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WASPS (CRABRONIDAE, SPHECIDAE, SCOLIIDAE, AND POMPILIDAE) OF RIVNE NATURE RESERVE AND THEIR TROPHIC RELATIONSHIPS WITH ANGIOSPERMS

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Background. The article presents data obtained as a result of our research on the territory of Rivne Nature Reserve during 2018–2022. We collected 118 individuals belonging to 43 species, 19 genera from the Crabronidae, Sphecidae, Scoliidae, and Pompilidae families. The captured insects fed on 12 plant species belonging to eight families.

A preliminary list of wasp species of the studied families that occur on the territory of Rivne Nature Reserve is presented. The studied individuals are stored in the entomological collections of the Zoological Museum of Ivan Franko National University of Lviv.

The aim of the research was to prepare a preliminary list of wasp species of Rivne Nature Reserve and to identify their trophic relationships with angiosperms.

Material and Methods. The object of the research was the wasps of the Crabronidae, Sphecidae, Scoliidae, and Pompilidae families. Insects were caught by an entomological net using the method of selective catching directly on plants to identify their trophic relationships. Konus Crystal 7x-45x binoculars (Konus, Italy) and specialized keys and descriptions were used to identify the insects. Identification of angiosperms was carried out with the help of special keys.

Results. We collected 43 species of wasps belonging to 19 genera (*Bembix*, *Cerceris*, *Crabro*, *Crossocerus*, *Ectemnius*, *Lestica*, *Nysson*, *Oxybelus*, *Gorytes*, *Pemphredon*, *Tachysphex*, *Ammophila*, *Sceliphron*, *Scolia*, *Priocnemis*, *Anoplius*, *Arachnospila*, *Episyron,* and *Dipogon*). Most of the wasps (40 species) were registered on the territory of Rivne Nature Reserve for the first time.

We identified trophic relationships between the adults of 27 wasp species and plants belonging to 12 genera. The publication provides a preliminary list of the species from the territory of Rivne Nature Reserve. The individuals are stored in the collections of the Zoological Museum of Lviv University.

Conclusions. Out of 43 species (19 genera) of wasps, 40 were recorded for the first time in Rivne Nature Reserve. These include *Sceliphron curvatum*, which is invasive in Europe.Trophic relationships of 27 adult wasp species with 12 angiosperm species were established. As a result, a preliminary list of wasp species for the territory of Rivne Nature Reserve was prepared and trophic relationships of some representatives of the families Crabronidae, Sphecidae, Scoliidae, and Pompilidae with angiosperms were revealed.

Keywords: Hymenoptera, wasps, fauna diversity, trophic relationships, angiosperms

INTRODUCTION

Representatives of the families Crabronidae, Sphecidae, Scoliidae, and Pompilidae are an important ecological group of insects that perform a number of functions in terrestrial ecosystems. In particular, imagoes feeding on the nectar of plants carry a small amount of pollen, so they are potential pollinators of numerous angiosperms (Gorobchishin & Protsenko, 2004). Also, to feed their offspring, adults hunt many arthropods, including the pests of agricultural lands and forests, thereby regulating their numbers. Despite the importance of wasps, they are an insufficiently studied group of insects in Rivne Nature Reserve in particular and in Western Ukraine in general (Zhuravchak, 2011).

Studies of wasps of the families Crabronidae, Sphecidae, Scoliidae, and Pompilidae were carried out previously on the territory of Ukraine by several authors (Gorobchishin, 1995; 1996; 2006; Gorobchishin & Protsenko, 2004; Kumpanenko *et al.*, 2021; Nepein & Dyumin, 2014; Protsenko, 2003; Protsenko & Gorobchishin, 2015) but they have not been conducted on the territory of Rivne Nature Reserve.

Our research is focused on the preparation of preliminary species list of wasps of the families Crabronidae, Sphecidae, Scoliidae, and Pompilidae on the territory of Rivne Nature Reserve and identifying their trophic relationships with angiosperms.

