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ICHNEUMONIDS (HYMENOPTERA: ICHNEUMONIDAE) FROM SOME MEADOWS IN THE CENTRAL MOLDAVIAN PLATEAU, NEW AND RARE FOR THE ROMANIAN FAUNA

CAMIL ȘTEFAN LUNGU-CONSTANTINEANU, RAOUL CONSTANTINEANU

The paper presents 15 species of 14 genera from Ichneumonidae, belonging to subfamilies Campopleginae, Cryptinae, Diplazontinae, Ichneumoninae, Orthocentrinae, Pimplinae and Tryphoninae. The species *Stenomacrus intermedius* (Holmgren) is new for the Romanian fauna. The other 14 species are rare or very rare in Romania.

Keywords: Hymenoptera, Ichneumonidae, new records, Central Moldavian Plateau, Romania.

INTRODUCTION

We consider important the study of the ichneumonological fauna in meadows, because we can draw conclusion on the state of degradation of the area, the changes in time and the anthropogenic impact on flora and fauna. Among insects, Hymenoptera is an important order, especially insects belonging to the family Ichneumonidae, part of the useful entomofauna, being considered bioindicators. Their large or small presence reveals important information about the phytosanitary status, about the degree of infestation or attack of specific pests. Ichneumonids number is directly proportional to the pest and bring important data about the attack.

Our research has been achieved in Dobrovăț, Schitu Duca and Poiana-Schitu Duca meadows, Iași county, in the Central Moldavian Plateau, Romania, during May 2015.

RESULTS

We present the synopsis of the 15 species from some meadows in the Central Moldavian Plateau, in 2015.

Family ICHNEUMONIDAE Latreille, 1802
Subfamily CAMPOPLEGINAE Förster, 1869

I. Genus *Casinaria* Holmgren, 1859

Type species: *Campoplex tenuiventris* Gravenhorst, 1829, Öfvers. Kong. Vet.-Akad. Förhandl., **15**: 321-330.

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1. *Casinaria nigripes* Gravenhorst, 1829, ♂

Material: 1 ♂, Dobrovăț, Iași county.

Length: 9 mm.

Hosts: *Tephрина arenacearia* Den. et Schiff. (Lep., Geometridae), *Calliteara pudibunda* (L.), *Orgya antiqua* (L.) (Lep., Lymantriidae) and *Dendrolimus pini* (L.) (Lep., Lasiocampidae). *Casinaria nigripes* is parasitized by *Theronia atalantale* Poda, as a secondary parasitoid (Atanasov *et al.*, 1981).

Geographical distribution: Western Europe, Russia (Samara). In Romania it is a rare species, being previously recorded only from Ineu, Arad county, Reșița, Caraș Severin county, Fundulea, Ilfov county.

Subfamily CRYPTINAE Kirby, 1837

II. Genus *Listrocryptus* Brauns, 1905

Type species: *Listrocryptus spatulatus* Brauns, 1905, Zeitschr. Syst. Hym. Dipt., **5**: 134-136.

2. *Listrocryptus spatulatus* Brauns, 1905, ♀

Material: 1 ♀, Dobrovăț, Iași county.

Length: 8 mm.

Hosts: *Pyrausta sticticalis* L. (Lep., Pyraustidae).

Geographical distribution: Germany, Hungary. In Romania it is a very rare species, being previously recorded only from “Ponoare” National Reservation, Suceava county (Constantineanu & Voicu, 1982).

III. Genus *Listrognathus* Tschek, 1871

Type species: *Listrognathus cornutus* Tschek, 1871, Verh. Zool.-Bot. Gesell. Wien, **18**: 437-448.

Synonyms: 1900 *Mesostenoides* Ashmead, Proc. US Nat. Mus., **23**: 1-220; 1903 *Sulvalta* Cameron, Zeitschr. Syst. Hym. Dipt., **3**: 298-304, 337-343; 1914 *Mesostenidea* Viereck, US Nat. Mus. Bull., 83-186.

3. *Listrognathus ligator* (Gravenhorst, 1829), ♂

Synonyms: *Mesostenus ligator* Gravenhorst, 1829, Ichn. Eur., **2**: 1-989; *Cryptus senilis* Rudow, 1882, Ent. Nachricht., **8** (20): 279-289; *Cryptus aculeatus* Rudow, 1883, Ent. Nachricht., **9** (19-20): 232-247.

Material: 1 ♂, Poiana Schitu Duca, Iași county.

Length: 14 mm.

Hosts: *Zygaena trifolii* Esp. (Lep., Zygaenidae), *Malacosoma neustria* L. (Lep., Lasiocampidae) and *Acrionicta rumicis* L. (Lep., Noctuidae).

Geographical distribution: Western Europe, Ukraine, Russia (Western and Southern). In Romania it is a rare species, being previously recorded from Hodod, Satu Mare county, Saschiz, Mureș county, Dealu Cetățuui-Perșani, Brașov county, and Slobozia-Ciurea, Iași county (Pisică, 2001).

4. *Listrognathus obnoxius* (Gravenhorst, 1829), ♂

Synonyms: 1873 *Mesostenus subovalis* Thomson, Opusc. Ent. Lund, **5**: 455-527; 1882 *Cryptus robustus* Rudow, preoccupied by *Cryptus robustus* Cresson, 1864; 1896 *Mesostenus subcircularis* Thomson, Opusc. Ent. Lund, **21**: 2343-2388.

Material: 1 ♂, Schitu Duca, Iași county.

Length: 11 mm.

Hosts: *Zygaena filipendulae* Zett., *Z. peucedani* Esp. and *Z. lonicerae* Schev. (Lep., Zygaenidae) (Pisică, 2001).

Geographical distribution: Western Europe, Ukraine, Russia (Daghestan). In Romania it is a very rare species, being previously recorded from Hodod, Satu Mare county and the Bucegi mountains (Pisică, 2009).

Subfamily DIPLAZONTINAE Viereck, 1918

IV. Genus *Promethes* Förster, 1869

Type species: *Bassus sulcator* Gravenhorst, 1829, Verh. Naturhist. Ver. Preuss. Phein. Westf., **25**: 135-221.

5. *Promethes bridgmani* Fitton, 1976, ♂

Synonyms: 1886 *Bassus scutellaris* Bridgman, preoccupied by *Bassus scutellaris* Cresson, 1868, Trans. Ent. Soc. London. 1848: 335-373.

Material: 1 ♂, Poiana Schitu Duca, Iași county.

Length: 5 mm.

Hosts: unknown.

Geographical distribution: Northern and Southern Europe, Belorussia, Ukraine (Poltava), Russia (Bryansk). In Romania it is a very rare species, being previously recorded only from Iacobeni, Suceava county (Constantineanu *et al.*, 2000).

Subfamily ICHNEUMONINAE Latreille, 1802

V. Genus *Diadromus* Wesmael, 1845

Type species: *Ichneumon troglodites* Gravenhorst, 1829, Nouv. Mém. Acad. Roy. Sci. Lett. et Beaux-Arts Belg., **18**: 1-239.

