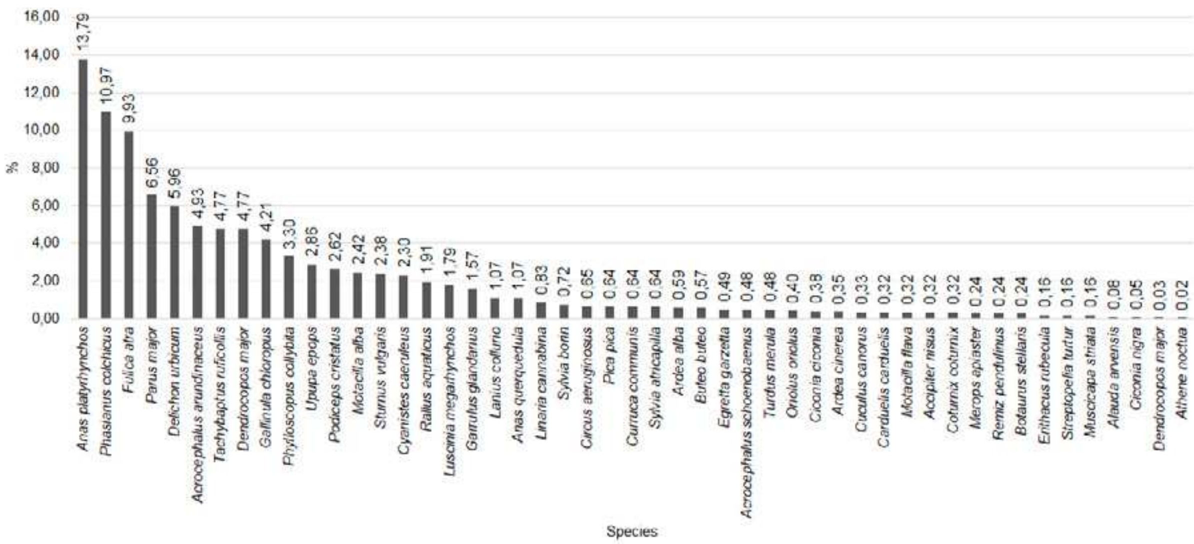

Fig. 2. Percentage composition of the ornithofauna of the Tóvár Ornithological Reserve by species.
Рис. 2. Відсотковий видовий склад орнітофауни орнітологічного заказника «То́вар».

Table 2. **Annual totals of birds observed in the Tóvár Ornithological Reserve**

Таблиця 2. **Загальна кількість птахів, спостережених протягом року в орнітологічному заказнику «Тóвар»**

Species	Abb.	2019	2020	2021	2022
P. cristatus	PoC	0	60	270	0
T. ruficollis	TR	0	90	510	0
A. alba	ArA	0	0	74	0
E. garzetta	EG	0	0	62	0
B. stellaris	BS	0	0	30	0
A. cinerea	AC	0	0	44	0
C. ciconia	CiC	0	4	44	0
C. nigra	CiN	0	0	6	0
A. querquedula	AQ	0	20	115	0
A. platyrhynchos	AP	5	100	1630	0
C. aeruginosus	CA	0	0	82	0
A. nisus	AN	0	0	40	0
B. buteo	BB	0	2	62	8
P. colchicus	PhC	50	120	1130	80
C. coturnix	CoC	0	0	40	0
R. aquaticus	RA	0	0	240	0
F. atra	FA	0	0	1250	0
G. chloropus	GC	0	0	530	0
S. turtur	ST	0	0	20	0
C. canorus	CC	0	3	38	0
A. noctua	AtN	0	0	2	0
M. apiaster	MeA	0	0	30	0
U. epops	UE	0	0	360	0
D. major	DM	0	0	4	0
A. arvensis	AlA	0	0	10	0

