BIOLOGICAL AND ECOLOGICAL ASPECTS AS FACTORS OF COLLISION RISK FOR BIRDS ALONG A SECTION OF THE HIGHWAY A7 MOLDOVA (ROMANIA)

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Abstract. We present results of three years of monitoring activity on the bird fauna presence and roadkill incidence for birds along the section Bacău bypass with its two access roads towards Onești, respectively Piatra-Neamț, as part of the Highway A7 (Moldova) and its surrounding areas. These highway sections have 30.82 km (total length) and intersect with the territory of the ROSPA0063 Buhuși-Bacău-Berești Reservoirs, crossing the confluence area of Siret and Bistrița rivers. We recorded 298 bird individuals killed through road collision along this highway, representing 39 bird species. We analyse the influence of the bird fauna's diversity, the variety and extent of suitable habitats, the seasonal presence and birds' behaviour during the annual biological cycle of them as factors of collision risk for birds along the investigated highway' sections. We mention the presence of five species included in Annexe 1 of the Birds' Directive among the identified roadkill bird species, and two species mentioned in the Romanian Red Book of Vertebrates.

Keywords: birds, diversity, ecology, behaviour, collision risk, highway.

Rezumat. Aspecte biologice și ecologice ca factori de risc de coliziune pentru păsări de-a lungul unei secțiuni a Autostrăzii A7 Moldova (România). Prezentăm rezultatele a trei ani de monitorizare a ornitofaunei prezente și a incidenței coliziunii rutiere în rândul păsărilor de-a lungul secțiunii Varianta ocolitoare a municipiului Bacău și a bretelelor de acces spre Onești, respectiv Piatra-Neamț ca segmente ale Autostrăzii A7 (Moldova) și a împrejurimilor acestora. Aceste secțiuni ale autostrăzii au o lungime totală de 30,82 km și se intersectează cu teritoriul ROSPA0063 Lacurile de acumulare Buhuși-Bacău-Berești, traversând zona de confluență a Siretului cu afluentul său Bistrița. Am înregistrat 298 de păsări victime ale coliziunii rutiere de-a lungul acestor sectoare de drum de mare viteză, reprezentând 39 de specii. Analizăm influența diversității ornitofaunei, varietății și întinderii habitatelor favorabile, prezenței sezoniere și comportamentului păsărilor de-a lungul ciclului lor biologic anual ca factori de risc de coliziune rutieră de-a lungul secțiunilor investigate ale autostrăzii. Menționăm prezența în rândul victimelor coliziunii rutiere a cinci specii de păsări incluse în Anexa 1 a Directivei Păsări și a două specii de păsări menționate în Cartea Roșie a Vertebratelor din România.

Cuvinte cheie: păsări, diversitate, ecologie, comportament, risc de coliziune, autostradă.

INTRODUCTION

The development of road infrastructure, including high-speed roads, represents a major priority for regional economic development and the well-being of local communities. At the same time, the road networks involve significant ecological costs expressed by the various impacts on wildlife everywhere. Between the main impacts of the road infrastructure on biodiversity, we can mention the increase in mortality risk for animals (roadkill), the appearance of movement barriers but also new corridors for species, including the invasive ones, the habitats fragmentation, degradation and loss, chemical and noise pollution (FORMAN & ALEXANDER, 1998; 2007).

The extent surface of our country transforms the necessity of the highway network's construction and expansion into a national objective, especially in the eastern part, where the general level of economic development is lower than in the southern and western regions. The construction of the section Bacău bypass with its two access roads towards Onești - Brașov, respectively Piatra-Neamț as part of the Highway A7 (Moldova), with a total length of 30.82 kilometres (km), reduces the transport time for goods and passengers, but also the pressure on the urban roads and the level of traffic inside the city. The transect of this section of Highway A7 (Moldova) intersects with the territory of the ROSPA0063 Buhuși-Bacău-Berești Reservoirs and ROSCI0434 Middle Siret, crossing the confluence area of Siret and Bistrița rivers (Fig. 1). There are two bridges crossing the Bistrița River: one crosses the river along the dam of Lilieci reservoir, while the second one crosses the river in the neighbourhood of Galbeni reservoir and intersects the territory of ROSPA0063 Buhuși-Bacău-Berești Reservoirs along a 700 metres (m) length, respectively, that of the ROSCI0434 Middle Siret along 1624 m length. The vegetation appears as a mosaic of habitats comprising meadow forests with willows and osiers (*Salix* sp.), poplars (*Populus alba*), and alders (*Alnus* sp.), open waters, compact reed beds with sedges (*Carex* sp.) and rushes (*Schoenoplectus lacustris* and *Juncus* sp.), small islands formed by pebble and grasslands with bushes (MITITELU & BARABAȘ, 1982). These suitable habitats shelter a rich fauna, including various groups of invertebrates and vertebrates. The existing ornithological data mentions the presence of a high diversity of bird fauna with a specific seasonal dynamic in the area, these valleys overlapping with important migration flyways in eastern Romania for the white storks (*Ciconia ciconia* Linnaeus 1758), duck and raptor species (RANG, 1968, 2002; FENERU, 2002; GACHE, 2021), while the large reservoirs shelter significant wintering populations of waterfowls (FENERU, 2002; GACHE, 2017; 2019). There are few published studies regarding other groups of vertebrates in this territory – for example, the amphibians and reptiles (GHERGHEL et al., 2008; GHIURCĂ et al., 2008; IFTIME et al., 2008) or the rodents among the mammals (NISTREANU et al., 2012-2015; BORDEI & BENEDEK, 2015).

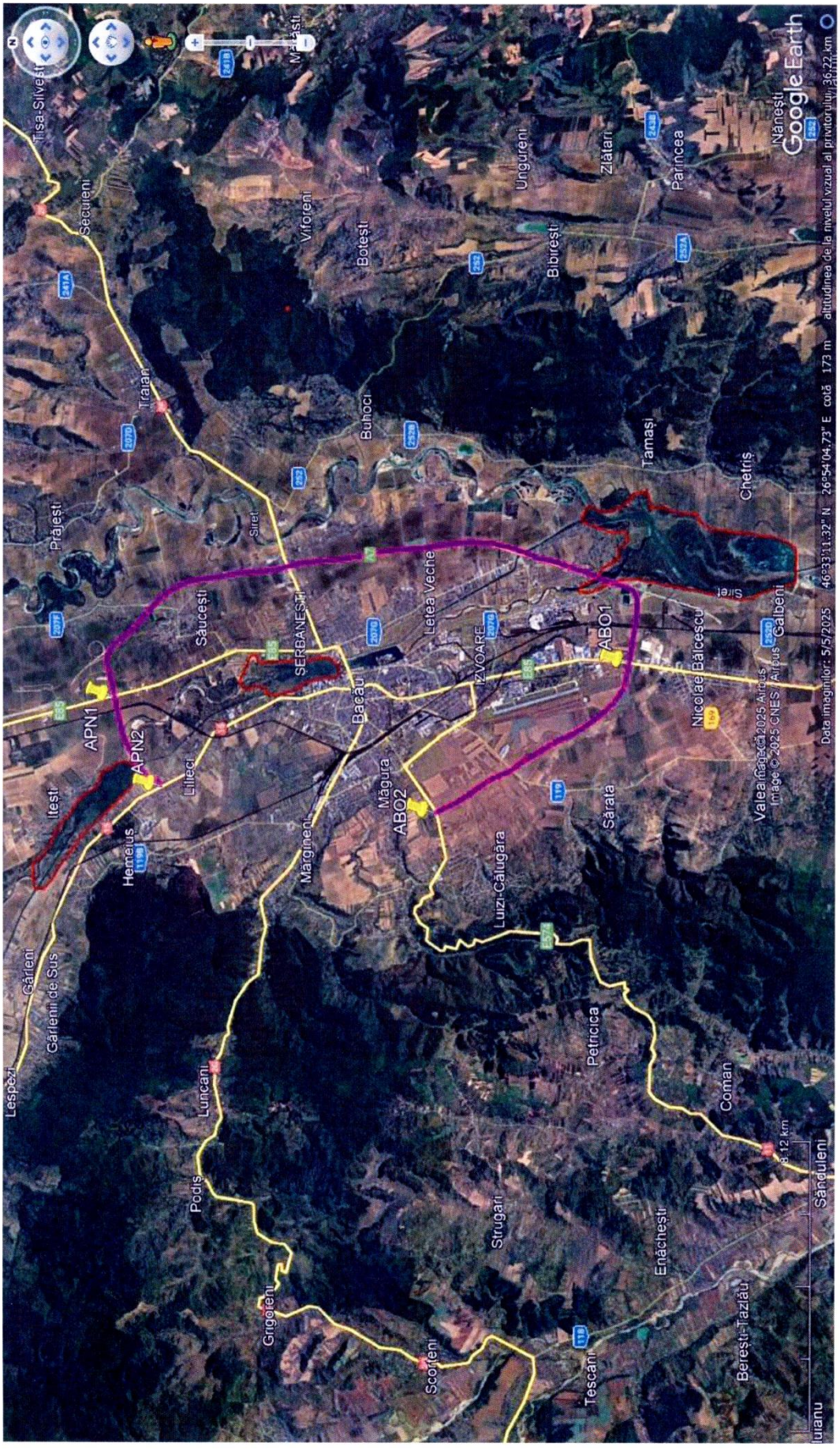

Figure 1. The location of the investigated area – with pink: the investigated section of Highway 7 (Moldova); the relation-road towards Piatra-Neamț marked with APN 1 – APN 2 and that towards Onești-Brașov marked with ABO1 – ABO2: with red: the perimeter of Lilieci, Bacău and Galbeni reservoirs part of ROSPA0063 Buhuși – Bacău - Bereşti Reservoirs (Sources: Satellite image. March 2025. Google Earth).

