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The diversity, spatial structure, and significance of the *Syrphidae* population in the territory of the Listové Lake Nature Reserve

Diverzita, priestorová štruktúra a význam populácie *Syrphidae* na území Prírodnej rezervácie Listové jazero

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ABSTRACT

In the territory of the Listové Lake Nature Reserve research on the family *Syrphidae* was conducted on two study areas during the years 2021 and 2022. Over the observed period, a total of 1108 individuals belonging to 29 species were captured and classified. Based on the ecosoziological assessment, *Neoascia interrupta* and *Parhelophilus versicolor* belonged to vulnerable species, and were abundant in the study area. Among the species preferring the wetland habitat, *Parhelophilus versicolor* showed eudominant representation during both years. According to the biological assessment, it can be stated that both study areas were relatively balanced in terms of species diversity, the number of vulnerable species, and the total number of species. However, in terms of ecological significance, the study area located in the southern part of the reserve received a higher rating.

Keywords: hoverflies, biodiversity, biotope, *Syrphidae*, nature reserve

SAŽETAK

Na území Prírodnej rezervácie Listové jazero sa počas rokov 2021 a 2022, na dvoch študijných plochách, realizoval výskum čeľade *Syrphidae*. V priebehu sledovaného obdobia bolo celkovo odchytených a klasifikovaných 1108 jedincov, patriacich k 29 druhom. Na základe ekosozologického hodnotenia k zraniteľným druhom patrili *Neoascia interrupta* a *Parhelophilus versicolor*, ktoré boli v sledovanej lokalite početne zastúpené. Z druhov preferujúcich habitat mokradí eudominantné zastúpenie počas obidvoch rokov vykazoval *Parhelophilus versicolor*. Podľa biologického hodnotenia možno konštatovať, že obidve študijné plochy z hľadiska druhovej diverzity, počtu zraniteľných druhov a celkového počtu druhov boli pomerne vyrovnané. Z hľadiska ekologickej významnosti bola vyššie hodnotená študijná plocha situovaná v južnej časti rezervácie.

Kľúčové slová: pestrice, biodiverzita, biotop, *Syrphidae*, prírodná rezervácia

INTRODUCTION

Hoverflies (*Syrphidae*) are the most numerous family of *Diptera* (Hadrava, 2019). Adult individuals of many *Syrphidae* species resemble *Hymenoptera* and play a significant role as pollinators for both cultivated and wild plants (Mazánek, 2009). There are approximately 6200 species known worldwide (Dawah et al., 2020), and in Slovakia, there are 384 species of hoverflies. They are characterized by a high diversity in variable body structure, as well as their occurrence in various habitats. Adult individuals and larvae are found in almost all types of biotopes, thriving in specific microenvironments such as meadows, forests, marshes, gardens, parks, and even human settlements. Adult hoverflies mainly feed on pollen and nectar (Wäckers et al., 2008; Inouye et al., 2015; Doyle et al., 2020), while larvae exhibit diverse food specializations (Králiková, 2015). Hoverflies actively seek out colonies of aphids on plants and lay their eggs nearby. Within two days, small worm-like larvae hatch from the eggs and feed on *Thysanoptera*, *Aphidoidea*, and other small insects. Hoverfly larvae represent up to 70% of all aphid predators on plants. Once fully fed, the larvae descend to the soil to pupate. Some hoverfly species produce multiple generations throughout the year, while others occur only in spring and spend the rest of the year in the pupal stage (Purkart, 2020). Hoverfly larvae can be saprophagous, feeding on decomposing vegetation, moist decaying wood, fresh tree sap, feces, and can even live inside insect nests (Králiková, 2013). Apart from their role in pollinating cultivated plants, hoverflies are also significant for preserving the biodiversity of natural areas. Hoverfly larvae can serve as bait for fish. Larvae of *Eristalis tenax* are commercially bred for this purpose (Králiková, 2015).

This work aims to provide insights into the distribution, species representation, habitat diversity, and importance of the *Syrphidae* family in the Listové Lake Nature Reserve.