Species	Abb.	2019	2020	2021	2022
D. urbicum	DU	0	100	650	0
M. alba	MA	0	0	305	0
M. flava	MF	0	0	40	0
E. rubecula	ER	0	0	20	0
L. megarhynchos	LM	0	0	225	0
M. striata	MS	0	0	20	0
T. pilaris	TP	0	0	450	150
T. merula	TM	0	0	60	0
S. borin	SB	0	0	90	0
S. atricapilla	SA	0	0	80	0
S. communis	SC	0	0	80	0
P. collybita	Pco	0	0	415	0
A. arundinaceus	AcA	0	70	550	0
A. schoenobaenus	AS	0	0	60	0
C. caeruleus	CyC	0	0	230	60
Parus major	PM	0	0	655	170
R. pendulinus	RP	0	0	30	0
O. oriolus	OO	0	0	50	0
L. collurio	LC	0	0	135	0
G. glandarius	GG	0	0	157	40
P. pica	PP	0	20	60	0
S. vulgaris	SV	0	0	300	0
C. carduelis	CaC	0	0	40	0
L. cannabina	LiC	0	0	80	25

The ornithofauna of Lake Dyida

During the entire study period, 15 213 individuals of 17 bird species were recorded at Lake Dyida (Table 3). Specimens of the great crested grebe were present on Lake Dyida at almost each time of observation. We concluded that the species forms a stable population and nests in the area. The mallard also showed the highest number of occurrences (55.10%), but its presence was typical for the autumn–winter period (Fig 3).

Our study showed that the majority of migratory waterbirds appeared at Lake Dyida between November and February. The number of birds on the lake, however, was much lower during summer

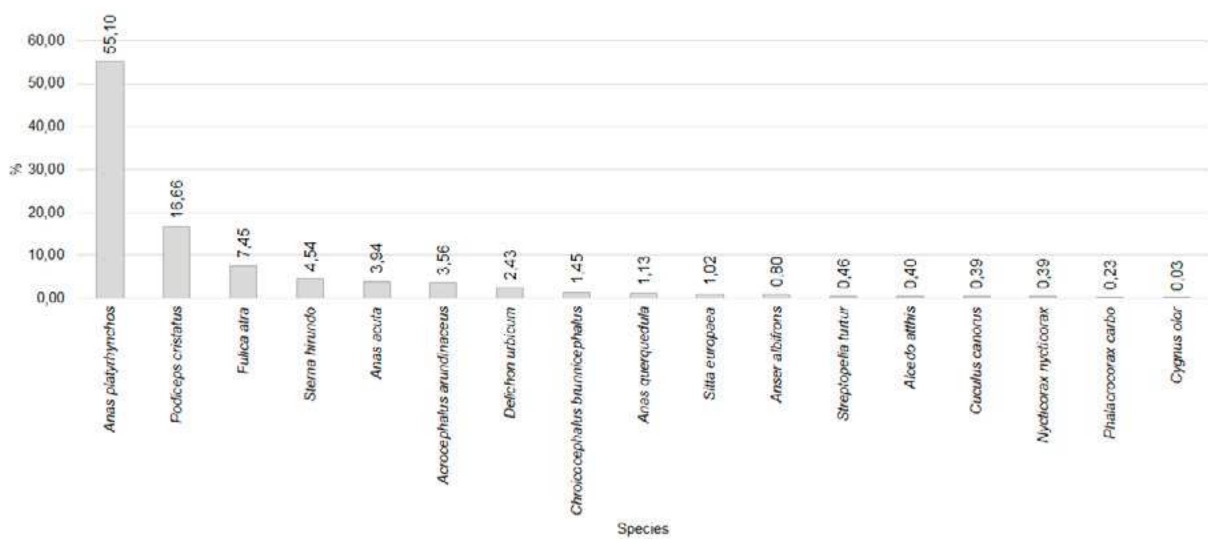

Fig. 3. Percentage composition of the ornithofauna of Lake Dyida by species.