The location of this high-speed road' section, correlated with the diversity and size of the birds' population in the area, results in high potential for the risk of road collision involving birds and other groups of animals. The ROSPA0063 Reservoirs Buhuși – Bacău - Berești has a management plan (OMMMP no. 2681/2012), as a result of a monitoring study done during the period 2009 - 2011.

METHODS AND PERIOD OF STUDY

For the present study, we analysed collected field data through a regular monitoring programme started in October 2021 and continued until August 2024, with 61 daily visits during these 35 months of field activity. The monitoring programme was carried out at the request of the National Company for the Management of Road Infrastructure (CNAIR) with two main objectives: to evaluate the diversity and number of birds' roadkill along the Bacău bypass section of Highway A7 (Moldova), respectively, to assess the main collision risk factors for the bird fauna along the investigated high-speed roads. We identified, took photos and GPS geolocation (Global Positioning System) for each roadkill incident along the high-speed road lane.

We focused our study on three sections of highway – Bacău bypass and the access road towards Onești - Brașov, as well as Piatra-Neamț. Additionally, we included the perimeter of Lilieci and Galbeni reservoirs in our study, as part of the Natura 2000 site ROSPA0063 Buhuși-Bacău-Berești Reservoirs, intersected by the high-speed roads. Our monitoring activity focused on the census of birds' roadkill, the birds' presence and diversity in the neighbourhood of the road and on the perimeter of reservoirs, respectively, the daily and seasonal movements of the birds in the area. As methods, we used the car transects along the roads, moving at a speed of 10 – 15 km/hour along the section with an emergency band, respectively, at a speed of 30 – 60 km/hour along the section with one band for each direction, depending on the road traffic values. We covered an average width of about 300 - 500 m on both sides of the roads to evaluate the bird fauna's diversity in the surrounding territories crossed by the highway sections. For the perimeter of both reservoirs, we also used car transects with several fixed points of observation along the western, southern and eastern banks. We established two transects along the valley of Bistrița River, too: first in the sector downstream of the dam of Lilieci reservoir, respectively, the second one in the area of the confluence with Siret River, between the bridge (Chimiei Street) crossing Bistrița River from Bacău city towards Ruși-Ciutea village and the area of distributaries and canals formed by the river before the confluence point on the tail area of Galbeni reservoir.

During our field activity, we used the direct observation by binoculars (Nikon Akulon 8 – 24x) and telescope (Swarowski 20 – 60x), but also the males' calling activity to identify and estimate the populations of passerines and the hidden life bird species inside compact vegetation, the crepuscular and nocturne ones, using also the Merlin Bird Sound ID app (Laboratory of Ornithology, Cornell University, USA). We estimated the aquatic bird populations by counting each bird from the small groups and used a quantitative evaluation in bands for the groups or flocks larger than 200 individuals. In the analysis of our results, we are using the SIBLEY & AHLQUIST taxonomic system (1995), as subsequently amended and supplemented (*** https://www.allaboutbirds.org/news/ and http://avibase.bsc-eoc.org/).

RESULTS AND DISCUSSIONS

The road traffic is permanent within the perimeter of monitored sections of highway, even if the traffic intensity may vary from one moment to another during the day and seasonally throughout the year. As a rule, on a high-speed road, all vehicles travel at a significant speed, in terms of increasing the risk of collisions for various groups of animals that may reach the perimeter of the roadway. The ecological impact associated with the roads' network is higher when it crosses open ecosystems (grasslands, cultivated areas, wetlands, etc.) than when the roads intersect woodlands, and the risk management requires integrated studies focused on the wildlife diversity and roads' characteristics (SEILER, 2001).

Looking for birds as roadkill along the investigated sections of Highway A7 (Moldova), we started from the premise that the bird fauna's diversity, population size, as well as the daily and seasonal movements of birds in the neighbourhood areas of the high-speed road, represent significant elements that influence the risk of road collision among the birds. We present the list of bird species identified along the three sections of the high-speed road during our 35 months monitoring programme in the Table 1, and quantitative data regarding their population size during the breeding season, migration and wintering time; the values for the bird population represent the minimum, respectively, the maximum number of counted birds or estimated population during a one-day visit in the perimeter of each section.

We recorded the presence of 142 bird species, but their specific diversity and population size differ along the three investigated sections of Highway A7 (Moldova): we identified 128 bird species in the perimeter of Bacău bypass, only 48 bird species along the access road towards Onești - Brașov, respectively, 114 species in the territory crossed by the access road towards Piatra-Neamț. The length of these three sections of high-speed road is significantly different; the general aspect of landscapes and ecosystems covering the neighbourhood of roads presents a large variety. The presence and surface covered by suitable habitats influence the diversity of bird fauna in a territory.

The access road towards Onești – Brașov, with a length of 7.36 km, crosses a territory covered by dry grasslands and cultivated areas (cereals and sunflower), with strips of bushes and isolated trees. As a result of the homogeneity of habitats, a small number of bird species find a suitable ecological niche to breed, feed and rest in this area. The bird fauna includes gallinaceous birds, doves, passerines (28 species), diurnal and nocturnal raptors (seven species), the last of which

use this perimeter as hunting territory. We notice the presence of a few bird species related to the aquatic ecosystems in this list. We observed only flying mallards (*Anas platyrhynchos*) and whooper swans (*Cygnus cygnus*), while the white storks (*Ciconia ciconia*), lapwings (*Vanellus vanellus*) and gulls (*Larus cachinnans*, *Chroicocephalus ridibundus*) feed in the grassland areas, on the freshly ploughed farmland or the stubble of cereals cultivated lands.

Table 1. Identified bird species and their estimated population in the territory crossed by the section Bacău bypass of Highway A7 Moldova (October 2021 – August 2024).

No.	Species	Bacău bypass				Relation-road Onești				Relation-road Piatra-Neamț				Romanian Red Book
		Breeding season		Migration & Pre-wintering (i)	Wintering (i)	Breeding season		Migration & Pre-wintering (i)	Wintering (i)	Breeding season		Migration & Pre-wintering (i)	Wintering (i)	
		Breeding (p)	Presence (i)			Breeding (p)	Presence (i)			Breeding (p)	Presence (i)			
1.	*Phasianus colchicus* Linnaeus 1758	5 - 6	2 - 5	2 - 11	2 - 11	2 - 4	2 - 3	1 - 2	1 - 2	2 - 4	1 - 7	1 - 5	1 - 5	-
2.	*Perdix perdix* Linnaeus 1758	3 - 4	1 - 2	2 - x	2 - x	3 - 5	1 - 5	2 - x	2 - x	1 - 2	0 - 5	2 - 7	2 - 7	-
3.	*Coturnix coturnix* Linnaeus 1758	2 - 3	1 - 2	5 - x	-	1 - 3	1 - 2	4 - x	-	0 - 1?	0 - 1	2 - x	-	-
4.	*Cygnus olor* Linnaeus 1758	2 - 3	4 - 16	21 - 109	6 - 512	-	-	-	-	1	2 - 5	5 - 13	0 - 12	-
5.	***Cygnus cygnus*** Linnaeus 1758	-	-	0 - 11	1 - 42	-	-	0 - 5	0 - 5	-	-	-	-	-
6.	*Anser anser* Linnaeus 1758	1 - 3	10 - 23	4 - 12	0 - 21	-	-	-	-	-	0 - 1	-	-	-
7.	*Anser albifrons* Scopoli 1769	-	-	12 - 7000	78 - 1600	-	-	-	-	-	-	-	-	-
8.	***Anser erythropus*** Linnaeus 1758	-	-	0 - 1	-	-	-	-	-	-	-	-	-	CE
9.	***Branta ruficollis*** Pallas 1769	-	-	0 - 5	-	-	-	-	-	-	-	-	-	P
10.	*Anas platyrhynchos* Linnaeus 1758	5 - 8	11 - 29	55 - 256	90 - 1340	-	-	0 - 4	0 - 4	1 - 2?	3 - 11	14 - 162	38 - 210	-
11.	*Anas crecca* Linnaeus 1758	-	0 - 8	18 - 72	28 - 265	-	-	-	-	-	0 - 2	10 - 36	18 - 67	-
12.	*Mareca strepera* Linnaeus 1758	2 - 3	6 - 28	22 - 54	8 - 128	-	-	-	-	-	-	8 - 28	5 - 34	-
13.	*Mareca penelope* Linnaeus 1758	-	-	4 - 118	12 - 80	-	-	-	-	-	-	10 - 84	6 - 73	-
14.	*Spatula querquedula* Linnaeus 1758	-	3 - 6	14 - 32	-	-	-	-	-	-	-	8 - 23	-	-
15.	*Spatula clypeata* Linnaeus 1758	-	-	2 - 4	1 - 4	-	-	-	-	-	-	0 - 8	-	-
16.	*Tadorna tadorna* Linnaeus 1758	-	-	0 - 14	0 - 14	-	-	-	-	-	-	-	-	V
17.	*Aythya fuligula* Linnaeus 1758	-	-	6 - 74	2 - 51	-	-	-	-	-	-	36 - 232	0 - 136	-
18.	*Aythya ferina* Linnaeus 1758	-	0 - 2	18 - 71	7 - 216	-	-	-	-	-	-	18 - 169	0 - 114	-
19.	***Aythya nyroca*** Gűldenstädt 1770	-	-	1 - 7	-	-	-	-	-	-	-	-	-	V
20.	*Mergus merganser* Linnaeus 1758	-	-	-	-	-	-	-	-	-	-	0 - 1	-	-
21.	***Mergellus albellus*** Linnaeus 1758	-	-	-	-	-	-	-	-	-	-	4 - 31	0 - 18	V
22.	***Gavia stellata*** Linnaeus 1758	-	-	-	-	-	-	-	-	-	0 - 1	-	-	-
23.	*Phalacrocorax carbo* Linnaeus 1758	-	5 - 82	13 - 49	2 - 53	-	-	-	-	-	1 - 5	1 - 11	1 - 8	-