6. *Diadromus arrisor* Wesmael, 1845, ♀♂

Material: 1 ♂, Dobrovăț, Iași county.

Length: 6 mm.

Hosts: *Ypsolophus persicellus* F. (Lep., Plutellidae).

Geographical distribution: Northern and Center Europe, Italy. In Romania it is a rare species, being anteriorly recorded only from Bârnova massif forest (Bârnova, Poieni, Schitu Duca commune, Repedea, Păun, Bârnova) (Constantineanu, 1965).

VI. Genus *Dicaelotus* Wesmael, 1845

Type species: *Ichneumon pumilus* Gravenhorst, 1829, Nouv. Mém. Acad. Roy. Sci. Lett. et Beaux-Arts Belg., **18**: 1-239.

7. *Dicaelotus parvulus* (Gravenhorst, 1829), ♀

Synonyms: 1829 *Ichneumon parvulus* Gravenhorst, Ichn. Eur., **1**: 591.

Material: 1 ♀, Dobrovăț, Iași county.

Length: 4-5 mm.

Hosts: *Lobesia botrana* (Schiff.) (Lep., Tortricidae) and *Plutella xylostella* L. (Lep., Plutellidae) (Mustață, 1979).

Geographical distribution: England, Sweden, Finland, Belgium, Germany and Austria. In Romania it is a rare species, being anteriorly recorded from Sadova, Dolj county, Moldovița, the Rarău mountains, Suceava county, Biczaz, Neamț county and Homorcea, Vrancea county.

VII. Genus *Tycherus* Förster, 1869

Type species: 1891 *Phaeogenes elongatus* Thomson, Verh. Naturhist. Ver. Preuss. Rheinl. Westf., **25**: 135-221.

8. *Tycherus elongatus* (Thomson, 1891),

Synonyms: 1891 *Phaeogenes elongatus* Thomson, Verh. Naturhist. Ver. Preuss. Rheinl. Westf., **25**: 135-221, 1901-1902 *Proscus elongatus* Dalla Torre, Cat. Brit. Hym., **3**: 741.

Material: 1 ♀, Dobrovăț, Iași county.

Length: 6 mm.

Hosts: unknown.

Geographical distribution: England, Sweden, Finland and Germany. In Romania it is a rare species, being anteriorly recorded from Repedea, Păun, Iași county and Dorohoi, Botoșani county (Pisică & Popescu, 2009).

VIII. Genus *Syspasis* Townes, 1965

Type species: 1829 *Ichneumon scutellator* Gravenhorst, Mem. Reale Acad. Sci. Torino, **24**: 275-388.

9. *Syspasis leucolomia* (Gravenhorst, 1829), ♀

Synonyms: 1829 *Ichneumon leucolomius* Gravenhorst, Ichn. Eur., **1**: 479; 1847 *Ichneumon salutator* Fonscolombe, Ann. Soc. Ent. France, **5**: 402; 1847 *Ichneumon dissectus* Fonscolombe, Ann. Soc. Ent. France, **5**: 404; 1933 *Stenichneumon leucolomius* Meyer, Parazit. Perep. Sem. Ichn., **1**: 79.

Material: 1 ♀, Schitu Duca, Iași county.

Length: 12 mm.

Hosts: unknown.

Geographical distribution: Spain, France, Austria, Germany and Ukraine (Harkov). In Romania it is a rare species, being anteriorly recorded only from Bârnova forest, Iași county (Constantineanu, 1959).

IX. Genus *Barichneumon* Thomson, 1893

Type species: *Ichneumon anator* Fabricius, 1793, Opusc Ent. Lund, **18**: 1889–1967.

10. *Barichneumon nubilus* Brischke, 1891, ♀

Synonyms: 1891 *Ichneumon nubilus* Brischke, Schrift. Naturf. Ges. Danzig., N. F., **7**: 58.

Material: 1 ♀, Dobrovăț, Iași county.

Length: 10 mm.

Hosts: unknown.

Geographical distribution: Germany. In Romania it is a rare species, being anteriorly recorded from Babadag, Constanța county, Torcești, Galați county, Lunca Rogoaza, Deleni commune, Iași county, Călian forest, Nicșeni commune, Botoșani county (Pisică & Popescu, 2009).

X. Genus *Ichneumon* Linnaeus, 1758

Type species: *Ichneumon extensorius* Linnaeus 1829

11. *Ichneumon analis* Gravenhorst, 1829, ♂

Material: 1 ♂, Dobrovăț, Iași county.

Length: 8 mm.

Hosts: unknown.

Geographical distribution: England, Germany, Belgium, Russia (Iaroslav). In Romania it is a rare species, being anteriorly recorded from Ruda, Hunedoara county and Bicaz Chei, Neamț county (Pisică & Popescu, 2009).

Subfamily ORTHOCENTRINAE Förster, 1869

XI. Genus *Orthocentrus* Gravenhorst, 1829

Type species: 1829 *Orthocentrus anomalus* Gravenhorst, Ichn. Eur., **3**: 1-1097.

12. *Orthocentrus frontator* Zetterstedt, 1838, ♀

Synonyms: 1838 *Tryphon frontator* Zetterstedt, Insecta Lapponica. Sectio Secunda. Hymenoptera, Lipsiae, 317-476; 1858 *Orthocentrus repentinus* Holmgren, Kong. Svensk. Vet. Handl. N.F., **1** (2): 305-394.

Material: 1 ♀, Dobrovăț, Iași county.

Length: 3.5 mm.

Hosts: unknown.

Geographical distribution: Sweden, Russia (St. Petersburg). In Romania it is a rare species, being anteriorly recorded from Hitiaș, Timiș county (Pisică & Popescu, 2009).

XII. Genus *Stenomacrus* Förster, 1869

Type species: *Orthocentrus silvaticus* Holmgren, 1858, Verh. Naturhist. Ver. Preuss. Phein. Westf., **25**: 135-221.

13. *Stenomacrus intermedius* (Holmgren, 1856), ♂

Material: 1 ♂, Dobrovăț, Iași county.

♂. Head is bulging, almost not narrowed behind. Face is shining. Frons is smooth enough. Antennae with 32 articles, the first one cylindrical. Radial vein starts at the middle of stigma. Legs short and stout.

Black. Palpi, clypeus, ventral side of antennae, wing basis, front coxae and trochanters yellow. Cheeks and anterior margin of frons yellow.

Length: 4 mm.

Hosts: unknown.

Geographical distribution: Northern and Southern Europe, Belarus, Ukraine (Poltava), Russia (Bryansk) (Yu & Horstmann, 1997).

New species for the Romanian fauna. This species belongs to Dr. Raoul Constantineanu's private collection, in Iași.

Subfamily PIMPLINAE Wesmael, 1915

XIII. Genus *Apechthis* Förster, 1869

Type species: *Ichneumon rufatus* Gmelin, 2318 Verh. Naturhist. Ver. Preuss. Phein. Westf., **25**: 135-221.