MATERIAL AND METHODS

Characteristics of the monitored area

The Listové Lake Nature Reserve is located at 47°53′29″S 18°03′07″E, in the southwest part of Slovakia, in the cadastral territory of Nesvady and Vrbová nad Váhom in the Komárno district, at an altitude of 108 meters above sea level and with an area of 41.02 hectares. The reserve is situated in the Danubian Lowland and is part of the Martovská wetlands. It was declared a nature reserve in 1988 with the aim of protecting the valuable habitat of aquatic and marshland birds. The bank vegetation is characterized by riparian forests (Varga and Pavlík, 2008). The vegetation is represented by ash-elm-oak forests, alder riparian forests, and willow-poplar riparian forests (Kočický et al., 2019). The area is classified under the 4th degree of protection and, as it plays a crucial role in the protection of certain animal and plant species, is part of a network of nature protection areas in the territory of the European Union NATURA 2000. The area of interest holds particular significance for the breeding and hibernation of waterfowl. Research has identified the presence of 178 species of higher plants and 236 species of vertebrates, including 167 bird species, 18 fish species, 6 amphibian species, 3 reptile species, and 42 mammal species (Varga and Pavlík 2008). Within the area of interest, 109 species of mollusks have been recorded, 22 of them being endangered, along with more than 1800 species of beetles. From small mammals, there is a notable relict occurrence of the northern vole (*Microtus oeconomus*) (Kočický et al., 2019).

The area of interest has clayey soil types with smaller areas containing clay-loam soils. The soils are generally non-skeletal to weakly skeletal. The main soil types include carbonate alluvial soils, accompanying alluvial gley soils, carbonate black soils, accompanying gley black soils, weakly gleyed chernozems, predominantly carbonate accompanying gley soils, and accompanying gley black soils (Varga and Pavlík, 2008).

The Listové Lake Nature Reserve is situated in a dry to moderately dry area with a warm and predominantly warm lowland climate and mild temperature inversions.

The average annual air temperature is 9.9 °C. The region is one of the driest areas in Slovakia, with an average annual precipitation of 550-600 mm. Snow cover is present for about 35 days per year, mainly during the months of January and February.

The area is one of the windiest regions in Slovakia. The windiest days occur during the winter and spring seasons. The prevailing wind direction is northwest (Regional Development Agency Komárno, 2015).

From a natural and hydrological perspective, the area belongs to the Váh River basin. Several drainage and irrigation canals run through the region, including the Vrbovský, Hlinický, Studený, Ostrovský, Listový, and Divý canals. The water bodies include dead arms of natural watercourses, ponds, and other water areas, forming smaller stagnant water surfaces. Among them are the Listové Lake and two smaller water bodies located on the premises of the Kindeš farm and a small pond near Čergov before the pheasantry (Municipal Plan of Vrbová nad Váhom, 2008; Regional Development Agency Komárno, 2015).

Methods and data analysis

The research on syrphidocenoses was conducted in the Listové Lake Nature Reserve in the years 2021-2022 on two study plots:

- Study plot no. 1 (N1) - located in the northern part of the reserve, with vegetation consisting of *Salix*, *Populus*, *Phragmites australis*, and herbaceous plants.
- Study plot no. 2 (N2) - located in the southern part of the reserve, with the occurrence of communities of *Salix*, *Populus*, *Phragmites australis*, and herbaceous plants.

Hoverflies were captured during the vegetation period from April to October, at monthly intervals during the years 2021 and 2022 using entomological nets or sweeping methods. Based on the representation of individual species, their dominance was evaluated according to Tischler (1949) and Heydemann (1955). The ecological significance of the individual study plots was assessed using the Shannon-Weaver diversity index (H', H'_{max}) and equitability index (e). Calculated diversity values (H') were compared with the maximum possible values (H'_{max}) and evenness values (e). The identification of individual hoverfly species was carried out based on the works of Stubbs and Falk (2002), Mazánek (2009), Speight and Sarthou (2010). Dominance was calculated according to Losos (1984; 1992):

$$D = (n_i / N) \times 100$$

where:

n_i - number of specimens of a species i

N - total number of individuals.

