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Trophic relationships of birds in forest plantings of the Azov region (Ukraine)

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The elements of the trophic structure of birds in the Ukrainian Azov region include: availability of food resources in habitats, feeding behavior and foraging methods, and specialization or euryphagous feeding patterns of certain species. Green plants form the basis of trophic relationships, but feeding schemes are much more complex and include animal organisms as well. The trophic relationships of birds in shelterbelts were conducted research during 2019–2021. Adjacent biocenoses, primarily agricultural lands, also serve as feeding sites. We analyzed trophic relationships within the framework of research on consortional relationships between birds and dominant tree species in shelterbelts: *Robinia pseudoacacia*, *Elaeagnus argentea*, and *Fraxinus excelsior*. During the study period, 1–4 bird species fed on *Elaeagnus argentea* on different days of the breeding period, and the correlation between the number of bird species and the number of trees on which birds fed was very weak. On *Robinia pseudoacacia* trees, 1–6 species fed, but this relationship also proved to be very weak. A significant correlation was found for *Fraxinus excelsior*; however, the functioning of this trophic consortium was sustained by an average of only 1.80 ± 0.33 (1–4) bird species. In the shelterbelts of the study region, 62 breeding species were identified and classified by dominant food sources into the following groups: entomophages – 25 species – birds whose food resources consisted of insects and arachnids; phytophages – 15 species – birds feeding on seeds, grain, fruits, and green plant organs; myophages – 9 species – birds feeding on mouse-like rodents and small mammals; pantophages – 8 species – birds feeding on various foods; and ichthyophages – 5 species – feeding on fish and small aquatic animals. According to foraging methods, the following categories of birds were identified: birds that perch on tree trunks, move along them, and extract insects and their larvae from under tree bark; birds feeding on insects and fruits on thin branches or leaves; predatory birds that capture small birds and insects on branches; birds that collect food primarily on the foliage of trees and shrubs; birds that peck food (insects, seeds) from the ground and search for it in the litter; predatory birds that catch their prey on the ground; species that find food (insects, seeds, grain) in open landscapes (agricultural lands, steppe, meadows, clearings, etc.); and birds that capture food in flight. In our research, we identified a trend of increase or decrease of certain bird groups in shelterbelts of different age. Thus, the number of entomophages increased from 20.0% (of the total number of breeding species in the studied shelterbelts) in young shelterbelts to 53.1% in old shelterbelts; the number of phytophages decreased with shelterbelt age (from 53.3% to 18.8%); and the myophage assemblage gradually increased depending on shelterbelt age (from 14.5% to 20.9%). Given the complexity of biocenotic relationships, we consider promising areas of research to include studying the relationship between the feeding patterns of avian populations in shelterbelts and a complex of factors: proximity to water bodies, shelterbelt structure, maturity and stability of plantings, and plant cover diversity. Also, in the context of trophic activity of birds, the phenomenon of zoochory is extremely interesting – the transport of plant propagules by animals, particularly birds, in various ways. By consuming plant seeds and fruits, birds leave undigested food remains in various locations, where over time we observed the emergence of vegetation patches.

Keywords: birds; trophic relationships; ornithoconsortia; ornithocenosis; avifauna; forest plantations; shelter belts.

Introduction

The biocenoses of the Ukrainian Azov region have undergone active transformation over the past three centuries. Steppe biotopes, which were separated by floodplains of small rivers with herbaceous and woody-shrub vegetation, were intensively converted into agrocenoses with a network of shelterbelts (Orlov, 1955; Vakulyuk & Samoplavskyi, 2006; Kostyushyn et al., 2014). The appearance of woody-shrub plantings significantly changed the living conditions of animals, particularly birds, creating a new ecological arena that replaced the disrupted or destroyed former stable relationships of steppe biocenoses (Volchanetsky, 1940; Budnichenko, 1968). Shelterbelts and forest plantings of the Ukrainian Azov region have become migration corridors for forest species from Crimea to the forests of the Forest-Steppe zone. As the plantings grew, becoming more structurally complex, there have been developing conditions, including trophic ones, for the colonization and nesting of demanding forest bird species (Kostiushyn et al., 2014; Pisotska, 2018; Ayubova, 2018). At the beginning of the twenty-first century, a notable degradation of shelterbelts occurred: tree felling, destruction of plantings by fire; simplification of shelterbelt structure – formation of monoculture plantings and loss of the network of interconnections between forest plantings and other biotopes (Bulahov & Myasoedova, 1975; Kuzmenko & Kuzmenko, 2010; Petrovych, 2014).

Biocenotic conditions in shelterbelts determine the trophic relationships of birds through food availability at nesting sites, foraging methods and behavioral patterns of birds, and specialization or euryphagous feeding of certain species (Malchevskij et al., 1953; Chaplygina et al., 2018; Ponomarenko, 2019). The study of various foraging techniques used by birds makes it possible to determine the position of individual species in the complex network of biotic relationships and the ecological niche of these species in biocenoses. In some studies (Marquis et al., 2025), the ecological niche is defined as "a system whose integral properties are determined by the nature of the function performed by the species in the ecosystem and are expressed in a specific method of food acquisition, or foraging behavior of birds." However, feeding and trophic relationships of birds in plantings can be dynamic, as birds adapt to feeding conditions in shelterbelts due to both internal and external factors (Chaplygina et al., 2019; Chaplygina & Pakhomov, 2020). The phenomenon of euryphagous feeding often results from seasonal changes in the nesting sites of avian populations in shelterbelts, when insectivorous species become phytophagous during the winter period (Koval, 1986; Corbin et al., 2015; Chaplygina et al., 2019; Chaplygina & Pakhomov, 2020). Changes in feeding patterns are also characteristic of various groups of herbivorous birds during the period of feeding nestlings in the early period, when the latter are provided with nutrition from various invertebrates rich in proteins and microelements necessary for this life stage (Blinkova & Shupova, 2018; Chaplygina et al., 2018). Changes in the food base in study areas can alter not only the feeding ecology of specific species but also the species composition of the regional avifauna (Novytskyi et al., 2017; Ponomarenko, 2019).