Рис. 3. Відсотковий видовий склад орнітофауни озера Дийда.

than during the autumn–winter migration. In our opinion, this may be due to migration factors as well as summer habitat disturbance, as some parts of the lake shore are used as beaches in summer. Furthermore, targeted nest destruction also occur by the lake operators, which may cause the absence of species more susceptible to human presence.

Table 3. **Annual totals of birds observed at Lake Dyida**

Таблиця 3. **Загальна кількість птахів, спостережених протягом року на озері Дийда**

Species	Abb.	2019	2020	2021	2022
P. cristatus	PoC	137	813	1555	30
P. carbo	PC	0	30	1	4
C. ridibundus	CB	0	190	30	0
A. querquedula	AQ	0	162	10	0
A. acuta	AA	0	202	290	50
A. platyrhynchos	AP	0	2048	5665	670
F. atra	FA	0	157	897	80
A. alba	ArA	0	64	50	8
C. olor	CO	0	2	2	0
A. arundinaceus	AcA	0	0	600	0
C. canorus	CC	0	0	60	0
S. hirundo	SH	0	0	690	0
N. nycticorax	NN	0	0	60	0
D. urbicum	DU	0	0	370	0
S. turtur	ST	0	0	70	0
A. atthis	AAt	0	0	53	8
S. europaea	SE	0	0	155	0

Seasonal characteristics of the ornithofauna of Lake Dyida and the Tóvár Ornithological Reserve

The cluster analysis based on the annual seasonal abundance data of birds in the two habitats (Jaccard index, cophen. corr.: 0.8769) indicated a certain degree of seasonal separation as expected in addition to the separation between habitats. Generally, the spring–summer and autumn–winter species compositions are distinct for both study sites. Therefore, in our opinion, the seasonal species composition is not solely dependent on seasonality but is also influenced by the current state of habitat conditions (Fig. 4).

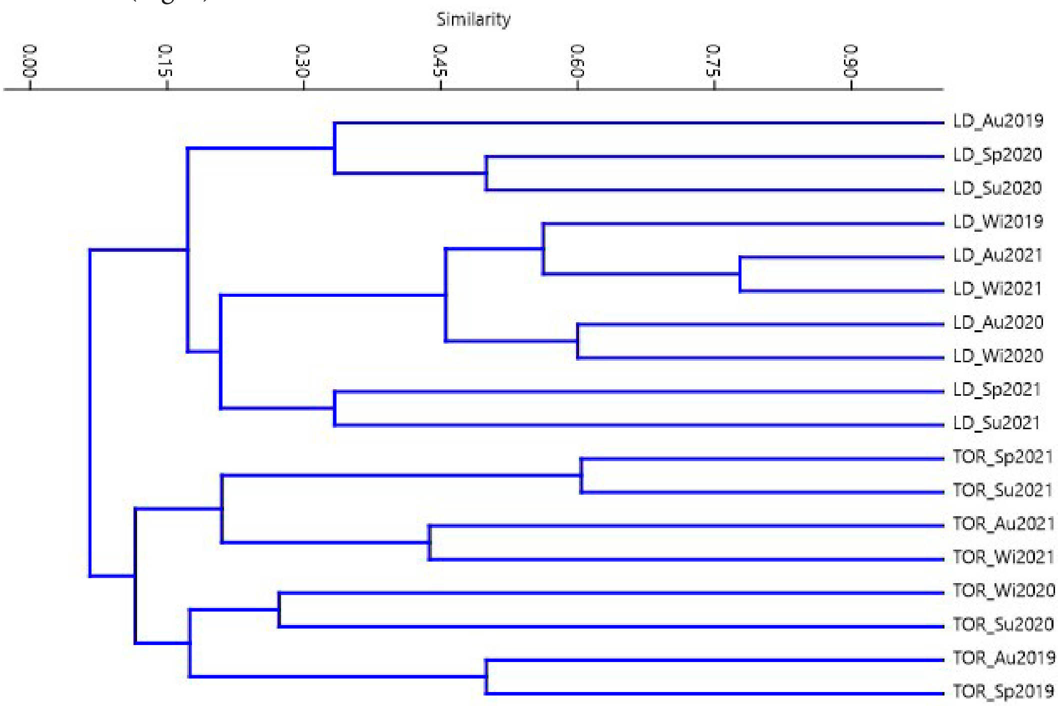

Fig. 4. Dendrogram of hierarchical cluster analysis (Jaccard index, paired group) results based on the number of individuals recorded in the two study sites (LD — Lake of Dyida; TOR — Tóvár Ornithological Reserve; Sp — spring; Su — summer; Au — autumn; Wi — winter).