The statistical evaluation of the impact of the year and study plot on the species representation was conducted using the Statistica 10 program, using the T-test for an independent sample.

RESULTS

Hoverflies play an irreplaceable role in ecosystems, as they significantly contribute to the pollination of not only cultivated but also wild-growing plants (Mebarkia et al., 2021). During the observed period, a total of 1108 hoverfly individuals belonging to 29 species were captured and classified.

In 2021, 417 individuals belonging to 6 subfamilies and 25 species were captured (Table 1). 10 hoverfly species were classified into the subfamily *Syrphini*, 2 species to *Bacchini*, and one each into the subfamilies *Pipizini*, *Brachyopini*, and *Milesini*, while 10 species were classified into *Eristalini*. Out of the total number of captured individuals in 2021, 124 hoverfly individuals were identified as belonging to 8 species that prefer wetland habitats. These species included *Platycheirus fulviventris*, *Neoascia interrupta*, *Eristalinus sepulchralis*, *Helophilus hybridus*, *H. pendulus*, *H. trivittatus*, *Parhelophilus versicolor*, and *Syritta pipiens*. It can be stated that within the observed period, these wetland-preferring individuals represented 29.74% of the total number of individuals and 32.0% of the total number of species.

Table 1. Abundance and dominance of *Syrphidae* in 2021

Species	2021				Total	
	N1	D1	N2	D2	N	D
Anasimyia interpuncta (Harris, 1776)	13	5.74	8	4.21	21	5.03
Episyrphus balteatus (De Geer, 1776)	38	16.74	42	22.11	80	19.18
Eristalinus aeneus (Scopoli, 1763)			4	2.10	4	0.96
E. sepulchralis (Linné, 1758)	9	3.96	12	6.32	21	5.03
Eristalis arbustorum (Linné, 1758)	10	4.40	15	7.90	25	6.00
E. tenax (Linné, 1758)	24	10.58	13	6.84	37	8.87
Eupeodes corollae (Fabricius, 1794)	4	1.76	6	3.16	10	2.39
E. luniger (Meigen, 1822)	1	0.44			1	0.24
Helophilus hybridus (Loew, 1846)	2	0.88			2	0.48
H. pendulus (Linné, 1758)	3	1.32	5	2.63	8	1.92
H. trivittatus (Fabricius, 1805)	1	0.44	2	1.05	3	0.72
Chrysotoxum bicinctum (Linnaeus, 1758)			1	0.53	1	0.24
Ch. cautum (Harris, 1776)	5	2.20			5	1.20
Myathropa florea (Linné, 1758)	2	0.88	2	1.05	4	0.96
Neoascia interrupta (Meigen, 1822)	7	3.08	11	5.79	18	4.32
Parhelophilus versicolor (Fabricius, 1787)	36	15.87	12	6.32	48	11.51
Pipizella viduata (Linné, 1758)	2	0.88	1	0.53	3	0.72
Platycheirus clypeatus (Meigen, 1822)	1	0.44			1	0.24
P. fulviventris (Macquart, 1829)	2	0.88	2	1.05	4	0.96
Scaeva pyrastri (Linné, 1758)			2	1.05	2	0.48
Sphaerophoria scripta (Linné, 1758)	42	18.50	28	14.74	70	16.79
Syritta pipiens (Linné, 1758)	7	3.08	10	5.26	17	4.08
Syrphus ribesii (Linné, 1758)	3	1.32	5	2.63	8	1.92
S. vitripennis (Meigen, 1822)	15	6.61	7	3.68	22	5.28
Xanthogramma pedissequum (Harris, 1780)			2	1.05	2	0.48
Total	227	100	190	100	417	100