24.	***Microcarbo pygmaeus*** Linnaeus 1758	0 - 1?	1 - 3	14 - 69	1 - 19	-	-	-	-	-	-	1 - 118	0 - 1	V
25.	***Botaurus minutus*** Linnaeus 1766	4 - 6	2 - 4	2 - x	-	-	-	-	-	0 - 1	0 – 1	1 - x	-	-
26.	***Ardeola ralloides*** Scopoli 1769	1 - 2?	1 - x	x	-	-	-	-	-	-	-	-	-	V
27.	***Nycticorax nycticorax*** Linnaeus 1758	1 - 3?	4 - 6	1 - 5	-	-	-	-	-	-	-	-	-	V
28.	***Egretta garzetta*** Linnaeus 1766	1 - 2	3 - 13	19 - 42	-	-	-	-	-	-	1 - 3	0 - 3	-	P
29.	***Ardea alba*** Linnaeus 1758	3 - 4	3 - 9	9 - 37	1 - 7	-	-	-	-	-	1 - 7	2 - 22	1 - 5	P
30.	*Ardea cinerea* Linnaeus 1758	2 - 4	2 - 7	5 - 11	1 - 9	-	-	-	-	-	1 - 3	1 - 9	0 - 2	-
31.	***Ardea purpurea*** Linnaeus 1766	0 - 1	0 - 1	2 - 3	-	-	-	-	-	-	0 - 2	-	-	P
32.	***Plegadis falcinellus*** Linnaeus 1766	-	-	0 - 4	-	-	-	-	-	-	-	-	-	V
33.	***Ciconia ciconia*** Linnaeus 1758	3 - 4	73-374	254 - 1470	1 - 18	-	16 - 76	23 - 29	-	2 - 4	0 - 13	110 - 920	-	V
34.	***Haliaeetus albicilla*** Linnaeus 1758	-	0 - 1	-	-	-	-	0 - 1	-	-	1 - 2	0 - 2	0 - 1	CE
35.	***Clanga pomarina*** Brehm 1831	-	-	0 - 2	-	-	-	-	-	-	-	1 - 245	-	V
36.	***Circaetus gallicus*** Gmelin 1788	-	-	2 - 13	-	-	-	-	-	-	-	1 - 13	-	V
37.	*Buteo buteo* Linnaeus 1758	-	1 - 4	2 - 7	3 - 8	-	-	1 - 3	2 - 6	-	1 - 2	1 - 3	1 - 4	-
38.	*Buteo lagopus* Pontoppidan 1763	-	-	0 - 2	0 - 1	-	-	-	-	-	-	0 - 2	0 - 1	-
39.	***Buteo rufinus*** Cretzschmar 1829	-	0 - 1	0 - 1	0 - 1	-	-	-	-	-	-	0 - 1	0 - 1	V
40.	***Circus aeruginosus*** Linnaeus 1758	1 - 2	1 - 2	2 - 4	0 - 2	-	-	0 - 1	-	-	0 - 1	0 - 2	-	-
41.	***Circus cyaneus*** Linnaeus 1766	-	-	0 - 1	0 - 1	-	-	-	-	-	-	-	-	-
42.	*Accipiter gentilis* Linnaeus 1758	-	-	0 - 2	0 - 1	-	-	-	-	-	0 - 1	1 - 2	0 - 1	-
43.	*Accipiter nisus* Linnaeus 1758	-	0 - 1	0 - 1	0 - 1	-	-	-	-	-	0 - 1	1 - 2	0 - 1	-
44.	***Pandion haliaetus*** Linnaeus 1758	-	-	-	-	-	-	-	-	-	-	0 - 1	-	V
45.	***Falco columbarius*** Linnaeus 1758	-	-	-	0 - 1	-	-	-	-	-	-	-	-	-
46.	*Falco subbuteo* Linnaeus 1758	-	-	0 - 1	-	-	-	0 - 1	-	-	0 - 1	0 - 1	-	-
47.	*Falco tinnunculus* Linnaeus 1758	1 - 2	2 - 7	3 - 10	2 - 6	1	1 - 2	1 - 3	1 - 4	1 - 2	1 - 4	1 - 3	1 - 2	-
48.	***Zapornia parva*** Scopoli 1769	1 - 2?	2 - 3	2 - x	-	-	-	-	-	-	-	-	-	-
49.	*Gallinula chloropus* Linnaeus 1758	3 - 5	2 - 15	5 - x	0 - 3	-	-	-	-	0 - 1	1 - 3	4 - x	-	-
50.	*Fulica atra* Linnaeus 1758	10 - 16	11 - 52	72 - 406	113 - 930	-	-	-	-	0 - 1?	1 - 7	72 - 290	0 - 134	-
51.	***Calidris pugnax*** Linnaeus 1758	-	-	1 - 18	-	-	-	-	-	-	-	-	-	-

52.	*Calidris minuta* Leisler 1812	-	-	-	-	-	-	-	-	-	-	2 - 5	-	-
53.	*Lymnocryptes minimus* Brunnich 1764	-	-	0 - 1	-	-	-	-	-	-	-	-	-	-
54.	*Numenius arquata* Linnaeus 1758	-	-	0 - 1	-	-	-	-	-	-	-	-	-	-
55.	*Actitis hypoleucos* Linnaeus 1758	-	-	4 - 7	-	-	-	-	-	-	-	1 - 4	-	-
56.	*Tringa ochropus* Linnaeus 1758	-	-	0 - 1	-	-	-	-	-	-	-	0 - 2	-	-
57.	***Tringa glareola*** Linnaeus 1758	-	-	2 - 6	-	-	-	-	-	-	-	-		-
58.	*Tringa nebularia* Gunnerus 1767	-	-	-	-	-	-	-	-	-	-	0 - 1	-	-
59.	*Tringa totanus* Linnaeus 1758	-	-	1 - 7	-	-	-	-	-	-	-	0 - 2	-	-
60.	*Charadrius dubius* Scopoli 1786	-	-	0 - 2	-	-	-	-	-	-	-	-	-	-
61.	*Vanellus vanellus* Linnaeus 1758	2 - 4	4 - 18	6 - 38	0 - 1	0 - 2?	0 - 2	0 - 2	-	-	-	-	-	-
62.	***Himantopus himantopus*** Linnaeus 1758	-	0 - 1	0 - 2	-	-	-	-	-	-	-	-	-	P
63.	*Larus fuscus* Linnaeus 1758	-	-	1 - 8	-	-	-	-	-	-	-	-	-	-
64.	*Larus cachinnans* Pallas 1811	-	39-152	118 - 824	104-1900	-	26 - 67	83 - 324	51 - 380	-	0 - 4	2 - 7	3 - 55	-
65.	*Larus canus* Linnaeus 1758	-	-	0 - 1	-	-	-	-	-	-	-	-	-	-
66.	*Chroicocephalus ridibundus* Linnaeus 1766	-	9 - 52	152 - 1220	16 - 763	-	5 - 13	-	-	-	1 - 3	7 - 21	1 - 8	-
67.	***Chlidonias hybrida*** Pallas 1811	1 - 2	4 - 11	16 - 23	-	-	-	-	-	-	-	0 - 4	-	-
68.	***Chlidonias niger*** Linnaeus 1758	-	-	2 - 21	-				-	-	-	0 - 2	-	-
69.	*Chlidonias leucopterus* Temmink 1815	-	-	7 - 18	-	-	-	-	-	-	-	-	-	-
70.	***Sterna hirundo*** Linnaeus 1758	2 - 9	4 - 18	10 - 19	-	-	-	-	-	-	0 - 1	2 - 6	-	-
71.	*Podiceps cristatus* Linnaeus 1758	1 - 2	4 - 13	6 - 12	0 - 2	-	-	-	-	-	0 - 1	2 - 9	0 - 4	-
72.	*Podiceps nigricollis* Brehm 1831	-	-	0 - 4	-	-	-	-	-	-	-	6 - 22	0 - 13	-
73.	*Tachybaptus ruficollis* Pallas 1764	1 - 2	2 - 9	13 - 84	8 - 93	-	-	-	-	-	0 - 2	2 - 6	1 - 5	-
74.	*Columba livia domestica* Gmelin 1789	x	17 - 53	58 - 300	47 - 480	x	2 - 11	21 - 72	19 - 181	x	10 - 19	23 - 42	17 - 78	-
75.	*Columba oenas* Linnaeus 1758	-	0 - 2	7 - 28	-	-	0 - 3	0 - 5	-	-	-	7 - 60	-	-
76.	*Columba palumbus* Linnaeus 1758	2 - 4	5 - 11	11 - 87	32 - 108	1 - 3	2 - 17	2 - 11	0 - 7	3 - 5	3 - 8	9 - 13	2 - 12	-
77.	*Streptopelia turtur* Linnaeus 1758	1 - 2	1 - 3	2 - 5	-	-		1 - 3	-	1 - 2?	2 - 5	4 - 12	-	V
78.	*Streptopelia decaocto*	x	3 - 7	11 - 84	7 - 252	x	2 - 5	1 - 3	2 - 5	x	12 - 47	9 - 31	6 - 67	-