Рис. 4. Дендрограма результатів ієрархічного кластерного аналізу (коефіцієнт Жаккара, парна група) за кількістю виявлених особин у двох досліджених ділянках (LD — озеро Дийда; TOR — орнітологічний заказник «Тóвар»; Sp — весна; Su — літо; Au — осінь; Wi — зима).

Since the series of regular observations between March 2021 and February 2022 were the most comprehensive and the most coordinated for both habitats during our research, the data obtained for this period was used for a deeper analysis of the effects of environmental variables and seasonal characteristics on the fauna composition. The normality test [Shapiro & Wilk 1965] performed on the mean number of individuals observed per season in the study year 2021–2022 showed a normal distribution of the data. In the case of Lake Dyida and the Tóvár Ornithological Reserve, one-way ANOVA based on the seasonal numbers of birds showed no significant differences between the autumn (F = 0.6261; p = 0.4304) and winter (F = 0.7464; p = 0.3895) periods, in contrast to the spring (F = 15.65; p = 0.0001) and summer (F = 4.057; p = 0.0463) periods.

There are also considerable differences between the two habitats regarding seasonal differences in numbers of individuals and species and subsequent diversity indices. Maximum numbers are recorded in spring and summer at the Tóvár and in autumn and winter at Lake Dyida. In the case of Lake Dyida, these could partly be due to the autumn–winter appearance of migratory waterbirds and the end of the beach season. We have observed that, in contrast to the Tóvár Ornithological Reserve, waterbirds also prefer the large water surface of Lake Dyida during the migration period as a resting place (Figs. 5–6).

The water level in Lake Dyida is generally stable throughout the year, while the Tóvár Ornithological Reserve can become either dry during periods of low precipitation or flooded during periods of heavy precipitation. As water level data are not measured for either area, it was not possible to examine the impact of water level fluctuations directly, so we have based our analysis on seasonal precipitation totals and on the seasonal extent of flooded area calculated from satellite images (Table 4).