MATERIALS AND METHODS

The research was conducted on the territory of Rivne Nature Reserve. The reserve is one of the largest in Ukraine with an area of 42,288.7 ha. It is located in the north of Rivne region (Onyshchenko *et al.*, 2015). It includes four separate territories: landscape reserve „Biloozerskyi" (Volodymyretsky district), general zoological reserve „Perebrodivskyi" (Dubrovytskyi and Rokytnivskyi districts), botanical reserve „Syra Pogonya" (Rokytnivskyi district), and hydrological reserve „Somyno" (Sarnenskyi district) which are divided into six departments (Biloozerske, Pivnichne, Starosilske, Hrabunske, Bilske, and Karasynske) (Zhuravchak, 2011) (**Fig. 1**).

Rivne Nature Reserve is located in a zone of mixed forests (coniferous and broad-leaved). More than 50 % of the total area of the reserve is covered by forest (mostly cultivated). The other half of the reserve (non-forest areas) is almost entirely made up of swamps. (Gulay *et al.*, 2021).

The object of the research is the wasps of the Crabronidae, Sphecidae, Scoliidae, and Pompilidae families in Rivne Nature Reserve. Insects were caught with an entomological net by the "selective capture" method on flowering plants. The sampling was carried out during the vegetation seasons of 2018–2022 on the territory of all six reserve departments. During the research period, it was possible to carry out 11 expeditions within the territory of the reserve. Starting from 2020, the number of expeditions decreased due to Covid-19 quarantine restrictions, and in 2022 – due to the state of war on the territory of Ukraine.

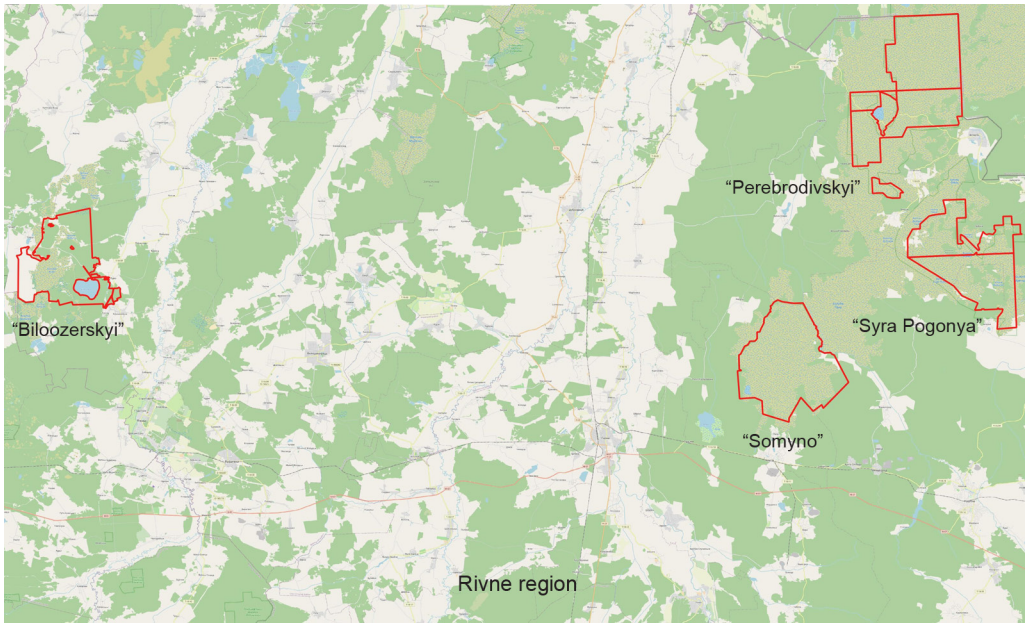

Fig. 1. Rivne Nature Reserve: landscape reserve "Biloozerskyi"; hydrological reserve "Somyno"; botanical reserve "Syra Pogonya"; zoological reserve "Perebrodivskyi"

Konus Crystal 7x-45x binoculars (Konus, Italy) and specialized keys and descriptions were used to identify insects (Dollfuss, 1991; Bitsch, 2007). The nomenclature and systematics of the wasps of the Crabronidae and Sphecidae families are based on the electronic catalog of Sphecidae (Pulawskyi, 2020).

The studied angiosperm samples were photographed, herbarized, and identified using special keys (Barbarych *et al.*, 1965).