	Frivaldszky 1838													
79.	*Cuculus canorus* Linnaeus 1758	4 - 8	3 - 11	3 - x	-	2 - 3	2 - 4	2 - x	-	3 - 5	2 - 5	4 - x	-	-
80.	*Apus apus* Linnaeus 1758	-	0 - 6	13 - x	-	-	-	-	-	-	-	-	-	-
81.	*Athene noctua* Scopoli 1769	x	x	x	x	x	x	x	x	x	x	x	x	-
82.	*Asio otus* Linnaeus 1758	x	x	x	x	x	x	x	x	x	x	x	x	-
83.	*Strix aluco* Linnaeus 1758	-	-	-	-	-	-	-	-	x	1 - 2	x	x	-
84.	*Merops apiaster* Linnaeus 1758	-	3 - 7	4 - 13	-	-	-	1 - 3	-	4 - 5	7 - 9	21 - 47	-	-
85.	***Alcedo atthis*** Linnaeus 1758	-	-	0 - 1	-	-	-	-	-	-	-	0 - 1	0 - 1	-
86.	*Upupa epops* Linnaeus 1758	-	1 - 2	1 - 2	-	-	-	-	-	1 - 2	1 - 2	7 - 18	-	V
87.	*Picus viridis* Linnaeus 1758	0 - 1	1 - 3	0 - 1	1 - 2	-	-	-	-	1 - 2	2 - 3	-	1 - 3	-
88.	*Picus canus* Gmelin 1788	-	-	-	-	-	-	-	-	1	1 - 3	-	0 – 1	-
89.	*Dendrocopos major* Linnaeus 1758	2 - 3	2 - 5	1 - 4	1 - 3	-	-	-	-	1 - 2	1 - 3	-	2 - 4	-
90.	***Dendrocopos syriacus*** Hemprich & Ehrenberg 1833	3 - 5	3 - 7	1 - 2	1 - 2	-	-	-	-	1 - 3	2 - 4	-	1 - 4	-
91.	*Oriolus oriolus* Linnaeus 1758	2 - 4	2 - 7	3 - x	-	-	-	-	-	1 - 2	1 - 3	2 - x	-	-
92.	***Lanius collurio*** Linnaeus 1758	3 - 4	5 - 7	2 - 8	-	1 - 2	1 - 4	1 - 5	-	2 - 3	2 - 6	2 - 9	-	-
93.	***Lanius minor*** Gmelin 1788	1 - 3	2 - 4	2 - 5	-	0 - 1	1 - 2	1 - 3	-	1	1 - 3	1 - 4	-	-
94.	*Lanius excubitor* Linnaeus 1758	-	-	1 - 3	1 - 2	-	-	1 - 2	0 - 1	-	-	1 - 3	0 - 1	-
95.	*Pica pica* Linnaeus 1758	1 - 3	8 - 12	7 - 31	6 - 80	-	1 - 2	3 - 4	4 - 6	3 - 4	7 - 18	8 - 21	3 - 27	-
96.	*Garrulus glandarius* Linnaeus 1758	-	0 - 1	0 - 1	0 - 2	-	-	0 - 2	1 - 3	2 - 3	2 - 3	1 - 3	4 - 5	-
97.	*Coloeus monedula* Linnaeus 1758	2 - 3	3 - 18	4 - 21	11 - 70	2 - 3	4 - 6	1 - 4	0 - 4	3 - 5	11 - 41	11 - 23	8 - 32	-
98.	*Corvus frugilegus* Linnaeus 1758	17 - 23	89-69	47 - 338	269-3472	-	22-175	72 - 430	67 - 1520	21 - 33	28-186	71 - 212	53 - 285	-
99.	*Corvus cornix* Linnaeus 1758	-	1 - 3	0 - 5	3 - 14	-	0 - 3	1 - 3	1 - 5	1 - 2	1 - 2	3 - 18	1 - 14	-
100.	*Corvus corax* Linnaeus 1758	1	3 - 11	7 - 18	6 - 26	-	1 - 7	5 - 17	2 - 21	2 - 3?	3 - 12	1 - 18	1 - 14	P
101.	*Parus major* Linnaeus 1758	-	0 - 1	1 - 3	1 - 5	-	-	1 - 3	2 - 9	5 - 7	6 - 12	3 - 7	2 - 14	-
102.	*Cyanistes coeruleus* Linnaeus 1758	-	-	0 - 1	0 - 2	-	-	-	-	1 - 2	2 - 5	1 - 5	2 - 6	-
103.	*Bombycilla garrulus* Linnaeus 1758	-	-	-	0 - 126	-	-	-	-	-	-	-	-	-
104.	*Panurus biarmicus* Linnaeus 1758	5 - 6	4 - 14	37 - x	3 - x	-	-	-	-	1 - 2	2 - 7	8 - x	-	-
105.	*Galerida cristata* Linnaeus 1758	5 - 6	3 - 12	3 - 19	4 - 28	3 - 5	4 - 9	3 - 11	2 - 22	1 - 2	1 - 5	2 - 7	3 - 16	-
106.	*Alauda arvensis* Linnaeus 1758	18 - 21	16 - 35	16 - 35	-	8 - 12	5 - 13	4 - 19	-	3 - 5	4 - 5	8 - 21	-	-
107.	*Riparia riparia* Linnaeus 1758	x	6 - 18	52 - 215	-	-	-	-	-	18 - 24	12 - 35	82 - 320	-	-