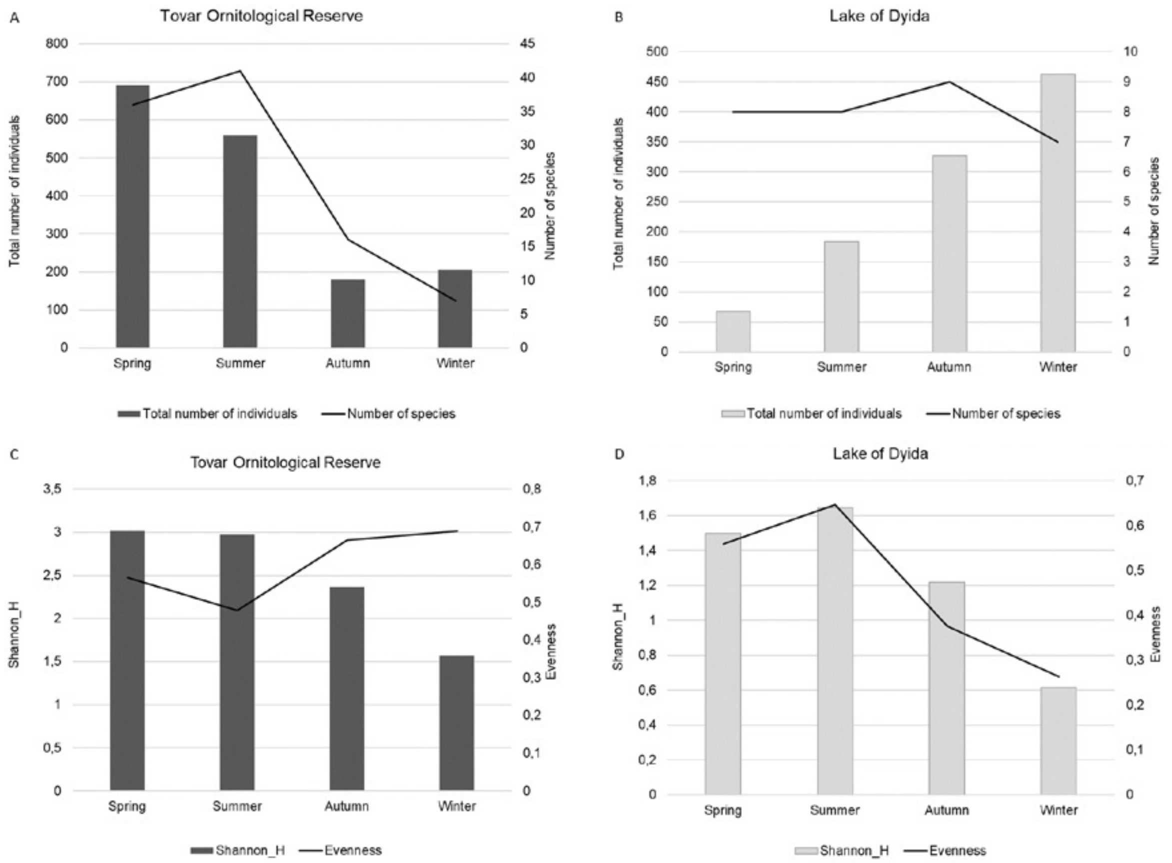

Fig. 5. Seasonsal dynamics of the number of bird species and specimens and diversity indices in the Tóvár Ornithological Reserve (A, C) and Lake Dyida (B, D) in 2021–2022.

Рис. 5. Сезонні зміни кількості видів, особин та показників різноманіття птахів в орнітологічному заказнику «Тóвар» (A, C) та на озері Дийда (B, D) у 2021–2022 рр.

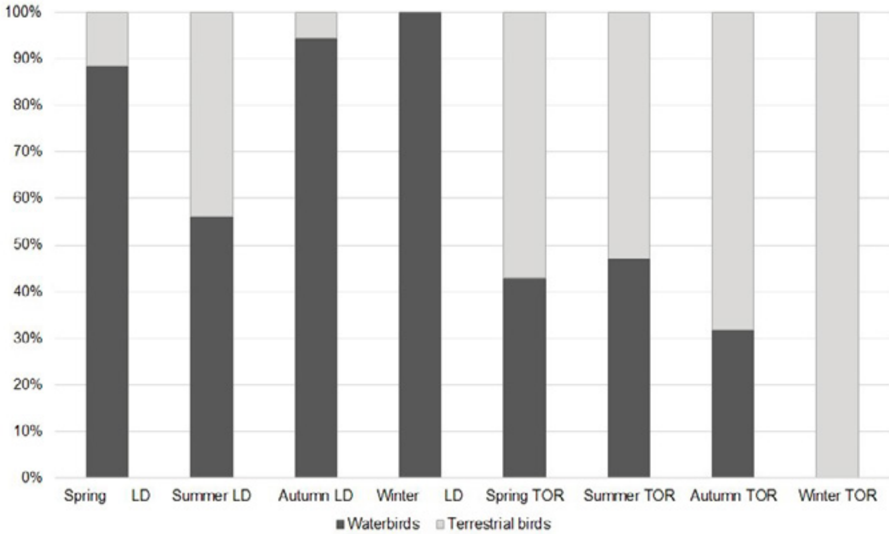

Fig. 6. Seasonal percentages of waterbirds and terrestrial birds observed in the Tóvár Ornithological Reserve (TOR) and at Lake Dyida (LD) in 2021–2022.