Regarding dominance, eudominant species (D>10%) included *Episyrphus balteatus*, *Sphaerophoria scripta*, and *Parhelophilus versicolor*. Observed dominant species (5%≤D<10%) were *Syrphus vitripennis*, *Anasimyia interpuncta*, *Eristalinus sepulchralis*, *Eristalis arbustorum*, and *E. tenax*. Subdominant species (D>2<5%) were *Eupeodes corollae*, *Neoascia interrupta*, and *Syritta pipiens*. Recedent species (1%≤D<2%) were *Chrysotoxum cautum*, *Syrphus ribesii*, *Helophilus pendulus*, and subrecedent species (0%<D<1%) included *Chrysotoxum bicinctum*, *Eupeodes luniger*, *Scaeva pyrastri*, *Xanthogramma pedissequum*, *Platycheirus clypeatus*, *Platycheirus fulviventris*, *Pipizella viduata*, *Eristalinus aeneus*, *Helophilus hybridus*, *H. trivittatus*, and *Myathropa florea*. In 2022 a total of 691 hoverfly individuals belonging to 6 subfamilies and 26 species were captured and classified (Table 2).

Table 2. Abundance and dominance of *Syrphidae* in 2022

Species	2022				Total	
	N1	D1	N2	D2	N	D
Anasimyia interpuncta (Harris, 1776)	17	4.71	13	3.94	30	4.34
Episyrphus balteatus (De Geer, 1776)	43	11.91	54	16.36	97	14.04
Eristalinus sepulchralis (Linné, 1758)	8	2.22	3	0.91	11	1.59
Eristalis arbustorum (Linné, 1758)	19	5.27	32	9.70	51	7.38
E. tenax (Linné, 1758)	57	15.79	41	12.43	98	14.19
Eupeodes corollae (Fabricius, 1794)	6	1.66	12	3.64	18	2.60
E. latifasciatus (Macquart, 1829)	2	0.55	3	0.91	5	0.72
E. luniger (Meigen, 1822)	1	0.28	1	0.30	2	0.29
Helophilus hybridus (Loew, 1846)			4	1.21	4	0.58
H. pendulus (Linné, 1758)	9	2.49	4	1.21	13	1.88
H. trivittatus (Fabricius, 1805)	2	0.55	2	0.61	4	0.58
Chrysotoxum bicinctum (Linnaeus, 1758)	2	0.55	1	0.30	3	0.43
Ch. cautum (Harris, 1776)			3	0.91	3	0.43
Melanostoma mellinum (Linné, 1758)			2	0.61	2	0.29
Neoascia interrupta (Meigen, 1822)	13	3.60	21	6.36	34	4.92
N. podagrica (Fabricius, 1775)	6	1.66	2	0.61	8	1.16
Parhelophilus versicolor (Fabricius, 1787)	64	17.73	35	10.61	99	14.33
Pipizella viduata (Linné, 1758)	2	0.55	1	0.30	3	0.43
Platycheirus fulviventris (Macquart, 1829)	14	3.88	8	2.42	22	3.18
P. occultus (Goeldlin de Tiefenau Maibach & Speight, 1990)	7	1.94	9	2.73	16	2.32
Scaeva pyrastri (Linné, 1758)	2	0.55			2	0.29
Sphaerophoria scripta (Linné, 1758)	38	10.53	46	13.94	84	12.16
Syritta pipiens (Linné, 1758)	5	1.39	8	2.42	13	1.88
Syrphus ribesii (Linné, 1758)	11	3.05	8	2.42	19	2.75
S. vitripennis (Meigen, 1822)	23	6.37	15	4.54	38	5.50
Xanthogramma pedissequum (Harris, 1780)	10	2.77	2	0.61	12	1.74
Total	361	100	330	100	691	100