Extremely important in the trophic relationships of birds in shelterbelts is the provision of food resources at their nesting sites, the species diversity of plant and animal food objects, and their distribution and abundance in shelterbelts. Indeed, the ratio of bird species whose foraging methods range from the simplest to highly specialized characterizes the completeness and maturity of forest planting structure (Kuzmenko, 2010; Pisotska, 2018).

Materials and methods

The research was conducted during 2019-2021 in the northwestern Azov region in shelterbelts of various types (field-protective, roadside, water-protective), structure (permeable, openwork, dense), size, and age. Control routes through 14 shelterbelts were surveyed in the Melitopol, Tokmak, and Pryazovskyi districts of Zaporizhzhia Oblast, and in parks of Melitopol city. Special monitoring observations took place in other forest plantings of the Pryazovskyi and Azov-Syvash national nature parks; expeditionary trips were made to forest plantings located on the right slope of the Molochna River near Molochanskyi town (Tokmak District), in the floodplain of the Obytichna River near Pidsporie village and on Obytichna Spit (Prymorskyi district), in the floodplain of the Domuzla River near Novokostiantynivka village (Pryazovskyi District), and on Biriuchyi Island Spit (Fig. 1).

The study of trophic relationships of birds was conducted within the framework of our comprehensive research on the breeding avifauna of forest plantings in the northwestern Azov region as one of the research directions (Ayubova, 2018). To study the trophic relationships of birds, observations and investigations of feeding behavior in breeding species in the studied shelterbelts were conducted, and bird activity in adjacent biotopes was monitored (Table 1). We employed the system developed by V. N. Bekelemishev (1951) and L.G. Ramenskyi (1952), according to who a consortium is a structural unit of biocenosis comprising autotrophic and heterotrophic organisms based on spatial and food relationships. The species feeding directly on an edificator plant are considered first-order consort, and those related to the edificator through the first-order consort are considered second-order consorts, etc.

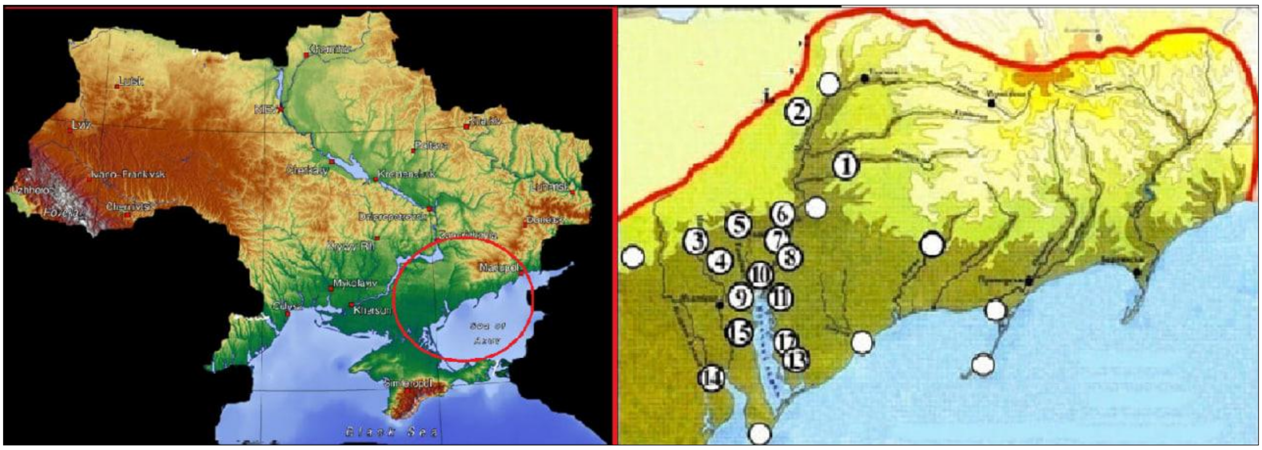

Fig. 1. Location of control shelterbelts and forest tracts of the Ukrainian Azov region: *1–14* – stationary survey sites; ○ – expeditionary survey sites

The occurrence and intensity of interactions between birds and plant objects were established through the study of consortional relationships of avian populations using the method of time-budget chronometry of birds per individual tree specimen (Dolnik, 1982). The method consisted of visual observation throughout daylight hours of the occurrence of bird arrivals and departures to/from plant objects (determinants). During observations, we identified and recorded both birds and plants, the type of functional interaction with the autotroph (topic, trophic, nesting, seed dispersal), and the amount of time spent by the bird with the plant consort. Visual observations were conducted at various distances – up to 1 m from concealment and at distances up to 5 m using binoculars, photo and video equipment. The duration of a specific type of interaction was determined in seconds using standard stopwatches (Ponomarenko, 2017).

Table 1
Complete list of the breeding bird species in the forest plantings of the Ukrainian Azov region

No.	Species of birds	Nesting places	Ecological group	Group by type of feed
1.	*Phalacrocorax carbo* (Linnaeus, 1758)	on the ground/in crowns	limnophiles	ichthyophagous
2.	*Nycticorax nycticorax* (Linnaeus, 1758)	in crowns	limnophiles	ichthyophagous
3.	*Egretta alba*, Linnaeus, 1758	in crowns	limnophiles	ichthyophagous
4.	*Egretta garzetta* (Linnaeus, 1766)	in crowns	limnophiles	ichthyophagous
5.	*Ardea cinerea* (Linnaeus, 1758)	in crowns/on the ground	limnophiles	ichthyophagous
6.	*Buteo rufinus* (Cretzschmar, 1829)	in crowns	dendrophiles	myophagous
7.	*Buteo buteo* (Linnaeus, 1758)	in crowns	dendrophiles	myophagous
8.	*Falco subbuteo*, Linnaeus, 1758	in crowns	dendrophiles	myophagous
9.	*Falco vespertinus*, Linnaeus, 1766	in crowns	dendrophiles	myophagous
10.	*Falco tinnunculus*, Linnaeus, 1758	in crowns	sclerophylles	myophagous
11.	*Perdix perdix (*Linnaeus, 1758)	on the ground	dendrophiles	phytophagous
12.	*Coturnix coturnix* (Linnaeus, 1758)	on the ground	campophiles	phytophagous
13.	*Phasianus colchicus*, Linnaeus, 1758	on the ground	dendrophiles	phytophagous
14.	*Columba palumbus*, Linnaeus, 1758	in crowns	dendrophiles	phytophagous
15.	*Streptopelia turtur* (Linnaeus, 1758)	in crowns	dendrophiles	phytophagous
16.	*Streptopelia decaocto* (Frivaldszky, 1838)	in crowns	sclerophylles	phytophagous