14. *Apechthis capulifera* (Kriechbaumer, 1887), ♂

Synonyms: 1874 *Pimpla destructor* Smith, preoccupied by *Pimpla destructor* Smith, 1863; 1901, *Pimpla japonica* Dalla Torre, Cat. Hym. **3**: 1-544; 1906 *Apechthis orbitalis* Ashmead, Proc. US Nat. Mus., **30**: 169-201; 1906 *Apechthis sapporoensis* Ashmead, Proc. US Nat. Mus., **30**: 169-201; 1914 *Apechthis japonica* Morley, preoccupied by *Apechthis japonica* (Dalla Torre, 1901).

Material: 1 ♂, Schitu Duca, Iași county.

Length: 16 mm.

Hosts: it is a polyphagous species, parasitising: Cerambycidae (Coleoptera); Tortricidae, Geometridae, Lasiocampidae, Lymantriidae, Noctuidae, Hesperidae, Papilionidae, Pieridae and Nymphalidae (Lepidoptera).

Geographical distribution: Northern and Western Europe, Ukraine, Russia (widespread). In Romania it is a rare species, being anteriorly recorded from Ineu, Arad county and Poieni, Iași county (Pisică & Popescu, 2009).

Subfamily TRYPHONINAE Shuckard, 1840

XIV. Genus *Netelia* (Fourcroy, 1869)

Type species: *Paniscus inquinatus* Gravenhorst, 1829, Ann. Mag. Nat. Hist. **5** (3): 339-342.

15. *Netelia virgata* (Fourcroy, 1785), ♀

Material: 1 ♀, Dobrovăț, Iași county.

Length: 12 mm.

Hosts: it is a polyphagous species, parasitising Cerambycidae (Coleoptera); Tortricidae, Geometridae, Lasiocampidae, Lymantriidae, Noctuidae, Notodontidae, Hesperiiidae, Papilionidae, Pieridae and Nymphalidae (Lepidoptera).

Geographical distribution: Northern Africa, Europe, Russia (wide spread), India, Korea and Japan. In Romania it is a rare species, being anteriorly recorded from the Retezat mountains, the Bucegi mountains and Agapia, Neamț county (Pisică & Popescu, 2009).

CONCLUSION

The authors present 15 ichneumonid species of 14 genera recorded from some meadows in the central Moldavian plateau. The species belong to the subfamilies Campopleginae, Cryptinae, Diplazontinae, Ichneumoninae, Orthocentrinae, Pimplinae and Tryphoninae. The species *Stenomacrus intermedius* (Holmgren) is new for the Romanian fauna. The following species: *Casinaria nigripes* Grav., *Listrocryptus spatulus* Brauns, *Listrognathus ligator* (Grav.), *Listrognathus obnoxius* (Grav.), *Promethes bridgmani* Fitton, *Diadromus arrisor* Wesm., *Dicaelotus parvulus* (Grav.), *Tycherus elongatus* (Thoms.), *Syspasis leucolomius* (Grav.), *Barichneumon nubilus* Brisch., *Ichneumon analis* Grav., *Orthocentrus frontator* Zett., *Apechthis capulifera* (Kriechb.) and *Netelia virgata* (Fourcr.) are rare or very rare in Romania.

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RESPONSE OF NECROPHILOUS ARTHROPODS TO DIFFERENT ANIMAL TISSUES USED AS ATTRACTANTS

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The accelerating rate of change in biodiversity patterns demands a better understanding of the structure of biological communities and its relationship with ecosystem functioning. Environmental variation induced by the anthropogenic changes may explain the observed differences in the distribution of arthropod species. Apart of this, biases induced by the experimental design are of an increasing concern. The present research is intended to contribute preliminary knowledge on the diversity of arthropods in a small island of the Lower Danube River System (LDRS) and their response to an experimental design that involved five types of different animal tissue as attractants. Patterns in the diversity and abundances of arthropod orders on different types of attractants are discussed and their attractiveness for necrophilous arthropods are compared. Results underline the importance of sampling strategies in the attempt to assess the biological diversity and the underlining mechanisms of its changing over both time and space. Our results provide the initial data and knowledge related to necrophilous arthropods in the LDRS that may generate new fields of research and open up opportunities with broad biodiversity and societal consequences.

Keywords: necrophilous arthropods, field experiment, chicken tissues, biodiversity assessment, food preferences, Small Island of Brăila.

INTRODUCTION

The accelerating rate of change in biodiversity patterns, mediated by ever increasing human pressures and global warming, demands a better understanding of the structure of biological communities and its relationship with ecosystem functioning (Mouillot *et al.*, 2011). Distribution of arthropod species and observed communities in human impacted sites may differ from those classically described. Many explanations of such discoveries can be justified in the light of environmental variations induced by anthropogenic changes, which are occurring with incredible velocity (Turchetto & Vanin, 2010). Additionally, the biases occurred in the attempt to assess and characterize the human induced changes in the level of biodiversity and communities' structure is notorious. The experimental design, including types of attractant and traps used are of a high concern (Ermakov, 2013; Devigne & De Biseau, 2014). Food strategies and high mobility of arthropods as well as the peculiarities of their movement make them difficult to sample and to assess changes in the community's structure (Devigne & De Biseau, 2014). In spite of the role necrophilous and necrophagous arthropods play in the integrating system,

their research mainly focuses on forensic issues aiming to either characterize the patterns of invertebrate's succession on a limited number of experimental carrions or identify the post-mortem interval (Barton *et al.*, 2013). Therefore the extrapolation of results to the scale of a whole ecosystem, under different environmental conditions, encounters serious limitations (Brundage *et al.*, 2011; Vasconcelos *et al.*, 2015).

The present research was conducted in the Lower Danube River System (LDRS), a region where the human impact through dams, drainage of wetlands, land use changes is well documented (Vădineanu, 2009). This resulted in significant changes of species richness and distribution, community composition and food web structure with important consequences for the ecosystem services in terms of their type, quantity and quality (Vădineanu *et al.*, 2001). So far, in the region (excepting the communities of primary producers) research was focused mainly on aquatic and river margin (riparian) systems with little attention being paid to structure and function of terrestrial systems, and especially to invertebrate communities. Studies related to the arthropod species attracted to carrions or baited traps are completely missing in the area.

Although the literature frequently mentions that the necrophagous invertebrates feed on carrions and the necrophilous are the predators and parasites of carrion-feeding invertebrates (Baz *et al.*, 2010), there is still great uncertainty regarding the trophic spectrum of the different orders of arthropods present on the tissues of animals in decomposition. Moreover, different meanings are associated to these notions. For instance, the necrophilous invertebrates are considered all those "attracted to carrions while not feeding on carrion itself"; those having a "behavioral attraction to carrion" (Rivers & Dahlem, 2013) or even "carrion frequenting" invertebrates (Watson & Carlton, 2003). As well, opportunistic or casual invertebrates visit the carrions and exploit this resource in different ways (Baz *et al.*, 2010). Consequently, in the current paper the term necrophilous designates invertebrates attracted to baited traps, for any reason: food (necrophagous, parasites and predators, saprophagous), reproduction (i.e. mating, oviposition), completing the biological life cycle (i.e. intake of protein), opportunistic or casual.