Рис. 6. Сезонне співвідношення водоплавних і наземних птахів, спостережених в орнітологічному заказнику «То́вар» та на озері Дийда у 2021–2022 рр.

Table 4. **Ornithological and habitat data from observations conducted in 2021–2022 (LD—Lake Dyida; TOR—Tóvár Ornitological Reserve; SP—spring; SU—summer; AU—autumn; WI—winter)**

Таблиця 4. **Орнітологічні дані та дані оселищ за період спостережень у 2021–2022 роках (LD — озеро Дийда; TOR — орнітологічний заказник «То́вар»; SP — весна; SU — літо; AU — осінь; WI — зима)**

Parameters	LD				TOR			
	SP	SU	AU	WI	SP	SU	AU	WI
Number of species	8	8	9	7	36	41	16	7
Total number of individuals	431	2251	3949	3255	3614	5662	1830	832
Shannon index, H	1.498	1.644	1.218	0.613	3.074	2.977	2.364	1.574
Evenness	0.559	0.646	0.375	0.263	0.600	0.478	0.664	0.689
Precipitation, mm	136.4	154	87.8	88.9	136.4	154	87.8	88.9
Water surface area, ha	51.9	51.9	51.9	51.9	24.05	7.58	2.29	1.79
Shrubland area, ha				12.6				49.2
Reedmace and rush area, ha				1.3				16.9
Grassland area, ha				1.9				15.8
Human landscape area, ha				10.8				0.1
Total number of plant species				36				70

The problems caused by drying are mainly concentrated in the area around the Tóvár Ornithological Reserve, and thus we focused on this area when analysing this issue. Pearson's linear correlation analysis indicated a strong positive correlation between the total seasonal number of individuals and seasonal precipitation totals for the study years 2021–2022 ($r = 0.967092$; $p < 0.05$), seasonal species number and seasonal precipitation totals ($r = 0.959747$; $p < 0.05$), as well as for the Shannon diversity index ($r = 0.843599$; $p < 0.05$). The evolution of precipitation totals showed a strong negative correlation with evenness ($r = -0.93326$). Similar results were obtained when comparing the seasonal extent of flooded areas (Table 5).

Table 5. **Comparison of the total number of species, total number of individuals, and diversity indices of birds observed in the Tóvár Ornithological Reserve (TOR) and at Lake Dyida (LD) in 2021–2022 with the seasonal extent of flooded areas and seasonal precipitation totals (Pearson's linear correlation, p < 0.05)**

Таблиця 5. **Порівняння загального числа видів, загальної кількості особин та показників різноманіття птахів, спостережених у районі орнітологічного заказника «То́вар» (TOR) і озера Дийда (LD) у 2021–2022 роках із показниками сезонної площі затоплених територій та сезонної кількості опадів**

Study site	Environmental variables	Number of species	Total number of individuals	Evenness	Shannon index, H
TOR	Water surface	0.659838	0.435817	–0.30171	0.719796
TOR	Precipitation	0.967092	0.959747	–0.93326	0.843599
LD	Precipitation	–0.013360	–0.732730	0.96129	0.831850

The water surface area of Lake Dyida did not change significantly over the study period due to the nature of the lake bed, water saturation and depth, and was therefore not analysed in this study. Such parameters, however, as seasonal precipitation totals and seasonal total numbers of individuals showed a negative correlation, which might be explained by the presence of some of the waterbirds in the Tóvár Ornithological Reserve during the wet periods.

Canonical correspondence analysis was used for a more in-depth investigation of the relationships between the seasonal species composition of the two sites and seven habitat variables (extent of woodland/shrubland, extent of reed–sedge area, extent of grassland, extent of anthropogenic landscape, extent of water surface, seasonal precipitation, and vegetation species number). In this case, the ordination analysis confirmed the results of the hierarchical cluster analysis. In 2021, the spring–summer and autumn and 2021/2022 winter faunal composition showed a closer relationship for both areas. The first two axes explain 85.1% of the variance (Table 6). A permutation test confirmed the significance of the axes (5000 permutations).