No.	Species of birds	Nesting places	Ecological group	Group by type of feed
17.	*Cuculus canorus*, Linnaeus, 1758	in crowns	limnophiles	entomophagous
18.	*Asio otus* (Linnaeus, 1758)	in crowns	dendrophiles	myophagous
19.	*Asio flammeus* (Pontoppidan, 1763)	on the ground	limnophiles	myophagous
20.	*Otus scops* (Linnaeus, 1758)	in hollows	dendrophiles	myophagous
21.	*Upupa epops* (Linnaeus, 1758)	in hollows	sclerophylles	entomophagous
22.	*Caprimulgus europaeus*, Linnaeus, 1758	on the ground	dendrophiles	entomophagous
23.	*Dendrocopos major* (Linnaeus, 1758)	in hollows	dendrophiles	entomophagous
24.	*Dendrocopos syriacus* (Hemprich & Ehrenberg, 1833)	in hollows	dendrophiles	entomophagous
25.	*Jynx torquilla*, Linnaeus, 1758	in hollows	dendrophiles	entomophagous
26.	*Motacilla alba*, Linnaeus, 1758	on the ground/in hollows	limnophiles	entomophagous
27.	*Lanius collurio*, Linnaeus, 1758	in shrubs	dendrophiles	myophagous/ entomophagous
28.	*Lanius minor* Gmelin, 1788	in crowns	dendrophiles	entomophagous
29.	*Sturnus vulgaris* Linnaeus, 1758	in hollows	sclerophylles	entomophagous
30.	*Oriolus oriolus* (Linnaeus, 1758)	in crowns	dendrophiles	entomophagous
31.	*Turdus merula* Linnaeus, 1758	on the ground/in crowns	dendrophiles	entomophagous
32.	*Turdus pilaris* Linnaeus, 1758	in crowns	dendrophiles	entomophagous
33.	*Turdus philomelas* C.L. Brehm, 1831	in crowns	dendrophiles	entomophagous
34.	*Phoenicurus phoenicurus* (Linnaeus, 1758)	in hollows	dendrophiles	entomophagous
35.	*Phoenicurus ochruros* (Gmelin, S.G., 1774)	in hollows	sclerophylles	entomophagous
36.	*Sylvia borin* (Boddaert, 1783)	in shrubs	dendrophiles	entomophagous
37.	*Sylvia communis* (Latham, 1787)	in shrubs	dendrophiles	entomophagous
38.	*Sylvia atricapilla* (Linnaeus, 1758)	in shrubs	dendrophiles	entomophagous
39.	*Curruca nisoria* (Bechstein, 1792)	in shrubs	dendrophiles	entomophagous
40.	*Erithacus rubecula* (Linnaeus, 1758)	in hollows/on the ground	dendrophiles	entomophagous
41.	*Luscinia luscinia* (Linnaeus, 1758)	on the ground	dendrophiles	entomophagous
42.	*Muscicapa striata* (Pallas, 1764)	in crowns/ in hollows	dendrophiles	entomophagous
43.	*Ficedula albicollis* (Temminck, 1815)	in hollows	dendrophiles	entomophagous
44.	*Parus major* Linnaeus, 1758	in hollows	dendrophiles	entomophagous
45.	*Parus caeruleus* (Linnaeus, 1758)	in hollows	dendrophiles	entomophagous
46.	*Emberiza calandra* Linnaeus, 1758	on the ground	campophiles	phytophagous
47.	*Emberiza citrinella* Linnaeus, 1758	on the ground	dendrophiles	phytophagous
48.	*Emberiza hortulana* Linnaeus, 1758	on the ground	dendrophiles	phytophagous
49.	*Emberiza melanocephala* Scopoli, 1769	on the ground	dendrophiles	phytophagous
50.	*Fringilla coelebs* Linnaeus, 1758	in crowns	dendrophiles	phytophagous
51.	*Chloris chloris* (Linnaeus, 1758)	in crowns	dendrophiles	phytophagous
52.	*Carduelis carduelis* (Linnaeus, 1758)	in crowns	dendrophiles	phytophagous
53.	*Linaria cannabina* (Linnaeus, 1758)	in shrubs	dendrophiles	phytophagous
54.	*Cannabina coccothraustes* (Linnaeus, 1758)	in crowns	dendrophiles	phytophagous
55.	*Passer domesticus* (Linnaeus, 1758)	in hollows/in crowns	sclerophylles	pantophagous
56.	*Passer montanus* (Linnaeus, 1758)	in hollows	sclerophylles	pantophagous
57.	*Corvus corax* Linnaeus, 1758	in crowns/ on the ground	sclerophylles	pantophagous
58.	*Corvus cornix* Linnaeus, 1758	in crowns	dendrophiles	pantophagous
59.	*Corvus frugilegus* Linnaeus, 1758	in crowns	dendrophiles	pantophagous
60.	*Corvus monedula* (Linnaeus, 1758)	in hollows/in crowns	sclerophylles	pantophagous
61.	*Pica pica* (Linnaeus, 1758)	in crowns	dendrophiles	pantophagous
62.	*Garrulus glandarius* (Linnaeus, 1758)	in crowns	dendrophiles	pantophagous