All specimens are sampled and stored in the entomological collection of the ZMD (Pytel *et al.*, 2022).

RESULTS AND DISCUSSION

As a result of research, we collected 118 individuals belonging to 43 species from four families: Crabronidae, Sphecidae, Scoliidae, and Pompilidae; they represent 19 genera: *Bembix, Cerceris, Crabro, Crossocerus*, *Ectemnius*, *Lestica, Nysson, Oxybelus*, *Gorytes, Pemphredon, Tachysphex, Ammophila, Sceliphron, Scolia, Priocnemis, Anoplius, Arachnospila, Episyron*, and *Dipogon* (**Table 1**).

Table 1. **Species diversity of wasps on the territory of Rivne Nature Reserve**

Family	Species	Reserve department	Number of specimens and sex	Status
Crabronidae	*Bembix rostrata* (Linnaeus, 1758)	Hr.	F	New
	Ectemnius fossorius (Linnaeus, 1758)	Bo., Kr.	4F, 1M	New
	Ectemnius continuus (Fabricius, 1804)	Bo., Kr.	F, M	New
	Ectemnius lapidarius (Panzer, 1803)	Bo., Hr.	6M, F	New
	Ectemnius lituratus (Panzer,1803)	Bo.	4M	New
	Ectemnius rubicola (Dufour & Perris, 1840)	Bo.	M	New
	Ectemnius rugifer (Dahlbom, 1845)	Kr.	F	New
	Cerceris arenaria (Linnaeus,1758)	Bl., Bo., Hr., Pv., Ss.	8M, 3F	New
	Cerceris rybyensis (Linnaeus, 1771)	Bo., Hr.	2M	New
	Cerceris ruficornis (Fabricius, 1793)	Hr.	F	New
	Cerceris media Klug, 1835	Bl.	M	New
	Crabro cribrarius (Linnaeus, 1758)	Bo.	M	New
	Crabro scutellatus (von Scheven, 1781)	Bl.	M	New
	Crossocerus subulatus (Dahlbom, 1845)	Bo.	F	New
	Lestica clypeata (Schreber, 1759)	Bo., Hr.	8F, 10M	New
	Lestica alata (Panzer, 1797)	Bo.	M	New
	Nysson spinosus (J. Forster, 1771)	Bo.	6F	New
	Nysson maculosus (Gmelin, 1790)	Bo.	F, M	New
	Nysson niger Chevrier, 1868	Kr.	F	New
	Oxybelus mucronatus (Fabricius, 1793)	Bo.	M	New
	Oxybelus argentatus Curtis, 1833	Bo.	F	New
	Gorytes laticinctus (Lepeletier,1832)	Kr.	F	New
	Gorytes quinquecinctus (Fabricius, 1793)	Bo.	2M	New
	Pemphredon lethifer (Shuckard, 1837)	Kr.	4M	New
	Pseneo exaratus (Eversmann, 1849)	Kr.	2F	New
	Tachysphex obscuripennis (Schenck, 1857)	Hr., Kr.	M, F	New
Sphecidae	*Ammophila pubescens* Curtis, 1836	Kr.	F, M	New
	Ammophila campestris Latreille, 1809	Bo.	F	New
	Ammophila sabulosa (Linnaeus, 1758)	Bl., Bo., Kr.	7M, F	New
	Sceliphron destillatorium (Illiger, 1807)	Kr.	F	2013
	Sceliphron curvatum (F. Smith, 1870)	Hr.	(nests)	New

Family	Species	Reserve department	Number of specimens and sex	Status
Scoliidae	*Scolia hirta* (Schrank, 1781)	Kr., Pv., Ss.	2F, 3M	2007
	Scolia quadripunctata Fabricius, 1775	Bo., Hr., Kr., Pv.	3F, M	2013
Pompilidae	*Priocnemis fennica* Haupt,1927	Kr.	F	New
	Priocnemis exaltata (Fabricius,1775)	Kr.	F	New
	Priocnemis coriacea Dahlbom,1843	Kr.	F	New
	Priocnemis vulgaris (Dufour, 1841)	Bo.	F	New
	Anoplius viaticus (Linnaeus,1758)	Bo., Hr.	3F	New
	Anoplius infuscatus (Vander Linden,1827)	Kr.	F	New
	Anoplius nigerrimus (Scopoli,1763)	Kr.	F	New
	Arachnospila minutula (Dahlbom,1842)	Bo.	M	New
	Episyron rufipes (Linnaeus, 1758)	Kr.	F	New
	Dipogon subintermedius (Magretti,1886)	Kr.	2F	New