108.	*Hirundo rustica* Linnaeus 1758	x	14 - 53	48 - 320	-	-	2 - 7	5 - 17	-	x	12 - 39	70 - 112	-	-
109.	*Delichon urbicum* Linnaeus 1758	x	2 - 20	12 - 51	-	-	-	-	-	x	3 - 12	12 - 37	-	-
110.	*Phylloscopus collybita* Vieillot 1817	1 - 2	2 - 3	5 - x	-	-	-	-	-	3 - 5	4 - 7	5 - x	-	-
111.	*Aegithalos caudatus* Linnaeus 1758	-	-	-	-	-	-	-	-	-	-	3 - 12	3 - 19	-
112.	*Locustella luscinioides* Savi 1824	8 - 11	9 - 16	17 - x	-	-	-	-	-	0 - 1?	1 - 2	2 - x	-	-
113.	*Acrocephalus arundinaceus* Linnaeus 1758	18 - 21	29 - 52	38 - x	-	-	-	-	-	3 - 5	5 - 7	5 - x	-	-
114.	*Acrocephalus scirpaceus* Hermann 1804	14 - 15	12 - 18	14 - x	-	-	-	-	-	-	0 - 2	2 - x	-	-
115.	*Acrocephalus melanopogon* Temmink 1824	1 - 3?	3 - 7	7 - x	-	-	-	-	-	-	0 - 1	1 - x	-	-
116.	*Acrocephalus schoenobaenus* Linnaeus 1758	15 - 17	15 - 21	18 - x	-	-	-	-	-	1 - 2	1 - 2	2 - x	-	-
117.	*Curruca communis* Latham 1787	2 - 4	3 - 6	7 - x	-	0 - 1	0 - 2	-	-	2 - 3	2 - 5	2 - x	-	-
118.	*Oenanthe oenanthe* Linnaeus 1758	3 - 4	3 - 11	5 - 11	-	1 - 2	1 - 3	-	-	1 - 2	1 - 6	7 - x	-	-
119.	*Saxicola rubetra* Linnaeus 1758	1 - 2	2 - 6	2 - 11	-	-	-	-	-	1 - 2	2 - 5	4 - x	-	-
120.	*Saxicola rubicola* Linnaeus 1766	1 - 2	3 - 7	2 - 13	-	-	-	1 - 2	-	0 - 1?	1 - 3	6 - x	-	-
121.	*Phoenicurus phoenicurus* Linnaeus 1758	-	-	-	-	-	-	-	-	1 - 2	1 - 3	2 - x	-	-
122.	*Phoenicurus ochruros* Gmelin 1774	x	2 - 5	2 - 7	-	-	-	-	-	1 - 3	1 - 5	5 - x	-	-
123.	*Erithacus rubecula* Linnaeus 1758	x	0 - 1	1 - x	-	-	-	-	-	1 - 3	1 - 5	2 - x	0 - 1	-
124.	*Turdus merula* Linnaeus 1758	-	-	-	-	-	-			3 - 4	3 - 7	5 - 11	2 - 5	-
125.	*Turdus philomelos* Brehm 1831	-	-	-	-	-	-			1 - 2	2 - 5	7 - 10	-	-
126.	*Turdus pilaris* Linnaeus 1758	-	-	7 - 52	18 - 31	-	-	-	-	1 - 2	3 - 7	23 - 61	19 - 142	-
127.	*Sitta europaea* Linnaeus 1758	-	-	-	-	-	-	-	-	2 - 4	3 - 9	7 - 11	5 - 7	-
128.	*Sturnus vulgaris* Linnaeus 1758	12 - 16	36-182	430 - 4880	17 - 210	-	19 - 68	150 - 1282	0 - 18	6 - 11	13 - 83	245 - 1050	0 - 5	-
129.	*Passer domesticus* Linnaeus 1758	x	7 - 21	18 - 52	26 - 210	x	3 - 6	9 - 14	12 - 17	x	15 - 51	21 - 37	18 - 25	-
130.	*Passer montanus* Linnaeus 1758	x	3 - 10	10 - 27	17 - 72	x	3 - 14	5 - 29	5 - 40	x	2 - 7	8 - 17	12 - 20	-
131.	*Motacilla alba* Linnaeus 1758	2 - 4	7 - 41	18 - 54	0 - 1	1 - 2	2 - 3	6 - 11	-	2 - 4	6 - 19	14 - 42	-	-
132.	*Motacilla flava* Linnaeus 1758	4 - 7	2 - 15	6 - 17	-	2 - 3	2 - 5	2 - 8	-	1 - 2	2 - 5	4 - 17	-	-
133.	***Anthus campestris*** Linnaeus 1758	2 - 3	2 - 7	3 - 5	-	1 - 2	1 - 3	1 - 2	-	0 - 1?	0 - 2	2 - x	-	-
134.	*Fringilla coelebs* Linnaeus 1758	-	-	9 - x	3 - 34	-	-	-	-	2 - 4	3 - 5	13 - x	5 - 34	-

135.	*Pyrruhula pyrrhula* Linnaeus 1758	-	-	-	-	-	-	-	-	-	-	3 - x	2 - 5	-
136.	*Spinus spinus* Linnaeus 1758	-	-	3 - 7	9 - 244	-	-	2 - 24	8 - 16	-	-	14 - 21	6 - 19	-
137.	*Chloris chloris* Linnaeus 1758	x	4 - 7	8 - 16	0 - 1	1 - 2	1 - 5	3 - 11	-	3 - 5	4 - 7	8 - 11	0 - 3	-
138.	*Carduelis carduelis* Linnaeus 1758	x	7 - 18	11 - 37	24 - 135	-	3 - 12	2 - 11	5 - 50	4 - 7	7 - 15	21 - 72	11 - 63	-
139.	*Linaria cannabina* Linnaeus 1758	x	9 - 15	9 - 28	8 - 64	-	2 - 5	5 - 17	3 - 9	2 - 3	5 - 12	3 - 17	2 - 8	-
140.	*Emberiza calandra* Linnaeus 1758	6 - 8	5 - 17	12 - 35	0 - 8	2 - 4	2 - 7	2 - 5	0 - 1	2 - 4	3 - 7	8 - 13	0 - 1	-
141.	*Emberiza schoeniclus* Linnaeus 1758	4 - 7	1 - 7	11 - x	7 - x	-	-	-	-	-	1 - 3	21 - x	5 - x	-
142.	*Emberiza citrinella* Linnaeus 1758	1 - 2	1 - 2	1 - 5	5 - 21	-	-	0 - 3	3 - 7	2 - 3	2 - 5	5 - 17	6 - 23	-
Total species		**70 + 5?**	**91**	**126**	**68**	**24 + 1?**	**37**	**48**	**29**	**60 +8?**	**90**	**114**	**65**	

Legend: p – pairs, i – individuals, x – not estimated population; ? – possible or irregular breeding species; the bolded species - species mentioned in Annex 1 of Birds' Directive (as species that need special conservative measures; Romanian Red Book of Vertebrates: CE – critically endangered species, P – endangered species, V – vulnerable species

We recorded the highest level of birds' diversity during the migration period (48 bird species) and the lowest level in the wintering time (29 species). We identified 37 bird species during the breeding season in the area, but only 24 are regular breeding species within this perimeter. The lapwing (*Vanellus vanellus*) could be at least an irregular breeding species in the dry grassland habitat. We also mention the constant presence of herds up to 300 sheep and goats, accompanied by three to five dogs, grazing in the area of dry meadows.

The Bacău bypass has a length of 20.29 km, including a bridge over Bistrița River (1235.40 m in length). This highway section overlaps with the confluence area between Siret and Bistrița rivers, presenting a flat and wide morphology, with a hilly and forested relief on the left side of Siret riverbed. This section intersects with the territory of two Natura 2000 sites: ROSPA0063 Buhuși-Bacău-Berești Reservoirs and ROSCI0434 Middle Siret. At the edges, the road crosses dry meadows and cultivated lands (rape, cereals, sunflower and alfalfa). The longest sector of this high-speed road passes through a territory dominated by habitats specific to the aquatic ecosystems. In this perimeter, there are two riverbeds, Bistrița River forming two arms, one of which flows into Siret River at the edge of Siretu village and the other in the tail area of Galbeni reservoir, ponds and canals between these two arms, strips of pebble and small islands, floodplain meadows, compact and strips of reed beds along the banks of water, clumps of willows, osier and poplars, interspersed with dry meadows and scrubs (*Eleagnus angustifolia*, *Tamarix ramosissima* and *Crataegus monogina*). This significant variety of habitats offers suitable conditions and shelters for various ecological groups of birds during the breeding season, migration and wintering periods. We recorded the presence of 91 bird species during the breeding season, the nesting bird fauna including 70 regular breeding species and another five possible nesting species in this perimeter: *Microcarbo pygmaeus*, *Ardeola ralloides*, *Nycticorax nycticorax*, *Zapornia parva* and *Acrocephalus melanopogon*. We identified 126 bird species during the spring and autumn migration, and only 69 species during the wintering time. Still, we noticed the unusual presence of the white storks during the cold season and a constant increase of wintering population for the wood pigeon (*Columba palumbus*) in all three years of our study in the area. We mention the appearance of the Bohemian waxwing (*Bombycilla garrulus*), an irregular winter visitor in our country, during our monitoring activity in this area – we observed a flock of 126 individuals in the neighbourhood of Bacău bypass on the 13th January 2023.

Analysing the list of bird fauna for this territory, our attention is drawn to the high diversity of the groups characteristic of the aquatic habitats – swans, geese and ducks (15 species), cormorants (two species), herons (eight species), waders (ten species), gulls and terns (eight species), grebes (three species), rails (three species) and 13 diurnal raptor species (Accipitriformes and Falconiformes) that use the open lands, including wetlands, as hunting territories. We notice the appearance of some bird species with larger population sizes compared to the quantitative data mentioned in previous studies (FENERU, 2002; GACHE, 2017, 2018, 2019). For example, during November and December 2022, we counted thousands of greater white-fronted geese (*Anser albifrons*) feeding alongside tens of whooper swans (*Cygnus cygnus*) on the cornfield stubble and winter wheat fields along this highway section. Except for a few aquatic species recorded with hundreds or thousands of individuals, especially during the migration and wintering times, the other bird species present small or medium populations that are nesting, migrating or wintering in the territory intersected by this high-speed road. For example, as semiaquatic birds, we recorded twelve wader species, but all of them appeared with no more than 30 - 40 individuals due to the small areas occupied by their suitable habitats. The heron species present more significant populations in this perimeter. At the same time, we observe a higher diversity for other ecological groups of birds, especially passerines, due to the mosaic of suitable habitats compared to the surrounding territory of the access road

towards Onești – Brașov. For example, we notice the riparian species – *Merops apiaster* and *Riparia riparia*, woodland species as the woodpeckers - *Picus viridis*, *Dendrocopos major* and *D. syriacus* or the reed beds passerines (*Panurus biarmicus*, *Locustella luscinioides*, *Acocephalus* sp. and *Emberiza schoeniclus*).

The anthropogenic presence is high and constant in the neighbourhood of the Bacău bypass, especially along the confluence area of Bistrița and Siret rivers. We met dozens of fishermen along the banks of the river, and also on boats on the open waters. Dozens of cattle, and herds up to three hundred sheep and goats are grazing on this perimeter.