The ornithoconsortia were analyzed with edifiers: *Robinia pseudoacacia* L., 1753, *Elaeagnus argentea* Pursch, 1817, *Fraxinus excelsior* L. and others. For each of these species, we calculated the correlation between the number of trees of this species and the number of bird species that fed on it using the formula:

$$cov(X,Y) = \frac{\sum(Xi-)\,(Yi-)}{n-1} \qquad \sum(X_i-)^2 \qquad \sum(Y_i-)^2 \qquad R = \frac{cov(X,Y)}{\sigma x\ \sigma y} \qquad (1)$$

The feeding of adult birds and nestling provisioning were studied separately, due to the specificity of feeding at different age periods, using the experience of researchers (Ponomarenko, 2002; Petrovych, 2014). To study trophic characteristics, a complex of nonlethal methods was employed (Mal'chevskij & Kadochnikov, 1953), including analysis of pellet and casting contents (103 specimens collected) and food remains around nests for certain species (*Falco vespertinus*, *F. tinnunculus*, *Asio otus*, *Lanius collurio*, *L. minor*, *Corvus frugilegus*, *C. cornix*, *C. monedula*, and *Garrulus glandarius*). Material was collected and dried at 60 °C for 5–6 hours, after which volume (mass) was determined. Under laboratory conditions, pellets and castings were examined for the presence of animal remains (bones, skin, fur, feathers, etc.) or plant material (fruit pits, seeds). The next stage involved identifying the species to which the pellet belonged and analyzing the excrement contents. When performing this work, recommendations and descriptions of trophic component samples in pellets and castings of various bird species from scientific and methodological literature were followed.

To study the nestling feeding, additional experimental methods were used: In separate monitoring areas of the Melitopol city park and in different years, nest boxes were specially equipped with cameras. The total number of the equipped nests was 64 nest boxes, with a total observation time of 4,608 hours over 36 days; each day one nest box was equipped with a camera for 2 hours per day. Analysis of the obtained material (food composition determination) was conducted similarly to analysis in other research directions.

When collecting biological materials and processing them during various field and laboratory studies, nonlethal methods were used and all bioethical rules were followed.

Results

In the shelterbelts of the northwestern Azov region during the summer period, 62 breeding bird species belonging to 11 orders were recorded (Table 1). The most diverse representation was of Passeriformes – 37 species (60.0% of the total number of species). Much less widespread in shelterbelts were Falconiformes – 5 species (8.0%), Ciconiiformes – 4 species (6.4%), Columbiformes, Strigiformes, Piciformes, and Galliformes – 3 species each (4.8% each), and Pelicaniformes, Caprimulgiformes, Upupiformes, and Cuculiformes – 1 species each (1.6% each). Among them, representatives of the families Muscicapidae, Corvidae, and Fringillidae dominated. Less represented families included: Ardeidae, Emberizidae, Sylviidae, Falconidae, Columbidae, Strigidae, Picidae, Phasianidae, Accipitridae, Laniidae, Paridae, Passeridae, and others.

The structure of our research on trophic relationships of shelterbelt birds consisted of several aspects: ornithoconsortia with tree plantings of shelterbelts; food resource availability on nesting sites; foraging methods – adaptive mechanisms of birds; specialization or euryphagous feeding of certain species, etc. In the studied shelterbelts, ornithoconsortia have a complex structure regarding the use of woody-shrub vegetation elements: Birds act as first- and second-order consorts. We analyzed ornithoconsortia with dominant species in the studied shelterbelts: *Quercus robur* L., 1753, *Robinia pseudoacacia* L., 1753, *Elaeagnus argentea* Pursch, 1817, *Fraxinus excelsior* L., 1753, *Euonymus europaea* L., 1753, *Crataegus sanguinea* Pall., 1784, and others.

Elaeagnus argentea is an edificator of shelterbelts and is highly abundant. It produced fruits that remained on the plant in the autumn period when other shelterbelt plants have ceased fruiting, and these were consumed by some herbivorous species (*Emberiza citronella*, *Turdus pilaris*). Also, the consorts of this plant included insectivorous species attracted by nectar-feeding insects (*Sturnus vulgaris*, *Passer montanus*).

Observations were conducted during the spring-summer period (May–August 2019–2020) and revealed low species diversity of birds feeding on it – 1–4 species, averaging 1.50 ± 0.29. Figure 2 shows observations at 13 locations (control shelterbelts) where visual observations were conducted. During feeding activity, a correlation between the number of bird species and the number of trees of this species was detected, but it was very weak (Fig. 2).

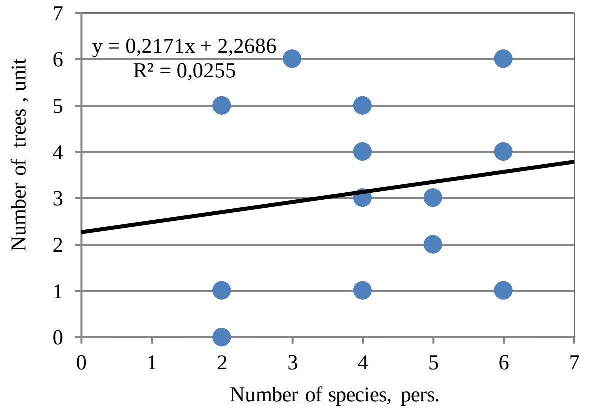

Fig. 2. Relationship between the number of trees and the number of bird species feeding on *Elaeagnus argentea* in the forest plantings of the Ukrainian Azov region (May–August 2019–2020)

Robinia pseudoacacia is a widespread species in the shelterbelts of the region. During the spring-summer period, during plant flowering, an increase was observed in the abundance of first-order consorts associated with the tree's generative organs, such as bumblebees and honeybees, and correspondingly second-order consorts – insectivorous birds, such as *Muscicapa striata*, *M. albicollis*, *Parus major*, *P. caeruleus*. The bark of *Robinia pseudoacacia* has a specific structure that also attracts insectivorous species, as it has cracks and furrows inhabited by numerous insects. On *Robinia pseudoacacia* trees, 1 to 6 species fed on different observation days, averaging 3.30 ± 0.49 species, but this relationship also proved to be very weak: R was only 0.35 (Fig. 3).