Broadly, the present research contributes knowledge on the diversity and distribution of necrophilous arthropods that represent a serious gap in knowledge in the LDRS. Specifically, it is intended to investigate the diversity and abundance of terrestrial necrophilous arthropods attracted by five different types of bait of animal origin and to compare the attractiveness of tissues used as attractants for the identified taxa.

MATERIAL AND METHODS

In May 2012, a field experiment aimed to characterize the arthropod fauna associated to different chicken tissues used as attractants was conducted for 13 days in the Harapu Island belonging to the Small Island of Brăila (the Lower Danube River

System – LDRS) (Fig. 1). The Harapu Island has low wildlife mammal population. This allows us to keep at the minimum level the unavoidable damages of pitfall traps. For better results, traps suspended in trees (2-liter plastic bottles, fitted with holes of 1 cm in diameter) were simultaneously used with pitfall traps so that to increase the catching probability of both flying and epigeous arthropods. A total of 195 traps (94 pitfall and 101 suspended) supplied with water and few drops of detergent were placed in 13 random sampling stations. Between 6 and 12 of each pitfall and suspended traps were replicated in a sampling station. For a better coverage of the habitat diversity 5 ± 0.25 grams fresh weight of different tissues: fresh and decaying (two days old) muscle, liver, bones and feathers were used. Carrions were collected immediately after chickens' natural death from an intensive poultry farm and sliced and frozen until they were used.

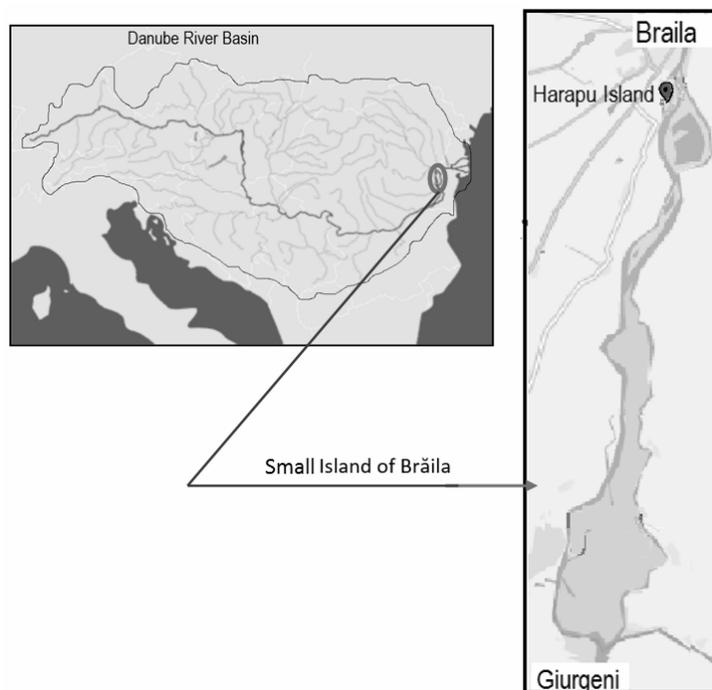


Fig. 1. Geographical position of the Small Island of Brăila and of the Harapu Island within the Danube River Basin.

Samples collected in field (at 1, 2, 3, 6, 9 and 13 days after installation) were preserved in 70% alcohol before to be analyzed and adult individuals identified to the order level (except Collembola) according to common identification key. 65 pitfalls and 73 suspended traps remained functional till the end of the experiment.

Classical calculation methods (Rîșnoveanu & Popescu, 2011) were used to assess occurrence frequencies (F%), densities (nr. ind./trap*day), Shannon diversity

index (H') and Shannon evenness (J') in baited traps. One-way ANOVA followed by Tukey post-hoc test (Statistica 10) was used to test the significant differences between taxa densities on different attractants. The analyses concern the patterns of arthropods responses to different types of attractants. The influence of the trap position was not discussed here.

RESULTS AND DISCUSSION

Arthropods were represented in samples by 22116 individuals belonging to six classes: Insecta (> 88%), Arachnida (6.6%), Malacostraca (6.3%), Diplopoda (0.7%), Chilopoda (0.05%) and Entognatha (0.03%). Nevertheless, only Insecta and Arachnida were constant in samples ($F > 50\%$), all the other arthropods being accidentals ($F < 25\%$). On the different attractant tissues, the total arthropod densities ranged between 4.25 (feathers) and 33.92 ind/trap*day (bones) (Fig. 2). Statistically significant differences were recorded between bones and both fresh muscle ($p < 0.05$) and feathers ($p < 0.05$).

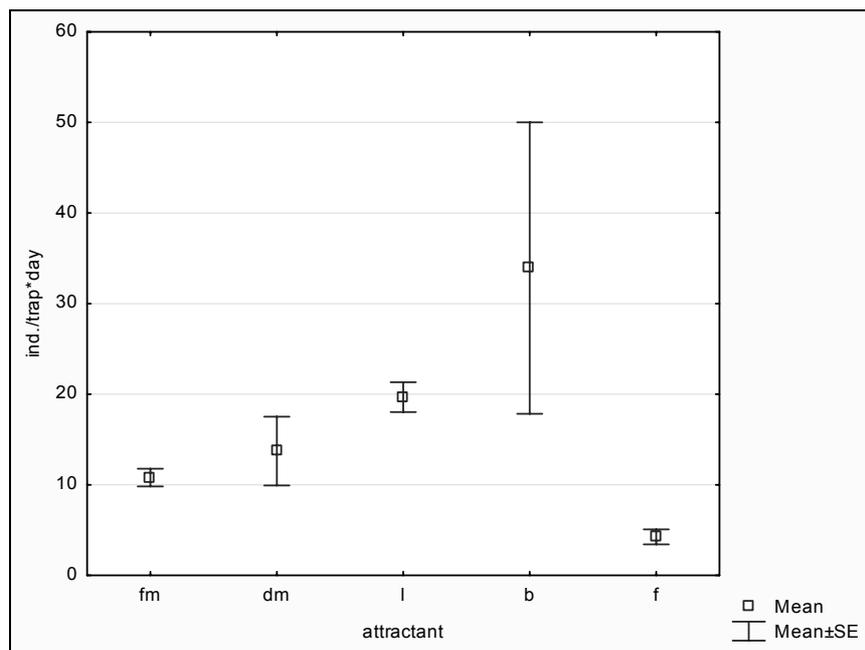


Fig. 2. Total density (ind./trap*day) of arthropods on different type of attractant.
fm = fresh muscle; dm = decaying muscle; l = liver; b = bones; f = feathers.