Comments: **Reserve department** (**listed in alphabetical order**): Bl. – Bilske; Bo. – Biloozerske; Hr. – Hrabun; Kr. – Karasynske; Pv. – Pivnichne; Ss. – Starosilske
Number of specimens and sex: this column shows the total number of samples taken on the territory of the respective departments
Status: New – for the first time indicated for the territory of the reserve; years – the first record in the reserve

Sceliphron curvatum (F. Smith, 1870) is the only wasp species found by its nests, which were registered on the territory of Hrabun department (**Fig. 2**).

Fig. 2. Nests of *Sceliphron curvatum* (F. Smith, 1870)

This is the first record of this species in the territory of Rivne Nature Reserve. *S. curvatum* is an invasive species in Europe and was first recorded in 1979 (Austria). The native range of the wasp extends from the east of Central Asia to Nepal and India. In Ukraine, the species was first recorded in 1999 in Kharkiv region and has actively colonised all regions of the country (Tymkiv *et al.*, 2015).

S. curvatum nests mainly near human dwellings, so in 2021, we were able to record this species for the first time on the territory of the reserve, finding nests of wasps in an old building.

The remaining 42 wasp species were sampled as imagoes and are represented in our collections.

Most of the wasps (40 species) were registered for the first time for the territory of Rivne Nature Reserve. All the insects caught belong to the NE (Not Evaluated) category of the International List of Nature Protection, which may indicate a lack of information about them.

The imagoes of Crabronidae, Sphecidae, Scoliidae, and Pompilidae are known to feed on plant nectar, sweet secretions of insects, hemolymph of insects and even nectar from the honey stomach of bees (Protsenko, 2003), while carrying a certain amount of pollen, being potential pollinators of many angiosperms. We identified trophic relationships between the adults of 27 species of wasps and plants belonging to 12 genera (8 species and 4 genera without species identification) (**Fig. 3**).

The numbers next to the species names of the plants are the number of specimens of wasps that fed on that plant. The numbers next to the wasps and between the links are the number of specimens of that wasp species caught on a particular plant.

The greatest diversity of the wasps fed on the nectar of the following plants: *Calluna vulgaris* (Ericaceae); *Rubus* sp. (Rosaceae); *Daucus carota* (Apiacea) and *Peucedanum palustre* – 6 species on each plant, respectively (**Fig. 4**).