Table 6. **The results of the canonical correspondence analysis**

Таблиця 6. **Результати канонічного аналізу відповідності**

Axis	Eigenvalue	%	p
1	0.5862	48.63	0.02120
2	0.4396	36.47	0.00939
3	0.1797	14.91	0.04299

The first axis is defined most clearly by the water surface. The bird fauna of Lake Dyida during the autumn and winter migration periods is largely influenced by the the water surface area and the presence of open and partly built-in beaches along the shore, which is favourable for migrating duck species seeking resting and feeding areas (Fig. 7).

In spring and summer, the effect of seasonal precipitation amounts dominated. However, the extensive reed and sedge population, the large areas of shrub and grassland, the species-rich flora and the fluctuating seasonal water cover of the Tóvár Ornithological Reserve were equally pronounced and more favourable for terrestrial bird species, which was the most noticeable in the spring–summer period.

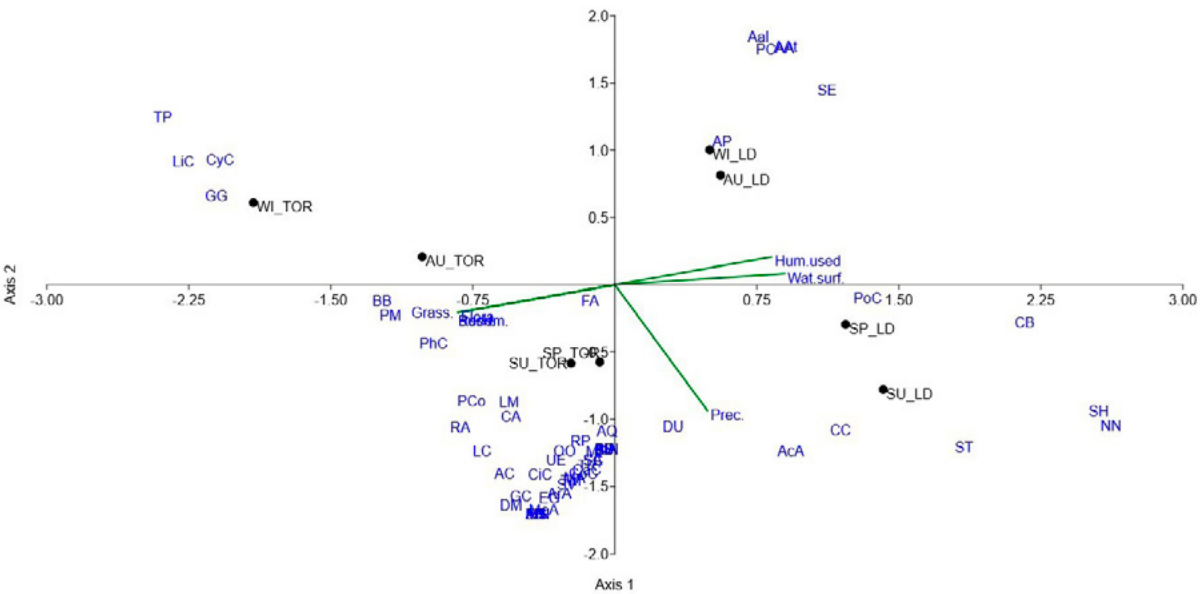

Fig. 7. Results of the canonical correspondence analysis of the relationship between the seasonal mean number of individuals for the 2021–2022 survey year and the seven habitat variables of the two study sites (abbreviations as in Tables 2–3).

Рис. 7. Результати канонічного аналізу відповідності між середньосезонною чисельністю особин за 2021–2022 рік дослідження та сімома змінними середовища двох досліджених оселищ (скорочення на основі таблиць 2–3).