The trunks of *Fraxinus excelsior*, which have considerable length, provide good feeding substrate for birds. *Muscicapa striata* and, less frequently, *Sylvia borin*, *S. communis* were observed feeding, hunting mainly insects in flight, which actively gathered in illuminated areas of the tree. Also associated with the trunk were *Parus major* and *P. caeruleus*, which gather food using a specific technique, extracting insects from bark crevices. In these relationships, we found a significant correlation (R = 0.74) between the number of bird species and *Fraxinus excelsior* specimens in shelterbelts (Fig. 4). However, the functioning of this trophic consortium was sustained by only 1–4 bird species (averaging 1.80 ± 0.33).

Thus, in this case as well, we must conclude that there is an absence of substantial trophic relationships during the breeding period between the main consorts and birds currently inhabiting the shelterbelts of the northwestern Azov region.

The feeding sites of breeding birds in the study region are represented primarily by shelterbelts and agricultural lands.

According to our research, shelterbelt birds select various feeding sites, and different maneuvers and foraging techniques are associated with these sites (Fig. 5). Thus, 29 species out of 62 breeding bird species in the studied shelterbelts (46.8%) were birds whose foraging was associated with tree and shrub canopies (branches and boughs). For example, representatives of birds of prey (*Buteo rufinus*, *B. buteo*, *Asio otus*, *Otus scops*) seized prey from branches, using flight maneuverability. Some insectivorous species gathered insects from thin branches of trees and shrubs while climbing on them in various directions, including head-down (*Parus major*, *P. caeruleus*) and maneuvering between branches with hovering flight (*Muscicapa striata*, *Ficedula albicollis*).

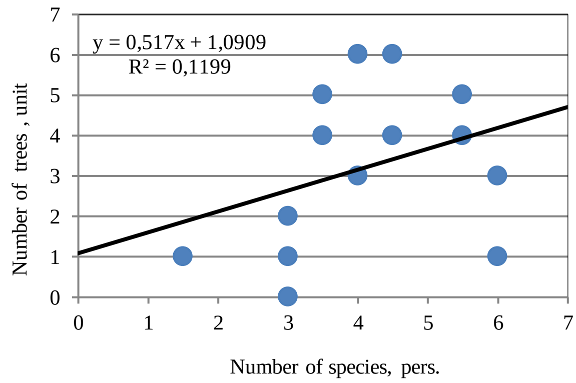

Fig. 3. Relationship between the number of trees and the number of bird species feeding on *Robinia pseudoacacia* in the forest plantings of the Ukrainian Azov region (May–August 2019–2020)

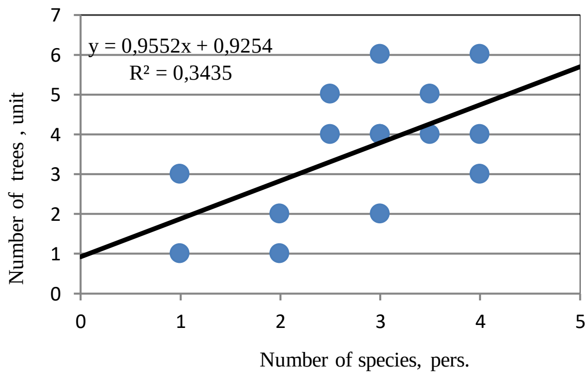

Fig. 4. Relationship between the number of trees and the number of bird species feeding on *Fraxinus excelsior* in the forest plantations of the Ukrainian Azov region (May–August 2019–2020)

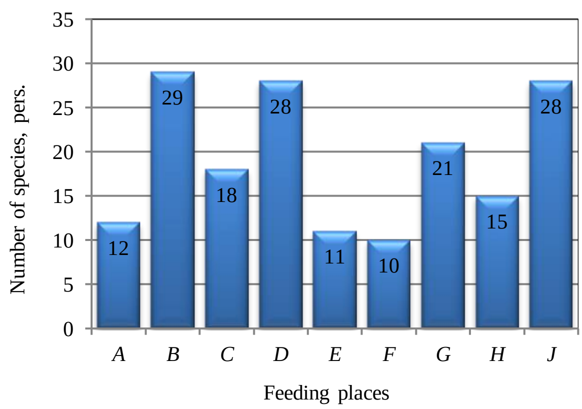

Fig. 5. Disitribution of bird feeding sites in forest belts and neighboring agrocenoses of the Ukrainian Azov region (May–August 2019–2021): *A* – tree trunks; *B* – branches, twigs; *C* – leaves; *D* – grass and soil in forest belts; *E* – litter; *F* – airspace above forest belts; *G* – agricultural land; *H* – airspace above agricultural land; *J* – grass and soil on agricultural land