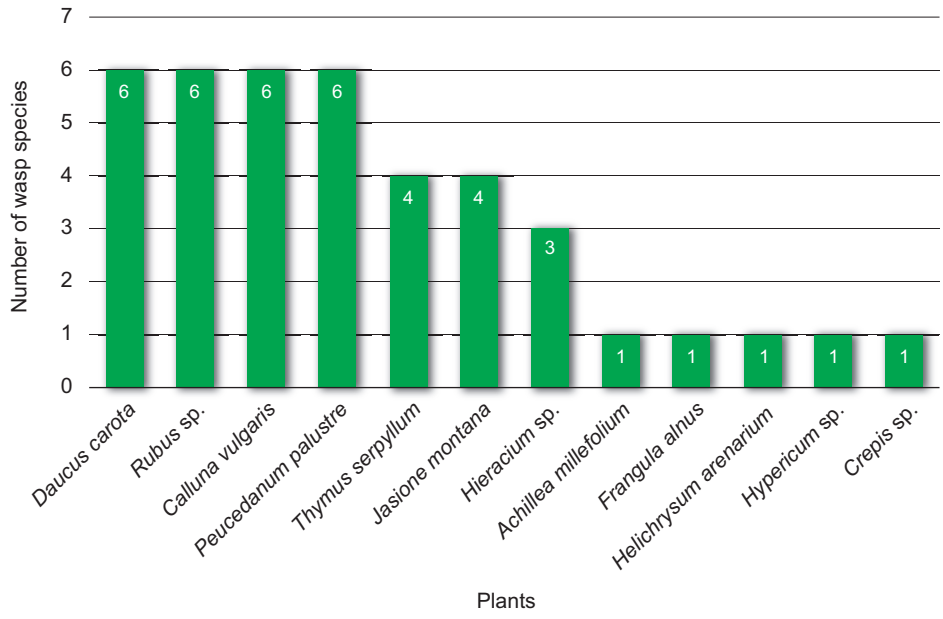

Fig. 4. The ratio of the number of wasp species that fed on the corresponding plants

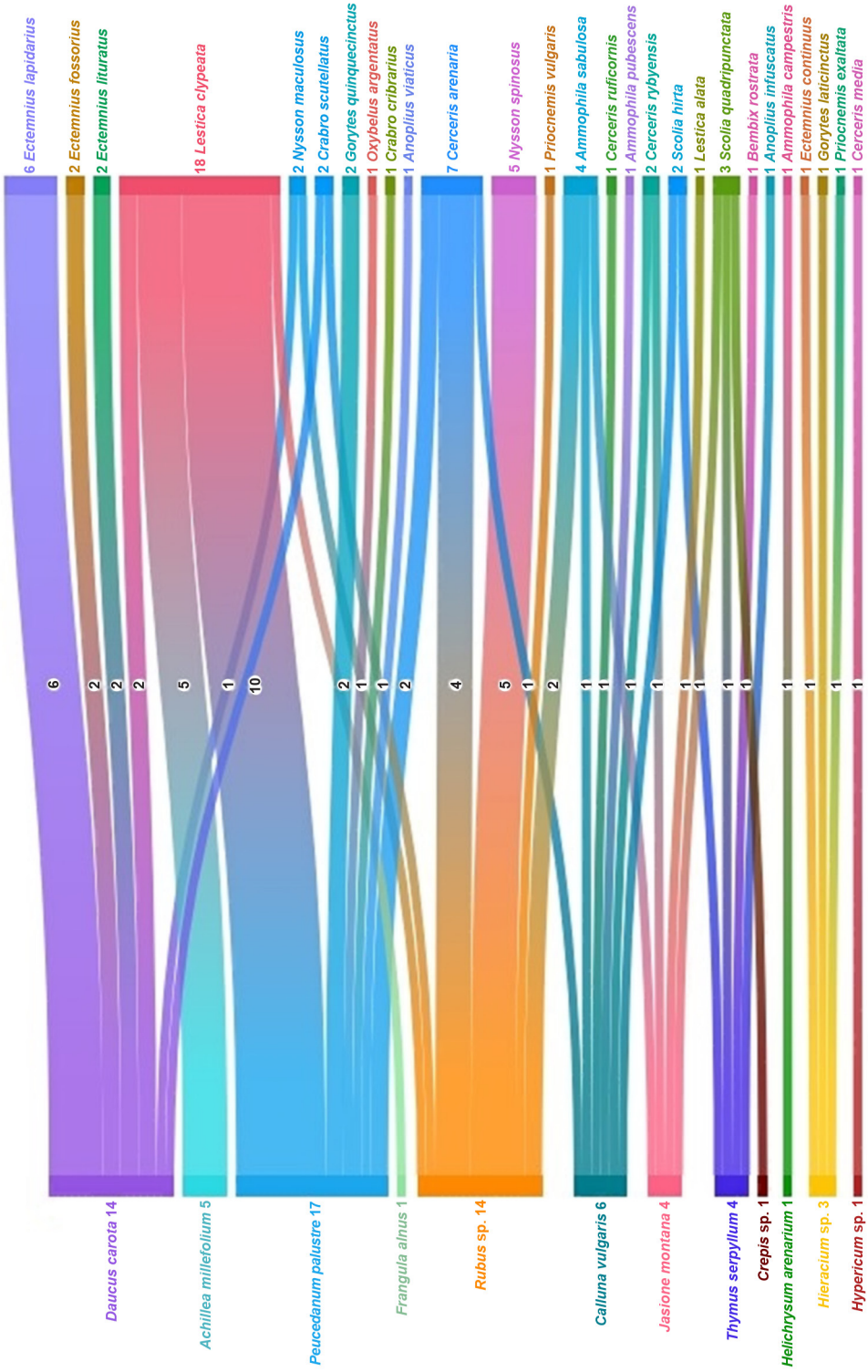

Fig. 3. Trophic associations of imagoes wasps with angiosperms. Illustration created using a web resource: https://flourish.studio