A total of 18 taxa (17 orders and one subclass, Collembola) of arthropods were identified in the samples (Fig. 3). The highest richness was recorded on fresh

muscle (15 taxa) and the lowest on bones (9 taxa). Generally, Coleoptera, Diptera and Hymenoptera are the most abundant taxa, followed by Araneae, Isopoda and Mecoptera. These taxa were frequently reported in literature of carrion decomposition (Watson & Carlton, 2003; Pechal *et al.*, 2011; de Carvalho Moretti *et al.*, 2013). The families, genera and species belonging to the identified orders exploit the decomposition matter of animal origin in different ways: they are necrophagous or predators (i.e. Coleoptera, ants), are sucking the interstitial fluid from the tissues and use the decomposing tissues for oviposition (i.e. Diptera), are completing their life cycle by intaking proteins (i.e. Diptera, Lepidoptera) or are opportunistic or casual species (i.e. Trichoptera, Neuroptera, Orthoptera).

Different patterns were noticed in the colonization of tissues used as attractants (Fig. 3). Significant differences were noticed regarding the highest densities reached by a taxa on different types of tissue: on fresh muscle (Fig. 3A) and liver (Fig. 3C) the highest densities were recorded by Coleoptera (5.1 ind/trap*day and 6.37 ind/trap*day, respectively); on decaying muscle (Fig. 3B) and bones (Fig. 3D) by Hymenoptera (5.83 ind/trap*day and 28.61 ind/trap*day, respectively), whereas on feather (Fig. 3E) by Diptera (1.36 ind/trap*day). Coleoptera, Diptera, Isopoda and Mecoptera reached their highest densities on the liver tissue (6.4 ind/trap*day, 4.99 ind/trap*day, 2.03 ind/trap*day and 0.93 ind/trap*day, respectively); Hymenoptera and Araneae on bones (28.61 ind/trap*day and 2.03 ind/trap*day, respectively).

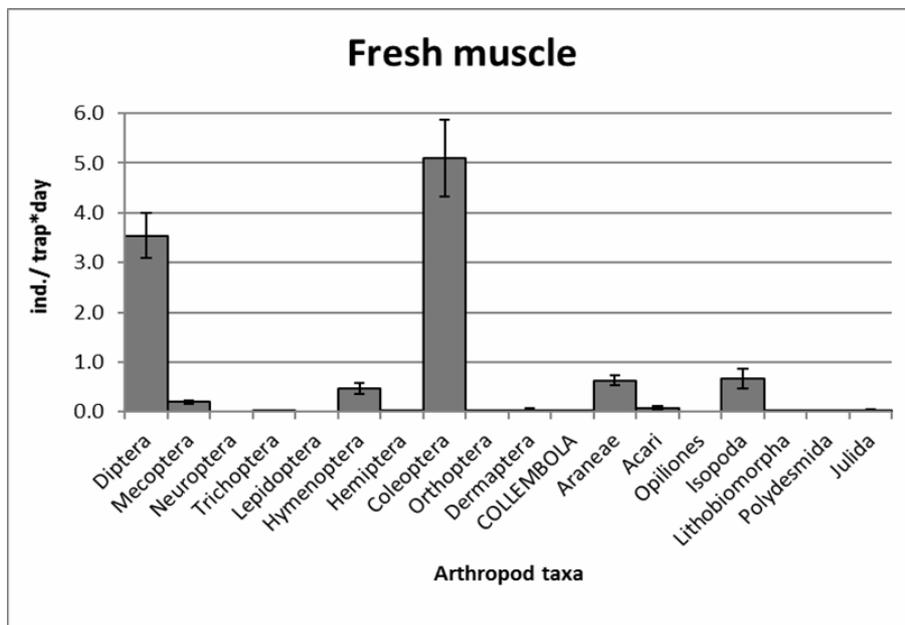


Fig. 3 A. Arthropod taxa' densities (ind./trap*day) on fresh muscle.

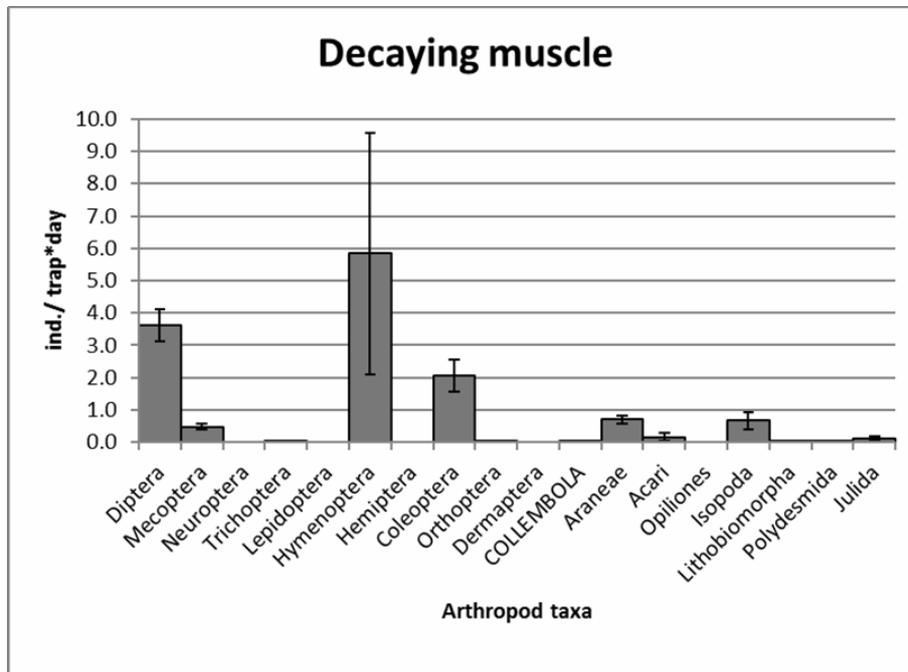


Fig. 3 B. Arthropod taxa densities (ind./trap*day) on decaying muscle.

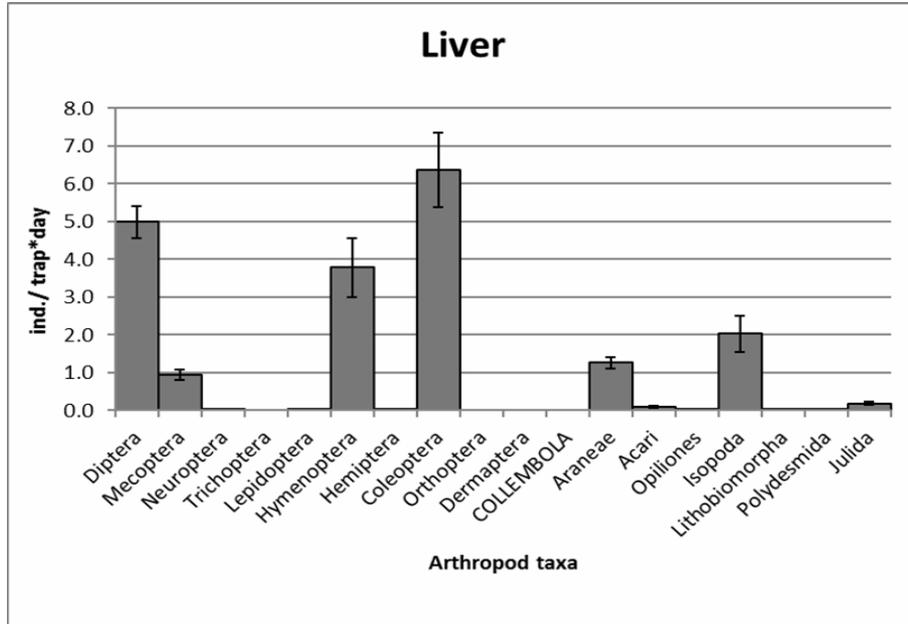


Fig. 3 C. Arthropod taxa densities (ind./trap*day) on the liver.