A total of 28 species (45.2%) were birds that found food in shelterbelts by pecking, seizing, or searching with their feet on the ground (*Buteo rufinus*, *B. buteo*, *Falco tinnunculus*, *Turdus merula*, *T. philomelos*, *Corvus corax*, *C. cornix*, *C. frugilegus*, *C. monedula*, *Pica pica*, *Garrulus glandarius*). A total of 21 species (33.9%) fed on insects in crop fields, particularly active during the nestling provisioning period. Feeding of granivorous birds was also associated with agricultural fields, where they collect fallen seeds of grain crops and weeds from fields (*Pica pica*, *Corvus frugilegus*, *Falco vespertinus*, *F. tinnunculus*, *Passer montanus*, *Sturnus vulgaris*, etc.). A total of 18 insectivorous species (29.0%) gleaned food from foliage on thin branches, maneuvering in flight between them and also hanging from branches (*Sylvia borin*, *S. communis*, *S. atricapilla*, *S. nisoria*, *Muscicapa striata*, *Ficedula albicollis*, *Chloris chloris*, etc.). Ten species (16.1%) captured prey in flight in shelterbelts (insects, spiders, and birds), while 15 species (24.2%) hunted territorially over open landscapes (*Muscicapa striata*, *Ficedula albicollis*, *Lanius collurio*, *L. minor*, *Falco vespertinus*, *F. subbuteo*). Twelve recorded species (19.4%) found insects and their larvae under bark and on wood by pecking the trunk; these were mainly cavity-nesting birds (*Dendrocopos major*, *D. syriacus*). The ability to gather food from forest litter was exhibited by 11 species (17.7%), mainly insectivorous birds (*Upupa epops*, *Turdus merula*, *T. philomelos*, etc.) and a group of pantophages (*Corvus cornix*, *C. frugilegus*, *C. monedula*, *Garrulus glandarius*). For the latter, this foraging method is used in combination with other feeding methods.

By food type, shelterbelt birds were divided into entomophages, phytophages, myophages, pantophages, and ichthyophages (Fig. 6).

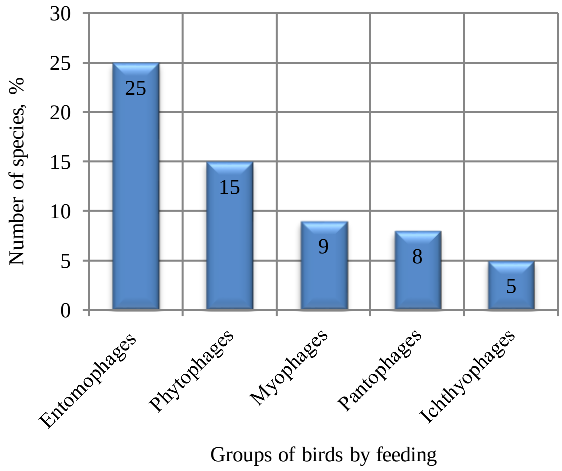

Fig. 6. Distribution of shelterbelt birds by feeding type (Ukrainian Azov region May–August 2019–2021)

The dominant group consisted of birds that prefer insects, spiders, and their larvae – entomophages – 25 species (38.2% of the total number of species). We attribute this to the fact that the majority (42 species of the shelterbelt bird assemblages) comprised dendrophilous species associated with woody-shrub vegetation (*Parus major*, *P. caeruleus*, *Turdus philomelos*, *T. merula*, *Lanius collurio*, *Dendroco pos major*, *Motacilla alba*, etc.) and found their food precisely there.

The second most numerous group, 15 species (27.3%), consisted of phytophages – granivorous and herbivorous species. The most abundant among them were *Dendrocopos major*, *D. syriacus*, *Fringilla coelebs*, *Chloris chloris*, *Carduelis carduelis*, *Garrulus glandarius*, *Emberiza citronella*, *Passer domesticus*, and *P. montanus*. Considerably fewer were myophages (predators) – birds that feed on mouse-like rodents, small birds, lizards, etc. – 9 species (14.5%). Pantophages – omnivorous birds – accounted for 8 species (12.7%): *Corvus frugilegus*, *C. cornix*, *Pica pica*, *Garrulus glandarius*; the nesting structures of Corvidae often attract Ciconiiformes – ichthyophages – to nest in shelterbelts, which colonize them. The proportion of ichthyophages – wetland birds – was represented by 5 species (7.3%), observed in water-protective shelterbelts, where they fed on aquatic invertebrates, fish, amphibians, and other organisms.

The feeding of adult birds and nestling provisioning were studied using nonlethal methods. Figure 7 presents the analysis of feeding in selected representatives of breeding species by food types.

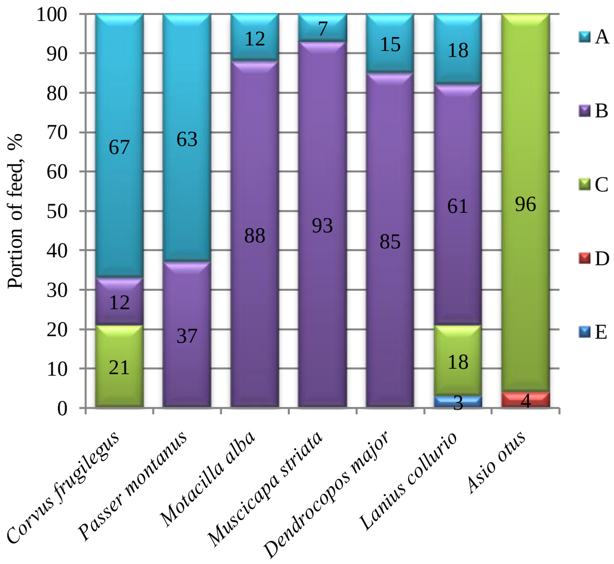

Fig. 7. Distribution of food in the diet of some breeding bird species during the spring-summer period (biomass, g) (Ukrainian Azov region May–August 2019–2021): *A* – seeds, berries, green plant parts; *B* – insects; *C* – small vertebrates; *D* – fish, aquatic invertebrates; *E* – carrion, animal remains

In the diet of some insectivorous synanthropic species, insects dominated, with the presence of plant food (during nestling provisioning – 2–3%, and during adult feeding – 7–15%), and a characteristic feature of their feeding was dietary diversity. Thus, 19 species were found in the food of *Motacilla alba* nestlings, and 38 species were found in the diet of *Muscicapa striata*. In the diet of *Motacilla alba*, Chironomidae and Trichoptera dominated, as well as Syrphidae. In the food of *Muscicapa striata* nestlings, various species of Lepidoptera and Diptera were present, with *Lytta vesicatoria* occasionally detected.