We assume that the wasps actively fed on *C. vulgaris* and *Rubus* sp. since the period of material sampling coincided with the flowering peak of these plant species on the territory of separate departments of Rivne Nature Reserve.

Most of the studied species build their nests under the ground in the form of soil burrows (24 species); 11 species build their nests in dead wood above the ground, hollow plant stems, etc.; three species are kleptoparasites that do not care for their offspring; biotic features of rest of the species (5) are still poorly known (**Table 2**).

Table 2. **Wasps of the families Crabronidae, Sphecidae, Scoliidae, and Pompilidae and some of their ecological and ethological characteristics**

No	Species	Plant family	Nesting		Prey
			above the ground	under the ground	
Family Crabronidae					
1.	*Bembix rostrata*	II		*	Diptera
2.	*Ectemnius fossorius*	I	*		Diptera
3.	*Ectemnius continuus*	VI	*		Diptera
4.	*Ectemnius lapidarius*	I	*		Diptera
5.	*Ectemnius lituratus*	I	*		Diptera
6.	*Ectemnius rubicola*	-	*		Diptera
7.	*Ectemnius rugifer*	-	N/A	N/A	N/A
8.	*Cerceris arenaria*	I, IV, V		*	Coleoptera
9.	*Cerceris rybyensis*	III, V		*	Hymenoptera
10.	*Cerceris ruficornis*	V		*	Coleoptera
11.	*Cerceris media*	VIII		*	Coleoptera
12.	*Crabro cribrarius*	I		*	Diptera
13.	*Crabro scutellatus*	IV		*	Diptera
14.	*Crossocerus subulatus*	-	*		Diptera
15.	*Lestica clypeata*	I, VI, VII	*		Lepidoptera
16.	*Lestica alata*	III		*	Diptera
17.	*Nysson spinosus*	IV		Kleptoparasite	
18.	*Nysson maculosus*	I, IV		Kleptoparasite	
19.	*Nysson niger*	-		Kleptoparasite	
20.	*Oxybelus mucronatus*	-		*	Diptera
21.	*Oxybelus argentatus*	I		*	Diptera
22.	*Gorytes laticinctus*	VI		*	Hemiptera
Family Crabronidae					
23.	*Gorytes quinquecinctus*	I		*	Hemiptera
24.	*Pemphredon lethifer*	-	*		Hemiptera
25.	*Pseneo exaratus*	-	N/A	N/A	N/A
26.	*Tachysphex obscuripennis*	-		*	Blattodea

No	Species	Plant family	Nesting		Prey
			above the ground	under the ground	
27.	*Ammophila pubescens*	V		*	Lepidoptera
28.	*Ammophila campestris*	VI		*	Lepidoptera
29.	*Ammophila sabulosa*	III, IV, V		*	Lepidoptera
30.	*Sceliphron destillatorium*	-	*		Araneae
31.	*Sceliphron curvatum*	-	*		Araneae
	Family Scoliidae				
32.	*Scolia hirta*	V		*	Coleoptera
33.	*Scolia quadripunctata*	II, III, VI		*	Coleoptera
	Family Pompilidae				
34.	*Priocnemis fennica*	-	N/A	N/A	Araneae
35.	*Priocnemis exaltata*	VI		*	Araneae
36.	*Priocnemis coriacea*	-		*	Araneae
37.	*Priocnemis vulgaris*	IV	N/A	N/A	Araneae
38.	*Anoplius viaticus*	I		*	Araneae
39.	*Anoplius infuscatus*	II		*	Araneae
40.	*Anoplius nigerrimus*	-	*	*	Araneae
41.	*Arachnospila minutula*	-	N/A	N/A	Araneae
42.	*Episyron rufipes*	-		*	Araneae
43.	*Dipogon subintermedius*	-	*		Araneae