Among them, 11 hoverfly species were classified into the subfamily *Syrphini*, 3 species into *Bacchini*, one into the subfamily *Pipizini*, 2 into *Brachyopini*, 8 into *Eristalini*, and 1 into *Milesini*. Out of the total number of captured individuals in 2022, 208 hoverfly individuals belonged to 9 species that prefer wetland habitats. These species include *Platycheirus fulviventris*, *Neoascia interrupta*, *N. podagrica*, *Eristalinus sepulchralis*, *Helophilus hybridus*, *H. pendulus*, *H. trivittatus*, *Parhelophilus versicolor*, and *Syritta pipiens*. Within the observed period in 2022, individuals preferring wetlands represented 30.10% of the total number of individuals and 34.62% of the total number of species. Eudominant species (D>10%) included *Episyrphus balteatus*, *Sphaerophoria scripta*, *Eristalis tenax*, and *Parhelophilus versicolor*. Dominant species (5%≤D<10%) observed were *Syrphus vitripennis* and *Eristalis arbustorum*. Subdominant species (D>2<5%) were *Eupeodes corollae*, *Syrphus ribesii*, *Platycheirus fulviventris*, *P. occultus*, *Neoascia interrupta*, and *Anasimyia interpuncta*. Recedent species (1%≤D<2%) were *Xanthogramma pedissequum*, *Neoascia podagrica*, *Eristalinus sepulchralis*, *Helophilus pendulus*, and *Syritta pipiens*. Subrecedent species (0%<D<1%) included *Chrysotoxum bicinctum*, *Ch. cautum*, *Eupeodes latifasciatus*, *E. luniger*, *Scaeva pyrastri*, *Melanostoma mellinum*, *Pipizella viduata*, *Helophilus hybridus*, and *H. trivittatus*.

According to the ecosozological assessment by Mazánek and Barták (2005) during the observed period, were identified *Neoascia interrupta* and *Parhelophilus versicolor* as vulnerable species. These two species were relatively abundant in the monitored area. It can be concluded that among the species preferring wetland habitats, *Parhelophilus versicolor* showed eudominant representation during both years. The eudominant aphidophagous species during both years of the research were *E. balteatus* and *S. scripta* and the dominant species were *S. vitripennis*.

Regarding the biological assessment in terms of species, the number of vulnerable species, and the overall number of species, both study areas showed relatively balanced diversity.

Based on the data in Table 3, the maximum value of the Shannon-Weaver diversity index ($H´$= 3.09; with $H´_{max}$ = 4.36) was recorded in the year 2021 at the study area located in the southern part of the reserve (N2), where the highest equitability value (e = 0.71) was also recorded. On the other hand, the minimum value of the Shannon-Weaver diversity index ($H´$= 2.48; with $H´_{max}$ = 3.93) was recorded in the year 2021 in the northern part of the reserve (N1). The lowest equitability value (e = 0.50) was observed in the year 2022 in the study area N2. Based on these findings, it can be concluded that in terms of ecological significance, the study area situated in the southern part of the reserve (N2) received the highest rating.

Statistical analysis showed that the influence of the year and study area on the species composition of *Syrphidae* was not significant during both years (Table 4).

Table 3. Shannon-Weaver index diversity values ($H´$ a $H´_{max}$) and equitability index (e)

Observed area and year	Number of species	$H´$	$H´_{max}$	Equatibility (e)	Number of specimens
N-1 (2021)	21	2.48	3.93	0.63	227
N-2 (2021)	21	3.09	4.36	0.71	190
N-1 (2022)	23	2.61	4.81	0.54	361
N-2 (2022)	25	2.62	5.28	0.50	330

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Table 4. The influence of the year and study area on the species composition of *Syrphidae*

Group 1 vs. Group 2	All Groups T-test for Independent Samples (Sheet1 in stat) Note: Variables were treated as independent samples										
	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std Dev. Group 1	Std Dev. Group 2	F-ratio Variances	*P* Variances
N-1 (2021) vs. N-1 (2022)	15,13333	24,06667	-0,627816	58	0,532588	30	30	41,72548	65,82628	2.488833	0,016660
N-1 (2021) vs. N-2 (2022)	15,13333	22,00000	-0,514178	58	0,609081	30	30	41,72548	60,07811	2,073145	0,054170
N-2 (2021) vs. N-1 (2022)	12,66667	24,06667	-0,838967	58	0,404932	30	30	34,72784	65,82628	3,592882	0,000938
N-2 (2021) vs. N-2 (2022)	12,66667	22,00000	-0,736684	58	0,464284	30	30	34,72784	60,07811	2,992795	0,004260

DISCUSSION

From a biological point of view, *Syrphidae* are one of the most diverse families within the order *Diptera*, making their research highly valuable for the protection and conservation of habitats (Sánchez Heredia et al., 2017).