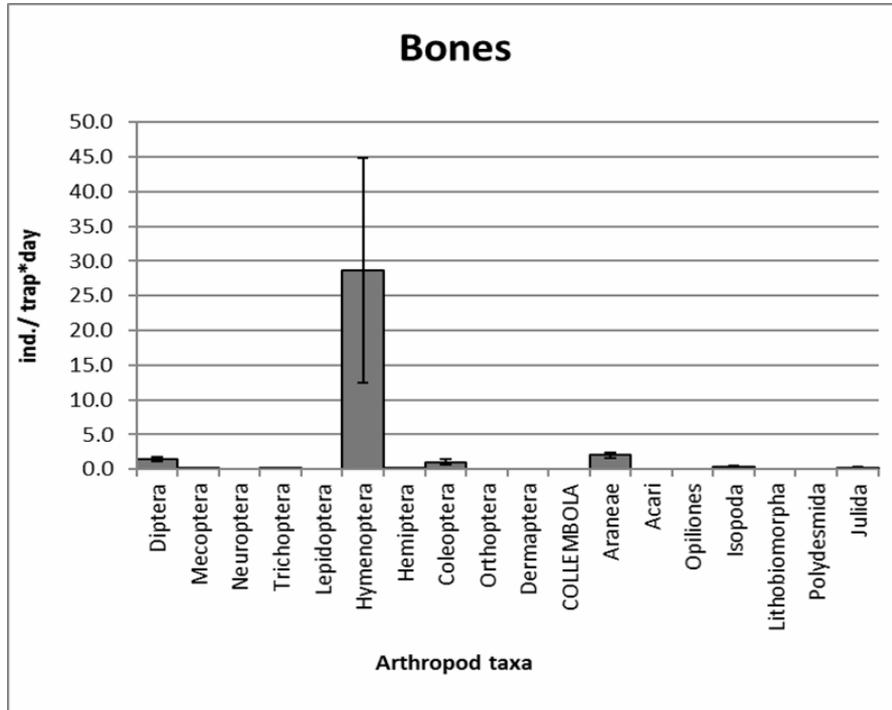


Fig. 3 D. Arthropod taxa densities (ind./trap*day) on bones.

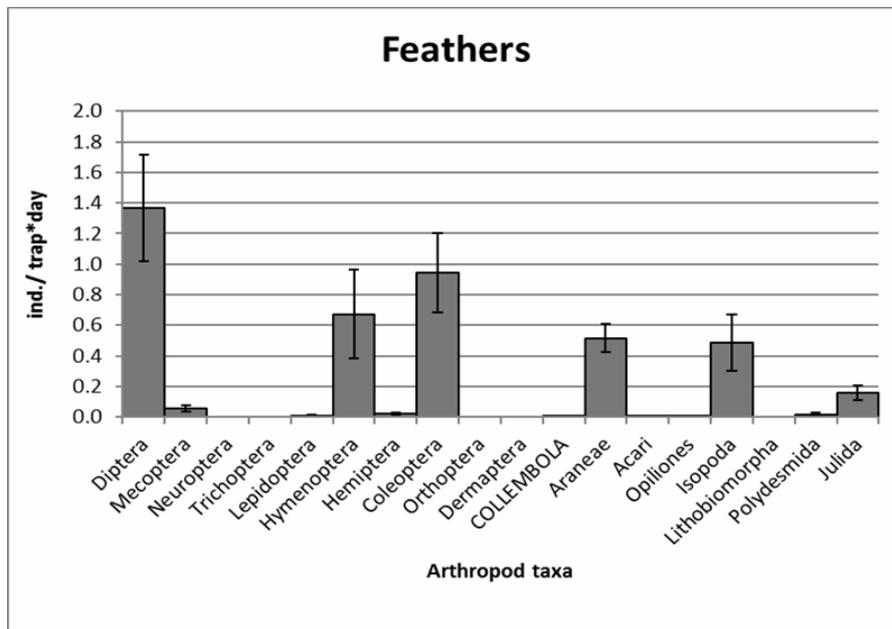


Fig. 3 E. Arthropod taxa densities (ind./trap*day) on feathers.

The high densities recorded by Hymenoptera on bones are due to the extremely high occurrence of ants (between 100 and 1257 ind/trap*day) in suspended traps in only one sampling station. The high abundances recorded by only one taxa explains the low values of evenness (0.3) recorded for the necrophilous community assemblage on bones (Fig. 4). In the literature, ants are reported as being necrophagous, predators as well as omnivores (Campobasso *et al.*, 2009; de Carvalho Moretti *et al.*, 2013; Andrade-Silva *et al.*, 2015). A higher abundance of Hymenoptera in suspended baited traps was also found by other authors (i.e. de Carvalho Moretti *et al.*, 2013). Due to their abundance and predatory behavior, Hymenoptera can lead to a decrease in the number of necrophagous flies caught in traps (Dupont *et al.*, 2012; de Carvalho Moretti *et al.*, 2013), so their presence may lead to underestimates of the assessed biological diversity.