The access road towards Piatra-Neamț is comparable with the access road towards Onești - Brașov in length (3.17 km), but is similar to Bacău bypass in terms of bird fauna's diversity - 114 bird species – despite its seven times shorter length. Croplands and dry meadows line the eastern half of this road, while the aquatic ecosystems appear from the starting point of the bridge over Bistrița River (462 m in length) and along the western edge. The bridge passes about 35 m from the concrete dam of Lilieci reservoir, crossing the river downstream of the dam and the Lilieci discharge channel. Lilieci reservoir is located on the northern side of the road. There exist several types of aquatic habitats in the neighbourhood of this highway section: open water surfaces, the wide meandering course of the river, with the flat western bank, respectively, high and steep eastern bank, with sectors of bare clay walls or covered by clumps of trees, strips and compact reed beds, strips of pebble, bushes and isolated old trees. The result is a puzzle of suitable habitats for birds that stretches both horizontally and vertically, supporting a significant diversity of bird fauna in a relatively small territory.

We noticed the presence of 90 bird species during the breeding time in this perimeter, 60 of them being regular nesting species with a small breeding population in the area. The diversity of the bird species characteristic of the aquatic habitats is lower than species that build their nests inside the trees and bushes. The group of passerines is well represented by 40 bird species, which nest inside reed beds, but also in woodland habitats and open lands. We mention 8 bird species as possible, or at least irregular breeding presence in this territory, as we observed adult and juvenile birds during the breeding time: *Coturnix coturnix*, *Anas platyrhynchos*, *Fulica atra*, *Streptopelia turtur*, *Corvus corax*, *Locustella luscinioides*, *Saxicola rubicola* and *Anthus campestris*. The appearance of one immature individual of red-throated diver (*Gavia stellata*) during July 2023 on the Lilieci discharge channel was an unusual summer presence in Romania.

We recorded the highest bird fauna diversity during the migration time (114 species) and the lowest one during the four months of the wintering period (65 species). Regarding the counted population size, we must mention that the diving species (*Aythya* sp., *Mergellus albellus*, *Fulica atra*, *Podiceps* sp. and *Tachybaptus ruficollis*) feed in the waters of Lilieci reservoir, in front of the dam, and are missing during the harsh winters when the ice-bed covers this area of the reservoir. We observed small groups of these bird species on the Lilieci discharge channel. We recorded flocks of more than one hundred individuals for the dabbling ducks (*Anas* sp. and *Mareca* sp.) and the pygmy cormorants (*Microcarbo pygmaeus*) along the watercourse of Bistrița River downstream of the Lilieci dam. We observed the white stork and raptor birds crossing towards the south direction during the migration time, flying at a significant height upper this high-speed road and the concrete dam of Lilieci reservoir. We met the wintering raptors using the trees from the area as perching points for hunting their prey.

We notice the constant presence of herds of sheep and goats in this perimeter, but also the summer anthropogenic recreational activities (sport fishing, beach and swimming) along this section of Bistrița River valley. These impacts can explain the small number of bird breeding pairs and their concentration in the downstream dam areas and along the left side of the riverbed with rugged relief and more difficult access.

The valleys of the Bistrița and Siret rivers represent an important migration flyway for the white storks and diurnal raptors in the eastern side of the Romanian Carpathians. Thousands of white storks cross this territory during the last decade of August. During the second part of September, tens and hundreds of individuals representing various diurnal raptor species fly along these valleys towards the southern wintering areas. For example, during the field visit on the 29th September 2023, we caught a glimpse of the eagles passing in groups of 11 – 33 individuals in the area of Bistrița River entrance into Lilieci reservoir: starting at 10:04 until 10:38 a.m., we counted 245 lesser spotted eagles (*Clanga pomarina*), flying alongside tens short-toed snake eagles (*Circaetus gallicus*), common buzzards (*Buteo buteo*), sparrowhawks (*Accipiter nisus*), one white stork and eleven ravens (*Corvus corax*). We announced our collaborators from the Regional Centre of Ecology Bacău (CRE Bacău) and the National Agency for Natural Protected Areas – Bacău Territorial Service, and they confirmed the passing of the birds over Bacău city towards the south and south-eastern directions, crossing also the perimeter intersected by the Bacău bypass. We observed a smaller group of lesser spotted eagles and short-toed snake eagles flying over this highway section during the same day, at 1:16 p.m.

As a result of their flight and intensive daily and seasonal mobility, the birds are among the animals with the easiest access to the perimeter of roads. Moreover, the roads' infrastructure offers many attractions for birds – resting places, perching sites for hunting, easily accessible food resources, etc. In this way, the mortality as roadkill represents a primary cause of anthropogenic death among birds (ERRITZØE et al., 2003). All the authors admit the underestimation of wildlife roadkill due to several reasons. In the case of bird species, some roadkill does not reach the lanes of the road, being thrown into the vegetation on road edges, and escape to identify and the registration process (HUSBY, 2016). As we saw during our field activity, small passerines, but also medium-sized birds as owls (Strigiformes), depreciate quickly by the repeated passage of vehicles. The necrophagous or opportunistic bird and mammal species consume roadkill and often remove it from the road (ANTWORTH et al., 2005). Usually, a bird cannot survive a road collision situation due to the flight speed and the anatomy of the cervical vertebras – during our 61 visits along Bacău bypass section of the Highway A7 (Moldova), we met only one surviving bird, an adult of long-eared owl (*Asio otus*), at the 21st April 2022. The bird

received treatment and was released in the area by our colleagues from the Regional Centre of Ecology Bacău (CRE Bacău) and the Centre for Wildlife Rehabilitation Focșani.

During our monitoring activity, we identified 298 birds as roadkill along the investigated highway sections (Table 2): 283 individuals along Bacău bypass, nine birds along the access road towards Onești – Brașov and another six along the access road towards Piatra-Neamț. We must mention that we searched for roadkill only along the lane of the road and under the two bridges over Bistrița River.

Analysing the bird fauna diversity and the incidence of road collision, we found a different situation from one section to the other sections of this high-speed road. The total number of roadkill represents 39 species, which means 27.46% of the recorded bird fauna along the investigated highway sections and their surroundings (142 species). We can correlate the higher diversity of bird species presented along the Bacău bypass and in its neighbourhood with a higher documented incidence of roadkill. The existing mosaic of habitats provides support for the birds' mobility in the area, and this increases the frequency of the birds' reaching the perimeter of the six-lane road. We identified 38 bird species as roadkill along the Bacău bypass, representing 29.68% of the bird fauna living or crossing this territory (128 species), and the number of road collisions along this road section varies from one species to another. We caught the birds flying both under (ducks, gulls, terns, herons, coot and grebes) and over (raptors, herons, storks, geese, ducks and gulls) the bridge that crosses the Bistrița River in this section of the A7 Highway (Moldova), but we met 19 roadkill on this bridge during our study. The diversity of habitats is lower along the access road towards Onești – Brașov where we recorded only four bird species as roadkill, representing 8.32% of the observed bird fauna in this perimeter (38 species). We cannot correlate the diversity of bird species with the incidence of road collisions along the third section, the access road towards Piatra-Neamț: the number of roadkill is smaller than the other two sections, but it represents five species, meaning 4.38% of the identified 114 bird species in the area. We recorded only a domestic pigeon (*Columba livia domestica*) as roadkill on the bridge over Bistrița River of this access road. We observed during our field activity that birds fly at a significant height over the bridge and the concrete dam of Lilieci reservoir, but we also saw egrets, herons, pygmy cormorants and waders flying under the bridge. We compared the number of identified roadkill along sections of equal length, reporting the total length of the access road to an equal section at the connecting edge of the highway. We identified 22 birds (11 species) as roadkill along the section of Bacău bypass of equal length as the access road towards Piatra-Neamț, where we recorded six birds as roadkill. At the other edge of the investigated high-speed road, we recorded 73 birds (including one flock of tree sparrows – *Passer montanus*) representing 11 species as roadkill along the section of Bacău bypass of equal length as the access road toward Bacău where we identified only nine birds as roadkill.

Table 2. Identified bird species and their number as roadkill along the section Bacău bypass of Highway A7 Moldova (October 2021 – August 2024).