In the studied shelterbelts, a small predator *Lanius collurio* was observed to include 43 animal species in the diet of its nestling. Small vertebrates were present, including one *Microtus* species and two small bird species, namely *Emberiza hortulana* and *Coccothraustes coccothraustes* (nestlings or juveniles), and invertebrates – 40 species (98.1% of all animals). The latter mostly consisted of insects, with Coleoptera prevailing, followed by Lepidoptera, Diptera, Orthoptera, Hymenoptera, and Heteroptera. In addition, 7 Arachnida species were found. Among small mammals, *Clethrionomys glareolus*, syn. *Myodes glareolus*, occurred most regularly. *Lanius collurio* can also feed on fresh carrion.

In the shelterbelts, we observed a group of entomophages that feed on both insects and seeds, berries, or other plant food. Specifically, *Dendrocopos major* often specializes in finding Coleoptera and their larvae; however, their diet included conifer seeds, berries, and fruits. During the first 8–10 days, *Passer montanus* and *Linaria cannabina* feed nestlings with caterpillars and scale insects of various Lepidoptera, later adding small Coleoptera, and only at the end – seeds and other plant food. In adult *Corvus frugilegus*, the main food objects were also plants: grains of cultivated cereals (*Triticum*, *Hordeum*, *Zea mays*), seeds of *Helianthus* L., succulent fruits, and cucurbit crops. By contrast, the nestling diet until fledging consisted of 100% animal food, in which Coleoptera dominated. In adult birds, animal components occurred in 33.0%.

Among myophages, we noted *Asio otus*, whose feeding is associated with fields, partly due to the accessibility of the main food – mouse-like pests of agricultural crops. The diet also included aquatic invertebrates, fish remains, and also *Eremias arguta* Pall., *Microtus* sp., remains of small birds (Fig. 7).

In our research, we analyzed the relationship between bird feeding type and shelterbelt age (maturity of their structure). The distribution of birds by feeding pattern shows a trend toward increasing entomophages (*Caprimulgus europaeus*, *Dendrocopos major*, *D. syriacus*, *Jynx torquilla*): from 20.0% in young shelterbelts to 53.1% in old shelterbelts (Fig. 8). Naturally, with increasing age, trees and shrubs undergo damage and disruption of wood integrity, which provides an excellent substrate for the proliferation of insects and arachnids (Koval, 1986). Such processes were observed in shelterbelts in our study.

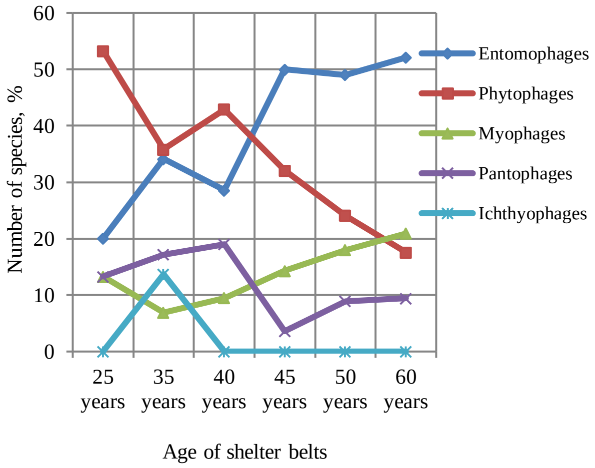

Fig. 8. Distribution of birds by feeding type in shelterbelts of different age of the Ukrainian Azov region (May–August 2019–2021)

By contrast, phytophages decreased with shelterbelt maturation (from 53.3% to 18.8%). The assemblage of predatory birds – myophages – also gradually increased depending on shelterbelt age (from 14.5% to 20.9%).

Discussion

Our research on the trophic relationships of shelterbelt birds in terms of ornithoconsortia with tree species (*Robinia pseudoacacia*, *Elaeagnus argentea*, *Fraxinus excelsior*) showed very weak correlation between the number of consort birds and tree specimens of these species. In our opinion, this indicates the absence of bird attachment to specific tree species in these plantings. There may be several probable reasons. First, the poor species composition of shelterbelts, their degradation, and monoculture nature, which is especially relevant for roadside shelterbelts. Some researchers also note trends of decreasing species and functional composition of bird consortional assemblages in transformed (degraded) plantations of the steppe Dnipro region (Ponomarenko, 2002). Second, the main dietary components of species nesting in shelterbelts are concentrated in the dominant agrocenoses, which have become their primary feeding sites. Third, the tree species we selected for ornithoconsortia research during our study period (spring-summer) are used by birds – second- and third-order consorts – as a source of similar food resources – first-order consorts (insects) concentrated around them, which are the main food source for adults and nestlings during the breeding period for both insectivorous and herbivorous species.

The latter also indicates another aspect of our study of bird trophics – specialization or euryphagous feeding of certain species. Our research and that of other scientists (Smogorzhevsky & Kotkova, 1973; Koval, 1986) showed that a characteristic feature of bird feeding during the period of provisioning nestlings with insects is the diversity of the latter's composition. Thus, we found 19 species in the food of *Motacilla alba* nestlings and 38 species in the food of *Muscicapa striata*. Probably, such euryphagous feeding allows these birds to quickly switch to other more accessible food when necessary. For example, *Muscicapa striata* found *Lytta vesicatoria* in rain, which were not present in nestling food under other weather conditions.

Among factors that may influence food selection are also weather or seasonal changes, nestling food acceptance, outbreaks of insect and spider abundance, including pests associated with agricultural lands. According to some researchers (Mal'chevskij & Kadochnikov, 1953; Koval, 1986; Tsaryk & Tsaryk, 2002), changes in the food base in a particular biotope lead to changes in the feeding ecology of avian complexes, as well as changes in the species composition of the avifauna.