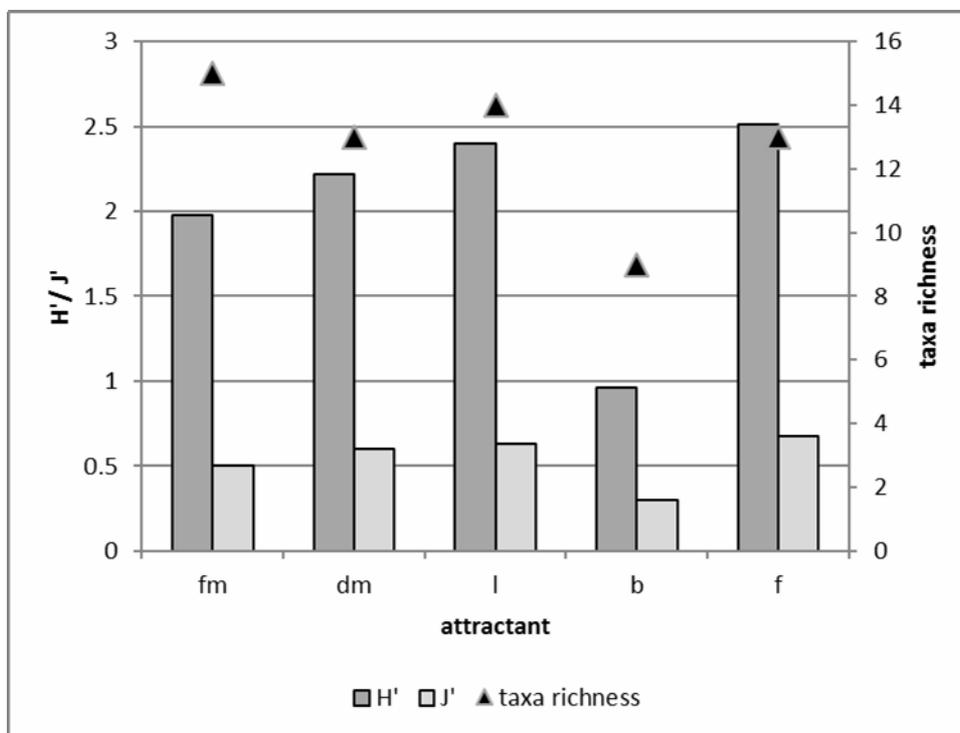


Fig. 4. Arthropod taxa diversity on different attractants. H' = Shannon diversity index; J' = Shannon evenness (J'); fm = fresh muscle; dm = decaying muscle; l = liver; b = bones; f = feathers.

Leaving apart this special situation of Hymenoptera on bones, we may notice that the liver tissue was the most efficient attractant for arthropods. It attracted the highest total arthropod densities (19.67 ind/trap*day) as well as the highest densities of four out of six dominant taxa. On the other side, fresh muscle attracted the highest number of taxa. Some of the less dominant taxa occurred also only on the

liver (Neuroptera) and muscle (Dermaptera and Orthoptera). Even if they were present at very low densities (< 0.03 ind/trap*day) their role in the provision of ecosystem services, as agents of biological pest control (Neuroptera; Stelzl & Devetak, 2012) or in the decomposition process (Dupont *et al.*, 2011; Martin-Vega *et al.*, 2013) is not to be neglected.

CONCLUSIONS

Different patterns of arthropod response to the type of tissue use as attractant were recorded. They underline the importance of sampling strategies in the attempt to assess the biodiversity and the underlining mechanisms of its changing over both time and space.

Our results provide the initial data and knowledge related to necrophilous arthropods in the LDRS that may generate new fields of research and open up opportunities with broad biodiversity and societal consequences.

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POPULATION DYNAMIC STUDY OF KURA BARBEL (*BARBUS LACERTA*: CYPRINIDAE) IN TIGRIS BASIN

HAKIMEH DOPEIKAR, YAZDAN KEIVANY

The present study describes the length-weight (LWR) relationships, age and growth of the kura barbel, *Barbus lacerta*, a cyprinid fish in Bibi-Sayyedana River, Tigris basin of Iran. A total of 389 specimens were captured by monthly collections from July 2010 to July 2011. Age groups ranged between 0⁺-7⁺. The sex ratio was determined as 1.5M:1F, a ratio significantly different from the expected ratio. Males and females become sexually mature in their first year. The largest female captured was 23.3 cm total length (TL), the largest male was 18.4 cm TL, at ages 7⁺ and 4⁺, respectively. The body condition factor ranged from 1.77 to 2.17. The von Bertalanffy growth equations and length-weight relationships indicated negative allometric growth rates for both sexes ($p < 0.05$). The $\hat{\phi}$ -value was calculated as $\hat{\phi} = 4.7$ for females and as $\hat{\phi} = 4.4$ for males. The average specific growth rate during the life span was calculated as $G = 0.44$ for females and as $G = 0.61$ for males. The life span or possible maximum age was calculated as 7.5 years for females and 7.7 years for males. The annual natural mortality rate was estimated as 0.55 for females and 0.48 for males, based on length information and as 0.61 for females and 0.50 for males, based on weight information. The results of this study indicate this species as a slow growing fish with a relatively high mortality rate. This information could be used for conservation purposes and fisheries management.

Keywords: age, growth, length-weight relationships.

INTRODUCTION

Fisheries management and research often require the use of biometric relationships and population characteristics and age composition of a fish stock in order to analyze data collected in the field into appropriate indices (Ecoutin & Albaret, 2003; Alavi-Yeganeh *et al.*, 2011; Daneshvar *et al.*, 2013; Ghanbarifardi *et al.*, 2014). The age profile of a stock gives an indication on how healthy the stock is (Metin & Ilkyaz, 2008; Keivany *et al.*, 2014). Age determination in fish can be carried out with direct or indirect methods (Morales-Nin, 1992). Length and weight measurements in conjunction with age data can give information on the stock composition, age at maturity, life span, mortality, growth and production (Beyer, 1987; Bolger & Connolly, 1989; King, 1996 a, b; Diaz *et al.*, 2000; Ghanbarzadeh *et al.*, 2013, 2014). By determining the age of a large number of individuals, it is possible to estimate the age structure of the whole population. Knowledge of the age structure provides an indication of how the stock is measured up to exploitation (Metin & Ilkyaz, 2008; Ilkyaz *et al.*, 2011).

Kura Barbel (*Barbus lacerta*) is a cyprinid fish widely distributed in Iran and adjacent countries (Coad, 2015), however, there is little information on the biology of this species, in general, and on its population dynamics, in particular, partly because this fish is not of commercial importance due to its slow growth rate and small size. Nevertheless, it is used as an edible fish at a local scale.

The human interference in the nature has changed the habitat and living condition of the populations, thus having a good knowledge of their characteristics would help in their management and conservation. The aim of this study was to investigate the growth parameters of *B. lacerta* population in Bibi-Sayyedana River of Semrom, Tigris basin. The main goal of this study is to expand our knowledge on this species. The results obtained from this study will be useful to fisheries biologist, providing the baseline information for the growth of Kura barbel from Bibi-Sayyedana River of Tigris basin and it can be used for the management of Kura barbel in the region in the future.

MATERIAL AND METHODS

Sampling

In total 389 fish specimens were collected from Bibi-Sayyedana River, Tigris basin, Iran. Regular monthly samples were obtained using various fishing gears from July 2010 to July 2011. After collection, specimens were anesthetized in 1% clove oil solution, preserved on ice and transferred to the laboratory. Total length (TL) fork length (FL) and Standard length (SL) were measured (length to the nearest 0.1 cm) using a digital caliper, while body weight was determined as total weight with and without gut and gonads, using a digital balance (Model Notebook 1108-8) to the nearest 0.01g. Fish were dissected to determine their sexes on the basis of gonads.