No.	Species	Recorded number of roadkill						
		Breeding Season (i)	Migration & Pre-wintering (i)	Wintering (i)	Bacău bypass (i)	Access-road Onești-Brașov (i)	Access-road Piatra-Neamț (i)	Total (i)
1.	*Phasianus colchicus*	7	-	4	10	-	1	11
2.	*Perdix perdix*	1	-	1	1	1	-	2
3.	*Gallus gallus*	-	-	1	1	-	-	1
4.	*Cygnus olor*	-	-	1	1	-	-	1
5.	*Anas platyrhynchos*	2	-	-	2	-	-	2
6.	***Botaurus minutus***	-	1	-	1	-	-	1
7.	***Ciconia ciconia***	-	3	-	3	-	-	3
8.	*Buteo buteo*	1	-	-	1	-	-	1
9.	*Accipiter nisus*	2	-	1	3	-	-	3
10.	*Falco tinnunculus*	1	-	-	1	-	-	1
11.	*Larus cachinnans*	2	-	2	4	-	-	4
12.	*Columba livia domestica*	32	-	12	42	-	2	44
13.	*Columba oenas*	-	2	-	2	-	-	2
14.	*Columba palumbus*	1	-	-	1	-	-	1
15.	*Streptopelia decaocto*	8	-	-	8	-	-	8
16.	*Cuculus canorus*	-	1	-	1	-	-	1
17.	*Athene noctua*	8	-	16	24	-	-	24
18.	*Asio otus*	27	-	3	29	-	1	30
19.	*Strix aluco*	-	-	1	-	-	1	1
20.	***Lanius collurio***	2	-	-	2	-	-	2
21.	***Lanius minor***	-	1	-	1	-	-	1
22.	*Pica pica*	-	-	3	3	-	-	3
23.	*Corvus frugilegus*	8	-	10	17	1	-	18
24.	*Corvus corax*	2	-	7	9	-	-	9
25.	*Galerida cristata*	3	-	2	4	1	-	5
26.	*Hirundo rustica*	3	-	-	3	-	-	3
27.	*Curruca communis*	1	-	-	1	-	-	1
28.	*Saxicola rubicola*	1	-	-	1	-	-	1
29.	*Erithacus rubecula*	-	1	-	1	-	-	1

30.	*Turdus pilaris*	-	1	-	1	-	-	1
31.	*Sturnus vulgaris*	5	18	-	23	-	-	23
32.	*Passer domesticus*	14	-	11	18	6	1	25
33.	*Passer montanus*	9	-	47	56	-	-	56
34.	*Motacilla alba*	-	1	-	1	-	-	1
35.	***Anthus campestris***	1	1	-	2	-	-	2
36.	*Carduelis carduelis*	2	-	-	2	-	-	2
37.	*Linaria cannabina*	1	-	-	1	-	-	1
38.	*Emberiza calandra*	1	-	-	1	-	-	1
39.	*Emberiza citrinella*	-	-	1	1	-	-	1
Total roadkill		**145**	**30**	**123**	**283**	**9**	**6**	**298**

Legend: i – individuals; the bolded species - species mentioned in Annex 1 of Bird's Directive (as species that need special conservative measures.

As for other fauna groups, various particularities of the birds' biology, ecology and behaviour represent the main factors that influence the rate and level of road collision risk to bird species (GARRAH et al., 2015; GARRIGA et al., 2017). We mention between them the age and sex of the individuals, category of chicks (nidifugous or nidicolous), the daily and seasonal intensity of movements and rhythm of activity, the diet and patterns of searching for food resources, the territorial dispersal behaviour, respectively, the type, size and location of nesting and feeding territories reported to the road network (KAMBOUROVA-IVANOVA et al. 2012).

Regarding the age of bird roadkill, the number of adult birds was three times higher than that of flying juvenile and immature birds. We cannot exclude the possibility of identifying some birds as adults during the end of autumn and winter time, especially for the passerine group that becomes adult birds within their first year of life, moult their plumage, and lose juvenile characteristics. The adult birds are particularly active during the breeding season. At the beginning of this period, birds are searching to identify, occupy and defend a breeding territory. During the interval covering the period of care and feeding the chicks at the nest, they search for food resources and bring them to the nest. These behaviour patterns involve particularly intense movement of adult birds within the area, increasing the risk of reaching the high-speed lane and their exposure to collision risk (HUSBY, 2016). The period of carrying the chicks is longer for the bird species with nidicolous chicks.

When we compare the nesting season to other periods of the year, the birds present a reduced spatial amplitude of daily movements, but their intensity is higher, and the height of flight is lower, which exposes the birds to intersecting with the perimeter of the road lane, including the risk of collision. We identified 145 birds (48.65%) as roadkill during the breeding season, along the high-speed road. During the seasonal migration time, the spatial area of daily birds' movement becomes significant. Numerous birds have a high cruising flight altitude, which reduces the risk of traffic collision when their trajectory crosses over the road network. During our studies, we observed that the passerines are flying at 40 – 60 m height, the medium-sized birds (for example, the doves - Columbiformes) are crossing at heights of ten up to 150 m, while the ducks, geese, storks or raptors pass at altitudes of hundreds to 1200 m in this perimeter. This situation can be a reasonable explanation for the small recorded number of individual roadkill (30 birds – 10.06%) during the migration period along the investigated sections of Highway 7 (Moldova). The resident and winter visitor bird species tend to form flocks of dozens of individuals, roaming to search for suitable feeding areas starting from the preceding winter time and during the cold season. During the late summer and in autumn, these birds accumulate fat reserves that cover their survival necessities when the days are not suitable for foraging (heavy rainfall, dense fog, etc.) and birds are forced to rest in various sheltering places. During this period of their annual biological cycle, the birds fly to lower altitudes, which facilitates the easy location of food resources and reduces the energetic costs of flight effort. Their daily movement trajectories can intersect the road network and expose them to a higher rate of collision risk – we recorded 123 birds (41.27%) as roadkill during this period along the monitored three sections of high-speed road.

Thirteen bird species of the 39 species recorded as roadkill along the investigated section of Highway 7 (Moldova) present sexual dimorphism, allowing us to identify 28 females and 22 males as roadkill. Their presence as victims in traffic along the road varies from one species to another and results from their different rhythm of activity and participation during the nesting period. For example, we identified nine males and only two females of pheasant (*Phasianus colchicus*) as roadkill in the area. The males appeared during the first part of the breeding season when they actively search for territories and look to form one pair, while we recorded the females as roadkill during the wintering time. For the mallard (*Anas platyrhynchos*) and sparrowhawk (*Accipiter nisus*), we recorded adult females, which are more active than males during the period of caring for their chicks.

For the birds, the suitable habitats define the ecological characteristics necessary during their breeding season: the place where the birds build their nests and the feeding territory. During the seasonal migration period and wintering time, suitable habitats for birds provide the necessary feeding resources and resting sites. Among the identified birds as roadkill in the area, the group of synanthrope bird species was dominant in terms of victims' number (205 individuals – 68.79%), but occupied the second position regarding the diversity (ten species), following the birds group that prefers the open lands (grasslands, dry meadows and cultivated lands) – 15 bird species. Except for the collared dove (*Streptopelia decaocto*) and house sparrow (*Passer domesticus*) that do not leave the anthropogenic perimeter, the other bird species nest within the localities but search for their food resources in the open lands. The specific diversity (eight species) and the number of bird victims (16 individuals – 5.36%) among the birds of aquatic ecosystems presented low values, contrary

to the situation described in other studies (FORMAN & ALEXANDER, 1998; GARRAH et al., 2015), but also if we consider the high diversity of this ecological bird group in the neighbourhood of the investigated highway (67 species) and significant surfaces covered by the aquatic and wetland habitats in the area. The group of woodland bird species contributed twice to the number of collision victims (32 birds – 10.73%), but with an equal number of species to the list of roadkill. The group of raptor bird species, including the raven (*Corvus corax*), due to its ecology and breeding behaviour, represented a key group among the recorded roadkill diversity (seven species) and number (69 individuals, 23.15%). We notice that seven bird species (*Asio otus*, *Athene noctua*, *Columba livia domestica*, *Corvus frugilegus*, *C. corax*, *Passer domesticus* and *P. montanus*) contributed by 206 individuals (69.12%) to the list of identified roadkill during our study. Most of them search for food along the roads and in the neighbourhood of the road network. Moreover, we met four of them (*Columba livia domestica*, *Corvus frugilegus*, *Passer domesticus* and *P. montanus*) as regular appearances on the road lane, using it as a feeding, resting and thermoregulation area.

The reduced abilities of flying, maneuvering and changing the flight trajectory define the flight of galiforms and represent significant factors in increasing the rate of road collision for this group of birds. The manner of perching on high supports and taking off following a linear descending trajectory, which are characteristic of the diurnal bird raptors, exposes them to the risk of roadkill. Nocturnal bird raptors have a lower altitude manner of flying when they search for their prey, which explains the significant number of roadkill among this group (GOMES et al., 2009). The incidence of roadkill among the passerines is the result of their small size, which facilitates the sucking of birds into the air currents generated by the moving vehicles along the road.

The birds' presence can be temporary within a territory from one stage to another along the annual biological cycle (for migratory species, for example). Beyond their presence, the type and spatial amplitude of birds' activity and their daily movements in the area present significant variations from one stage to another in the annual biological cycle and from one day to another under the influence of external factors (for example, the meteorological parameters). The collision risk along the roads was constant for the birds throughout the year (Fig. 2) in direct correlation with their annual biological rhythm of activity, which does not imply any inactive period in the daily life of birds.