Comments: I – Apiaceaea; II – Lamiaceae; III – Campanulaceae; IV – Rosaceae; V – Ericaceae; VI – Asteraceae; VII – Rhamnaceae; VIII – Hypericaceae; N/A – there are no data for the territory of the reserve

Twelve species of wasps (Crabronidae) feed their offspring on 12 species of dipterans (**Fig. 5**). In addition, members of the Crabronidae family hunt Hemiptera and Coleoptera – three species respectively. Only one species of wasp feeds its offspring on solitary bees (Hymenoptera), Blattodea and Lepidoptera.

The family Crabronidae also includes kleptoparasites (3 species) which do not care for their offspring. Instead, their larvae feed on food provided by the host wasp. Representatives of the families Pompilidae and Scoliidae feed their offspring only with spiders (10 species of wasps) and Coleoptera (2 species). Three species of wasps (Sphecidae) prey on Lepidoptera caterpillars and two species prey on spiders.

In several representatives of the studied families ecological and ethological features have not yet been sufficiently investigated. In particular, two Crabronidae species and three Pompilidae ones (**Table 2**).

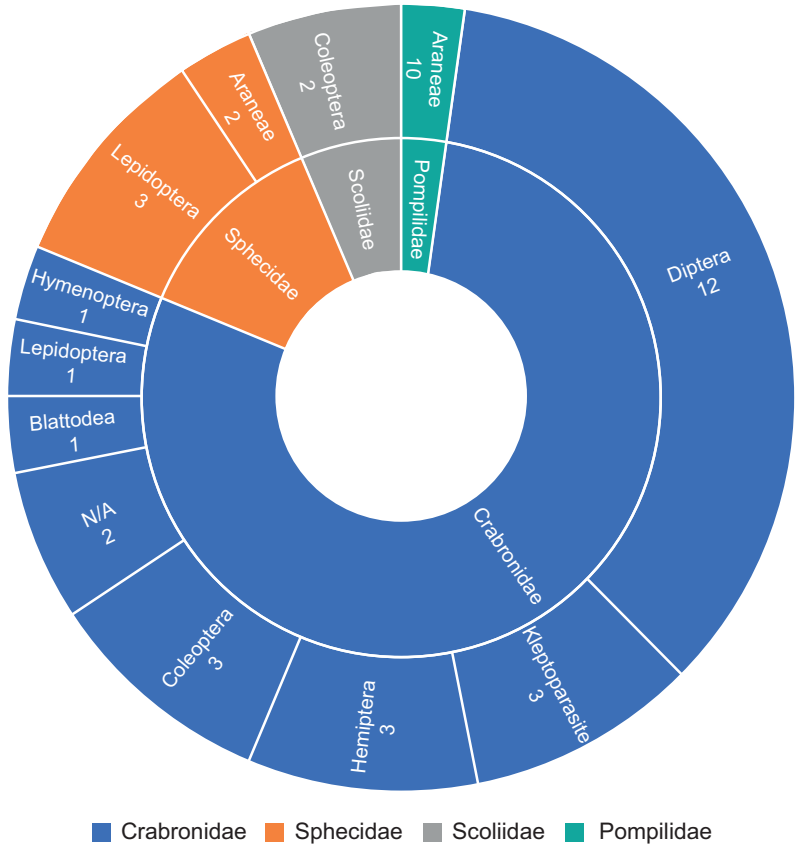

Fig. 5. Diversity of the wasp prey. N/A – No data

CONCLUSIONS

The diversity of wasps of the families Crabronidae, Sphecidae, Scoliidae, Pompilidae in the territory of the Rivne Nature Reserve is represented by 43 species, 40 of which we have recorded for the first time in the territory of the Reserve.

We determined the trophic relationships between adults of 27 wasp species and plants of 12 genera: 6 wasp species feeding on the nectar of *Calluna vulgaris* (Ericaceae), *Rubus* sp. (Rosaceae), *Daucus carota* (Apiacea) and *Peucedanum palustre* (Apiaceae), respectively.