Conclusions

In both investigated habitats, bird species are affected by severe anthropogenic disturbances. Our study revealed that the regular drying out of the Tóvár Ornithological Reserve has a considerable impact on the composition of the local bird fauna. A strong positive correlation was shown between the seasonal precipitation amounts, which determined the extent of water coverage, the number of species, and the number of individuals. Such effects are particularly threatening to the wading bird species [Hockin *et al.* 1992], several of which were also observed in the study area (great white egret, little egret, grey heron, Eurasian bittern, white stork, and black stork). The obtained results are in line with previous research [Zou *et al.* 2019] showing that the spatial extent of water surface and water depth are among the most important habitat characteristics determining the foraging efficiency of waterbird communities.

Lake Dyida is not subject to severe water level fluctuations, but the shoreline is parcelled out, built-in in places and used as a beach and recreation area in summer, which is also detrimental to disturbance-sensitive bird species during the nesting season. Although species tolerant of disturbance may persist in such places, their nesting and breeding success reduces, and they have much less time to forage. The occurrence of 5 species of ducks were observed in the two study areas (mute swan, greater white-fronted goose, garganey, northern pintail, mallard), but in the case of ducks, previous research showed that habitat disturbance can cause a loss in foraging time of up to 15–25% per day [Hockin *et al.* 1992; Madsen & Fox 1995], which can be particularly dangerous during periods of food scarcity [Navedo & Herrera 2012].

Despite their relatively close proximity, major differences were found in the bird fauna composition of the two wetlands. The study revealed that the protected area of the formerly naturally established Tóvár Ornithological Reserve, in general, has a higher number of species and higher diversity of birds than Lake Dyida, which was established a few decades ago. The Tóvár Ornithological Reserve is almost exclusively bordered by agricultural land and for some bird species, the presence of crops is associated with a broader spectrum of forage availability, especially considering that the natural flora of the area is much more species-rich than that of Lake Dyida. The disturbance effects of hunting in the surrounding areas on species composition are difficult to determine but it may contribute to the absence of waterbirds during the winter at the Tóvár Ornithological Reserve. Areas of woodland, scrub, and sedges flooded during wet periods have also been found to be more favourable for bird species such as the sedge warbler, great reed-warbler, Eurasian penduline tit, Eurasian skylark, common nightingale, common whiteroat, Eurasian blackcap, garden warbler, common chiffchaff, and white wagtail. It is noteworthy that during the study period, no traces of the great white pelican—a rare species in the region observed by locals in the 1990s at the Tóvár—were found in any of the habitats.

Lake Dyida is also bordered by agricultural lands, but the natural vegetation cover is less species-rich compared to the Tóvár, and the proximity of inhabited areas adds to the disturbance. In autumn, winter, and early spring, migratory waterbirds are more likely to use the large, continuous water surface of Lake Dyida as a resting and feeding area. The great cormorant, black-headed gull, northern pintail, greater white-fronted goose, mute swan, common tern, black-crowned night-heron, and common kingfisher, which are more closely associated with larger open water surfaces, were exclusively observed here. Mallards, which occur in both areas, were also present in much higher numbers during the migration period.

Obviously, there is migration between the two areas, but when comparing the bird fauna of the two habitats, it is complicated to accurately estimate the actual impact of external disturbance and its instantaneous effects on the composition of the bird fauna. The study revealed that the two wetlands could be temporary used as alternatives by some species, although, for migratory waterbirds, the Tóvár Ornithological Reserve has become a less attractive resting and feeding site than Lake Dyida. The results clearly showed that habitats of natural origin, even in a degraded state, can harbour much higher species diversity and provide a wider range of environmental conditions than a neighbouring habitat of artificial origin. In areas, where an alternative habitat that can partially take over some wetland functions is unavailable, we can expect to see a decline or complete abandonment of waterbirds. Therefore, the effective and efficient conservation and, where possible, regeneration of such areas is of paramount importance from a conservational point of view.

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