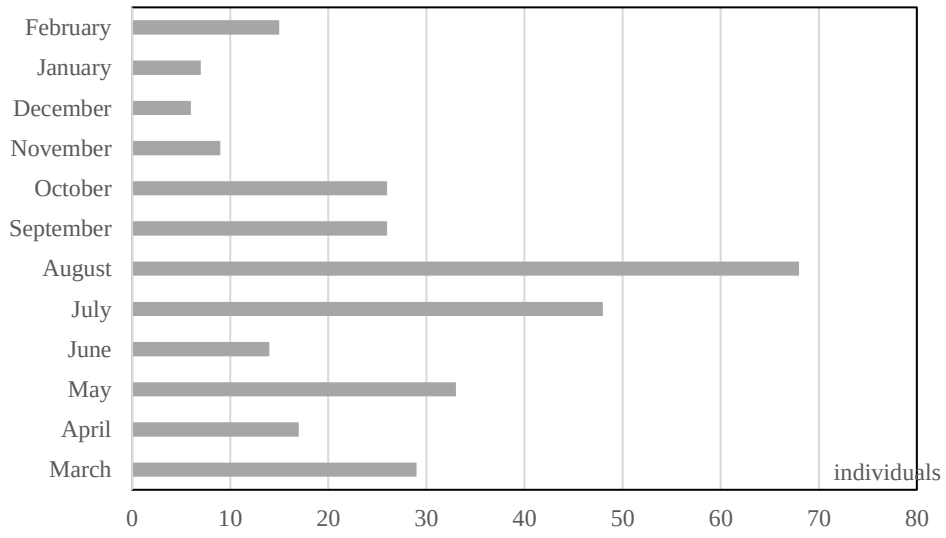

Figure 2. The monthly incidence of collision incidents (individuals)
for the bird species along the investigated section of Highway 7 (Moldova) from October 2021 until August 2024.

We noticed the seasonal variability in the rate of collision incidents, and the roadkill values peak in July-August, when the birds end the nesting season and prepare for the start of autumn migration and wintering period flying around to search food resources, respectively a lower frequency of roadkill during the cold season (November - February) when the birds are not so active in their movements around, a similar situation to other studies (HUSBY, 2016; GARRIGA et al., 2017).

The resident bird species in the area are the main contributors to the roadkill diversity along the investigated section of highway, with 17 species (43.58%) and 203 individuals (68.12%). Among these roadkill, we mention a flock formed by at least 30 tree sparrows (*Passer montanus*) identified during the field visit on the 8th August 2022. The second group was represented by summer visitors, with 13 bird species (33.33%) and 20 individuals as roadkill (6.71%). The partial migratory bird species was the last by diversity (8 species – 20.51%), but the second in terms of the victims' number (31 individuals – 10.40%). We included the wood pigeon (*Columba palumbus*) in this group, which is a summer visitor with rare presence during the winter in our country. This wild pigeon species becomes partially migratory in this region – we observed flocks larger than 100 individuals during the winter period in the last 10-15 years. We identified two domestic bird species as roadkill: the chicken (*Gallus gallus domesticus*) – one individual, probably escaped from a

vehicle transport and regarded as an incidental roadkill in the area, respectively, the feral domestic pigeon (*Columba livia domestica*), which represented the species with the highest number of collision victims – 44 individuals (14.76%), being a constant presence along the road and in it neighbourhood.

The birds have higher acoustic and visual sensitivities than other groups of animals, and develop the obstacle avoidance behaviour, changing their flight trajectory and height to fly on the edges, over or below obstacles, a movement pattern described for wind farms (HÖTKER et al., 2006). Flying birds can avoid the static infrastructural elements of the road networks. We observed individuals or flocks of egrets and herons (Ardeidae), storks (Ciconiidae), cormorants (Phalacrocoracidae), crows and ravens (Corvidae) flying several times over the investigated sections of the high-speed road, passing over or below the bridges over Bistrița River. But the road traffic speed (higher along the highway) combined with their speed during the flight makes it difficult for birds to observe and avoid vehicles moving along the road. Moreover, many bird species use various infrastructural elements as resting or perching points for hunting (informative and sound-absorbing panels, lighting poles, protection fences) or searching for food (alimentary waste, insects, rodents, etc.) along the road lane. Often, these birds notice the presence of imminent danger of collision too late, being surprised by the sudden appearance of a vehicle at a distance too short to allow them to leave the area at risk of collision. At the same time, most birds, including the larger ones (as buzzards – *Buteo* sp. or storks – *Ciconia* sp.), do not have enough strength to avoid the suction forces generated by moving large vehicles (trucks, buses) when they are flying at a lower height over the road or taking off from the resting or perching sites along the road.

During our monitoring activity, we identified along this section of Highway 7 (Moldova) several bird species with protection status. Among them, 31 bird species appear in the Annex 1 to the Birds Directive (79/409/EEC updated through the 2009/147/EC) as bird species that need special conservation measures concerning their habitats to ensure their survival and reproduction in their distribution range. We recorded five of these species as roadkill during our study: *Botaurus minutus*, *Ciconia ciconia*, *Lanius collurio*, *L. minor* and *Anthus campestris*. Only the little bittern (*Botaurus minutus*) appears as breeding species in the official standard form of ROSPA0063 Buhuși-Bacău-Berești Reservoirs (***. https://eunis.eea.europa.eu/sites/ROSPA0063). We also observed 35 bird species mentioned in the Annex 2 to the same directive, as hunting bird species under the national rules without jeopardising conservation efforts in their distribution area. Eleven bird species recorded as roadkill along Highway 7 (Moldova) are species mentioned in the Annex 2 to the Birds Directive: *Phasianus colchicus*, *Perdix perdix*, *Cygnus olor*, *Anas platyrhynchos*, *Larus cachinnans*, *Columba oenas*, *C. palumbus*, *Streptopelia decaocto*, *Pica pica*, *Corvus frugilegus* and *Sturnus vulgaris*.

We also mention the presence of 22 bird species included in the Romanian Red Book of Vertebrates (BOTNARIUC & TATOLE, 2005). Among them, two are critically endangered bird species, six are endangered bird species, and fourteen are vulnerable bird species. Only two of them appeared as roadkill along the investigated high-speed road: *Ciconia ciconia* (vulnerable species) and *Corvus corax* (endangered species).

Establishing the list of bird fauna and the seasonal presence of birds in a territory crossed by a road network represents the first step in managing the collision risks related to the development and modernisation of road infrastructure (BENNETT, 2017). The second one is to identify and understand the factors that influence the collision risk for the birds in the area (HUSBY, 2016). Subsequently, we can identify, define, and implement the appropriate mitigation measures to reduce and limit the risk of road collisions for birds that live, breed, feed, and transit in that territory using knowledge about the birds' biology, ecology, and behaviour, including the particularities observed in that perimeter (COFFIN, 2007; GARRIGA et al., 2017).

CONCLUSIONS

The diversity of bird fauna in the neighbourhood of a highway section represents a premise for assessing the level of the roadkill incidents; still, the correlation between a higher diversity of bird species and a high rate of collision risk is not obligatory. As we observed during our monitoring activity, the birds' diversity was similar in the territory crossed by the access road towards Piatra-Neamț with that identified in the neighbourhood of the Bacău bypass. The recorded incidence of roadkill was more than six times higher along the Bacău bypass. Even when we compared sections of equal length from these two roads, the number of roadkill and their specific diversity presented different values: 22 birds as roadkill, representing eleven species along the north-western edge of the Bacău bypass, versus six birds as roadkill, representing five species along the access road towards Piatra-Neamț.

Contrary to our initial work hypothesis and over similar studies, we identified a small number of birds representing the ecological group of aquatic ecosystems as victims of the traffic road collision along this section of Highway 7 (Moldova) during our 35 months monitoring activity in the area.

The diversity and the size of covered surfaces through suitable habitats for bird species influence not only their diversity but also their daily and seasonal movements within the territory and expose birds to a higher collision risk along the road network. The daily movements of the resident and summer visitor bird species do not have significant spatial coverage in the area during the nesting time. This is the time when the birds' flights between the nest's location and feeding territories have a higher frequency, and the lower height defines the daily movements of the birds in this perimeter. The rate of roadkill was higher during the breeding season than during the migration time, when we recorded the highest values for the diversity of bird fauna and the size of bird populations in the area. The migratory bird species fly at high altitudes over the perimeter crossed by the investigated sections of highway.

We noticed the level of roadkill incidence for two nocturnal bird raptors, 30 long-eared owls (*Asio otus*) and 24 little owls (*Athene noctua*), representing 18.12% among the identified bird victims of road collision during our study. The open lands represent their hunting territories and are the dominant ecosystems along Highway 7 (Moldova) in this perimeter. The long-eared owl has a slow, low-altitude search flight, initiating a sudden attack on prey once located in the area. We identified 25 victims of road collisions during the first stage of the nesting period, fifteen individuals in the February – April of 2024, which suggests that at least this species does not develop an avoidance flight behaviour for the road traffic infrastructure. The high number of little owls as roadkill can be correlated with its manner of perching, staying even on the ground and road lane, and the characteristic hunting flight at low altitude, with an undulating trajectory that exposes the birds to intersect the height of road traffic. The flashing and blinding lights of the vehicles' headlights affect the reaction capacity and spatial orientation in the nocturnal landscape of these raptors.

We identified the breeding presence of one pair of raven (*Corvus corax*) building its nest on a ledge of the bridge over Bistrița River in its confluence area with Siret River as part of Bacău bypass section. We recorded nine ravens as roadkill in the area, five of them being juvenile birds. This endangered bird species has a positive trend in this part of Romania.

Beyond the biological and ecological aspects related to the bird fauna, the morphology of a high-speed road, the relief of the surrounding area, and the parameters of road traffic have a strong influence on the rate of collision incidents involving bird species along the road lane, but this will make the object of a future analysis.

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