Most of the wasp species collected in the reserve build nests in the form of soil burrows (24); the main prey of the representatives of the Crabronidae caught by us are dipterans, Pompilidae feed their offspring only on spiders, most waps of the Sphecidae family prey on Lepidoptera caterpillars, and Scoliidae only on Coleoptera.

42 found species are native to the territory of Ukraine, only *S. curvatum* is invasive. The nests of this wasp were recorded on the territory of Hrabun department.

All caught insects belong to the NE category – not evaluated in the International List of Nature Protection, which may indicate insufficient information about them.

This research gives only a partial picture of the diversity of the entomofauna on the territory of Rivne Nature Reserve and is the basis for further research in this direction.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Human Rights: This article does not contain any studies with human subjects performed by the any of the authors.

Animal studies: All institutional, national and institutional guidelines for the care and use of laboratory animals were followed.

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ОСИ (CRABRONIDAE, SPHECIDAE, SCOLIIDAE ТА POMPILIDAE) РІВНЕНСЬКОГО ПРИРОДНОГО ЗАПОВІДНИКА ТА ЇХНІ ТРОФІЧНІ ЗВ'ЯЗКИ З ПОКРИТОНАСІННИМИ РОСЛИНАМИ

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Обґрунтування. У статті представлені дані, отримані в результаті наших досліджень на території Рівненського природного заповідника впродовж 2018–2022 років. Ми зібрали 118 особин представників родин Crabronidae, Sphecidae, Scoliidae та Pompilidae, що належать до 43 видів, 19 родів. Піймані комахи живились на 12 рослинах, що належать до восьми родин.

Подано попередній список видів ос досліджуваних родин, що трапляються на території Рівненського природного заповідника. Зібрані екземпляри інвентаризовано і зберігають в ентомологічних колекціях Зоологічного музею Львівського національного університету імені Івана Франка.

Метою досліджень є формування попереднього списку видів ос Рівненського природного заповідника та встановлення їхніх трофічних зв'язків з покритонасінними рослинами.

Матеріали і методи. Об'єктом дослідження є оси родин Crabronidae, Sphecidae, Scoliidae та Pompilidae. Комах відловлювали ентомологічним сачком, методом вибіркового лову безпосередньо на рослинах для встановлення трофічних зв'язків. Для визначення комах використовували бінокуляр Konus Crystal 7x-45x (Konus, Італія) та відповідні визначники. Покритонасінні рослини фотографували, закладали гербарій та ідентифікували за допомогою визначника.

Результати. Унаслідок досліджень виявлено 43 види ос, які належать до 19 родів: *Bembix*, *Cerceris*, *Crabro*, *Crossocerus*, *Ectemnius*, *Lestica*, *Nysson*, *Oxybelus*, *Gorytes*, *Pemphredon*, *Tachysphex*, *Ammophila*, *Sceliphron*, *Scolia*, *Priocnemis*, *Anoplius*, *Arachnospila*, *Episyron* та *Dipogon*. Сорок видів зареєстровано вперше для території Рівненського заповідника.

Встановлено трофічні зв'язки між імаго 27 видів ос та 12 родами покритонасінних рослин. Більшість виявлених видів ос будують гнізда у вигляді нірок у ґрунті (24 види); основною здобиччю представників родини Crabronidae були двокрилі (Diptera), а оси з родини Pompilidae вигодовують своє потомство виключно павуками. Три види ос з родини Sphecidae полюють на гусениць лускокрилих і два – на павуків, тоді як Scoliidae (2 види) полюють лише на твердокрилих.

Висновки. На території заповідника було зібрано 118 особин, що належать до 43 видів ос із 19 родів. 40 видів є новими для Рівненського природного заповідника, серед них один – *Sceliphron curvatum* – інвазійний на території країн Європи (виявлено гнізда).

У результаті досліджень складено попередній перелік видів ос на території Рівненського природного заповідника та встановлено трофічні зв'язки між виявленими представниками родин Crabronidae, Sphecidae, Scoliidae і Pompilidae та покритонасінними рослинами.

Ключові слова: Hymenoptera, оси, біорізноманіття, трофічні зв'язки, покритонасінні рослини

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