Food resource availability of nesting sites and foraging methods are additional factors that determine the qualitative and quantitative composition of shelterbelt avian populations. The species we studied in shelterbelts are trophically related to specific biotopes that characterize foraging methods and behavioral patterns of birds under various conditions of feeding site provision (Fig. 5). Analysis of groups by feeding location shows a greater diversity in the choice of food type and foraging method than in nesting. All of this, in our opinion, represents adaptive mechanisms of birds to conditions existing in nesting sites. The vast majority of species lack clear boundaries in the choice of food composition or location and method of its acquisition. Our observations showed that most birds of the studied shelterbelts, in addition to their main specialized food, use other, less specific but more accessible food in the given locality. Therefore, in case of disappearance of any food type, birds switched to another, reserve food, significantly deviating from their "trophic stereotype." Thus, maximum dietary diversity was exhibited by *Corvus frugilegus*, *Garrulus glandarius*, *Fringilla coelebs*, and *Carduelis carduelis*. Some plasticity was also observed in narrowly specialized species (classified as such because they mainly fed on a small number of insect species): *Turdus merula*, *T. philomelos*, *Parus major*, *P. caeruleus*, and *Motacilla alba*. Similar feeding lability was exhibited by *Lanius collurio*, which plays an important role as a small avian predator in our region. Its consumption of vertebrates varied by year, due to fluctuations in rodent abundance. Capture of some vertebrates increases in areas of their high concentration.

According to other studies (Knysh, 2001), in the left-bank forest-steppe at a density of 300 pairs/100 ha, permanent food objects of *Lanius collurio* are amphibians (41.8%). Most birds captured by it (9.2%) were nestlings or juveniles. The male red-backed shrike often pursues even small birds in flight. Small mammals (48.2%) were found in its diet in some years.

Thus, classification into groups by types of food relationships (entomophages, phytophages, myophages, pantophages, ichthyophages) is also conditional, considering possible deviations from the "trophic stereotype." For birds in which plant food dominates, mixed feeding with the presence of insects was observed, especially during the nestling provisioning period, while during other periods they fed on both insects and seeds, berries, or other plant food.

Representatives of birds of prey in shelterbelts bordering fields are closely associated with the availability of main food – mouse-like pests of agricultural crops, and use shelterbelt plantings for nest building. We also observed that the proportion of predatory species nesting or hunting over lands fluctuated in different years depending on rodent abundance, and the latter depend on both weather conditions and intensified control by farmers. The reason is probably in planting decay, decreased ability to fruit and provide fruits and berries for species feeding in shelterbelts. This occurs through representatives of the forest complex (*Buteo rufinus*, *B. buteo*, *Asio otus*, *Otus scops*, *Corvus corax*), for which old shelterbelts have sufficient food resources – small herbivorous-granivorous species (*Sylvaemus uralensis* Pallas, 1811; *Mus musculus* Linnaeus, 1758; *Mus spicilegus* Reinwaldt, 1927; *Lepus europaeus* Pall., 1778). The presence of dense shrub and herbaceous layers and old decaying trees promotes their reproduction (Gregory et al., 2007; Schulze et al., 2019; Wang et al., 2022). Through a similar pathway in other regions, colonization of old forest plantings by forest species occurs, for which true shaded forests where they directly nest and hunt are more characteristic (Myasoedova & Bulakhov, 1975; Pisotska et al., 2020).

Conclusions

According to our research, we found that there are consortional, particularly trophic, relationships between birds of the region and dominant tree species of shelterbelts (*Robinia pseudoacacia*, *Elaeagnus argentea*, *Fraxinus excelsior*), but the correlation between the number of bird species and the number of trees on which birds fed was very weak (R = 0.21 and R = 0.35). In relationships with *Fraxinus excelsior*, although a significant correlation was found (R = 0.74), we observed an average of only 1.80 ± 0.33 (1–4) bird species feeding. On other mentioned tree species, species diversity was also low (averaging from 1.50 ± 0.29 to 3.30 ± 0.49). Thus, we conclude that trophic ornithoconsortia with the most widespread tree species of the studied shelterbelts are present, but no attachment to specific species during the breeding period was detected in bird species.

Based on our observations, we classified bird species nesting in shelterbelts into groups according to foraging methods: 29 species (46.8%) of birds whose feeding is associated with tree and shrub canopies (branches and boughs); 28 species (45.2%) of birds that find food in grass and on the ground in shelterbelts; 21 species (33.9%) that feed on harmful insects in crop fields and collect fallen seeds of grain crops and weeds from fields; 18 species (29.0%) of insectivorous species that glean food from foliage; 10 species (16.1%) and 15 species (24.2%) that capture prey in flight in shelterbelts and over open landscapes; 12 species (19.4%) that gather insects and their larvae from under bark and from wood by pecking the trunk; and 11 species (17.7%) that have the ability to collect food from forest litter.

We divided breeding species by predominant food type into: entomophages (insectivorous), phytophages (granivorous and herbivorous), myophages (predatory), pantophages (omnivorous), and ichthyophages (piscivorous). This classification is not fixed, as birds under certain conditions can switch to other food types or combine several feeding types. Thus, we found that phytophage species exhibited mixed feeding with the presence of insects, especially during the nestling provisioning period, and conditionally classified them as phyto-entomophages. Overall, representatives of all groups (to a lesser extent large predators – myophages) were observed to begin feeding nestlings with easily digestible food (caterpillars, larvae, etc.), which is also rich in protein necessary for growth and development. At later stages of growth, plant or animal (vertebrate) food was added. More distinct specialization was observed in adult individuals, but a characteristic feature of breeding birds in the studied shelterbelts is the combination of different food types.

The studied shelterbelts of our region have various characteristics: They differ in age, structure, density, light exposure, have different levels of plant species composition diversity, and different levels of development or degradation. Also, the location of forest plantings and adjacent biocenoses are among the factors influencing trophic relationships of birds. We analyzed the relationships among these influencing factors, particularly the age and degradation state of shelterbelts, and found a relationship between bird feeding type and the age structure of shelterbelts, which shows an upward trend in entomophages: from 20.0% in young shelterbelts to 53.1% in old shelterbelts. At the same time, the number of phytophages decreased with shelterbelt maturation (from 53.3% to 18.8%) and the myophage assemblage gradually increased depending on shelterbelt age (from 14.5% to 20.9%).

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