Hoverflies are important pollinators of numerous wild plants (Orford et al., 2015; Sakurai, Takahashi, 2017; Moquet et al., 2018) and biological control against insect pests (Dunn et al., 2020; Pekas et al., 2020; Rego et al., 2022). In some cases, they perform ecological functions that are equally essential as those of bees (Forup et al., 2008). Additionally, they are significant pollinators of many agricultural crops (Inouye et al., 2015; Rader et al., 2016). Hoverflies are an important group of pollinators that not only preserve biodiversity, but also play a vital role in crop pollination, and interest in their importance is increasing due to their role as pollinators (Lucas et al., 2018a; Lucas et al., 2018b). Moreover, they serve as valuable ecological indicators, being easily captured and identified, with well-known life cycles and larvae with varying environmental requirements (Sommaggio and Burgio, 2014; Ball and Morris, 2015; Dunn et al., 2020). They belong to an abundant group *Diptera* with more than 6000 known species (Evenhuis and Pape, 2021) and are easily distinguishable from other insects due to their color patterns, unique morphology, and flight behavior (Ball and Morris, 2015). Adult hoverflies feed on honeydew, pollen, and nectar, and belong to the most important flower visitors across different ecosystems (Inouye et al., 2015; Doyle et al., 2020). On the other hand, hoverfly larvae utilize a wide range of feeding habits, including feeding on sporocarp of fungi (mycophagy), manure, tree sap, nests of social insects, decaying vegetation and wood (saprophagy), leaves and plant stem (phytophagy), or predation on other insects (zoophagy) (Rotheray, 1993). Male hoverflies hover above flowers, waiting to mate with females (Skevington et al., 2019; Moran et al., 2022). Klecka et al., 2018 found that different hoverfly species show varying levels of specialization, while some hoverflies visit similar ranges of flowers, others have broader preferences.

Authors state that *Eristalinae* hoverflies strongly prefer white flowers, *Pipizinae* mostly visits white and yellow flowers, while *Syrphinae* shows a lower influence of flower color.

Hoverflies are diverse not only in terms of species but also in their ecological roles. They inhabit various biotopes and regions (Marshall, 2012), pollinate numerous plants, and regulate populations of other insects (Rotheray and Gilbert, 2011). They can serve as indicators of habitat integrity (Lorenzo et al., 2020) and global climate change (Rotheray and Gilbert, 2011). Climate change could negatively impact hoverflies; for example, in southern Europe, it is expected that the populations of saproxylic species (larvae dependent on moist microhabitats in trees) will decline due to the predicted warming (Marcos García and Ricarte, 2009).

CONCLUSION

The research on syrphidocenoses was conducted in the years 2021 and 2022 within the territory of the Listové Lake Nature Reserve. During this period, a total of 1108 individuals of hoverflies belonging to 29 species were captured. Based on dominance, the eudominant species in both years were *Episyrphus balteatus*, *Sphaerophoria scripta*, and *Parhelophilus versicolor*. In terms of the occurrence of vulnerable species associated with this type of habitat, the studied location can be considered highly significant. It can be stated that, from an ecological perspective, the highest-rated study area was located in the southern part of the reserve, where in the year 2021, the maximum value of Shannon-Weaver diversity index ($H' = 3.09$; with $H'_{max} = 4.36$) and the highest value of equitability ($e = 0.71$) were observed. Based on species representation, the studied location is evaluated as biologically significant. The impact of the year and study area on the species representation of the *Syrphidae* family did not show statistical significance.

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