Measurements and ageing

Total length (TL) was measured to the nearest 0.1 cm and the total weight (TW) to the nearest 0.01 g for small specimens and 1 g for larger specimens. The individuals were sexed by macroscopic examination of the gonads. Age determination was done by scale and opercular (Daget & Le Guen, 1975; Castanet *et al.*, 1992). The embedded scales were gently removed with the help of sharp blade and fine forceps from the posterior side of the body between the dorsal fin and lateral line. Scales and operculars were cleaned manually using the fine brush and rinsed in triple distilled water, dehydrated in the ascending series of ethanol alcohol and finally dried at room temperature. After that they were observed by microscope and stereo microscope. Then they were immersed in a solution of glycerin and read

under a compound microscope at $12.5 \times$ magnification using reflected light (Campana & Neilson, 1985). Also, the age reading was performed by three investigators and only coincident readings were accepted to assure the accuracy of the readings.

Growth models, condition factor and mortality rates

Parameters of the length-weight relationship were calculated for both sexes and for the whole sample, by fitting the power function to length and weight data using equation $W = aL^b$ (Froese, 2006). Pauly (1984). The t-test was used to determine if the slope of relationships was significantly different from the expected 3 value. Length-weight relationships were originally used to provide information on the condition of fish and may help determine whether somatic growth is isometric or allometric (Ricker, 1973; Spiegel, 1991; Santos *et al.*, 2002).

Growth was modeled using the von Bertalanffy (1938) growth equation for length $L_t = L_\infty [1 - e^{-k(t+t_0)}]$ and weight $W_t = W_\infty [1 - e^{-k(t+t_0)}]$, where L_t is the fish total length at age t , L_∞ is the asymptotic total length, K is the growth coefficient and t_0 is the hypothetical age when fish would have been at 0 cm total length and W_t is the fish total weight at age t and W_∞ is the asymptotic total weight. The K , L_∞ and W_∞ were calculated using Gulland & Holt (1959) plot and equation: $\Delta L/\Delta t = K * L_\infty - K * L_t$. The t_0 was calculated using von Bertalanffy (1938) plot and equation:

$$L = t_0 - 1/K * \ln(1 - L/L_\infty)$$

The life span, the approximate maximum age (t_{max}) that fish of a given population would reach was calculated following Taylor (1958), it is calculated as the age at 95% of L_∞ , using the parameters of the von Bertalanffy growth function as $t_{max} = t_0 + 3/K$.

The condition factor was measured using the equation $Cf = (W/L^3) \times 100$, where, W = weight of fish (g), L = length of fish (cm). The fi prime value was calculated as $\phi' = L_n K + 2L_n L_\infty$. The spontaneous growth rate was calculated by $G = (\ln W_{t+1} - \ln W_t) / \Delta t$ for different ages and sexes.

The natural mortality rate was estimated based on Pauly (1984) empirical equation for length as $\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$, and for weight as $\log M = -0.2107 - 0.0824 \log L_\infty + 0.6757 \log K + 0.4627 \log T$, where T is the mean annual water temperature.

Statistical Analyses

Statistical differences between the means were determined by Independent-sample *t*-test. In order to test for possible significant differences between the sex ratio from the 1:1 ratio, chi-square test was used. The degree of association between the variables was computed by the determination coefficient, r^2 . All the statistical analyses were performed at 95% confidence limit using SPSS.18 computer software.

RESULTS AND DISCUSSION

Amongst the 389 specimens of *B. lacerta* used for the length-weight relationship, 234 were males (60%), while 155 were females (40%), indicating a sex ratio of about 1M:0.7F. The TL and weight of females ranged from 6.4 to 23.3 cm (mean and standard deviation 14.23 ± 4.19) and 2.65 to 123.17 (54.90 ± 41.59) g and those of males from 5.7 to 18.4 (11.24 ± 2.58) cm and 2.02 to 58.8 (19.01 ± 14.24) g, respectively. The results of length weight relationship indicated a negative allometric growth pattern for both females ($W = 0.0115L^{2.9586}$, $r^2 = 0.99$) and males ($W = 0.0271L^{2.7566}$, $r^2 = 0.98$) ($p < 0.05$) (Fig. 1). The b values ranges between 2.5 to 3.5 (Pauly & Gayanilo, 1997) and our result fall within this range. Yildirim *et al.* (2001) reported an isometric growth for males and females of *B. plebejus escherichi* (a close species or even synonym of *B. lacerta*) in Oltu Stream of Coruh River (Artvin-Turkey). Also, Bircan *et al.* (1897) found an isometric growth pattern for *B. plebejus escherichi* in Bafra-Altinkaya Reservoir, Turkey. Karatas *et al.* (2005) found a negative allometric growth for *B. plebejus* from Almus Reservoir, Turkey. Therefore, the b value in this species as in other fishes is variable. The b values in fish vary due to species, sex, age, seasons, feeding (Ricker, 1975; Bagenal & Tesch, 1978), habitat, gonad maturity, stomach fullness, health and preservation techniques (Tesch, 1971; Bagenal & Tesch, 1978; Alavi-Yeganeh *et al.*, 2011; Keivany *et al.*, 2012; Asadollah *et al.*, 2015). In addition, changes in fish shape, physiological conditions, life span or growth increment can all influence the b growth exponent (Frost, 1945; Cardinale *et al.*, 2004; Treer *et al.*, 1998, 1999; Hasankhani *et al.*, 2013, 2014; Tabatabaei *et al.*, 2014).

The body condition factor of 389 *B. lacerta* ranged from 1.77 to 2.17 and the differences between females and males in the same age groups were not significant ($P > 0.05$), but it was significant in different months ($P < 0.05$) (Fig 2.).

The Length-at-age analysis indicated the growth parameters as $L_{\infty} = 34.14$ cm, $K = 0.0943$ and $t_0 = -2.2958$ ($L_t = 34.19 [1 - e^{-0.0943(t+2.2958)}]$) for females and as $L_{\infty} = 23.85$ cm, $K = 0.1419$ and $t_0 = -1.9140$ ($L_t = 23.85 [1 - e^{-0.1419(t+1.914)}]$) for males (Fig. 3). The Weight-at-age analysis indicated the mean asymptotic weight as $W_{\infty} = 577.32$ g ($W_t = 577.32 [1 - e^{-0.0943(t+2.2958)}]$) for females and as $W_{\infty} = 169.88$ g ($W_t = 169.88 [1 - e^{-0.1419(t+1.914)}]$) for males (Figs. 4, 5). As observed in many other fishes, the females reach higher length and weight. Coad (2015) reported the maximum length for this species as 37.5 cm, although he did not point to their sex. In *Barbus lacerta cyri*, the maximum length was reported as 18 cm (Berg, 1949; Dadikian, 1986).

The \bar{f}_i value was calculated as $\bar{O} = 4.7$ for females and as $\bar{O} = 4.4$ for males. The average spontaneous growth rate during the life span was calculated as $G = 0.44$ for females and as $G = 0.61$ for the males, indicating a faster growth rate for males. However, this rate varies at different ages and is higher in the first year of the males and the second year of the females (Table 1). There is no other study on G value of this species in other regions to compare with. The life span or maximum age was calculated as 7.5 years for females and 7.7 years for males. The natural mortality rate was estimated as 0.55 for females and 0.48 for males, based on length information and as 0.61 for females and 0.50 for males, based on weight information.

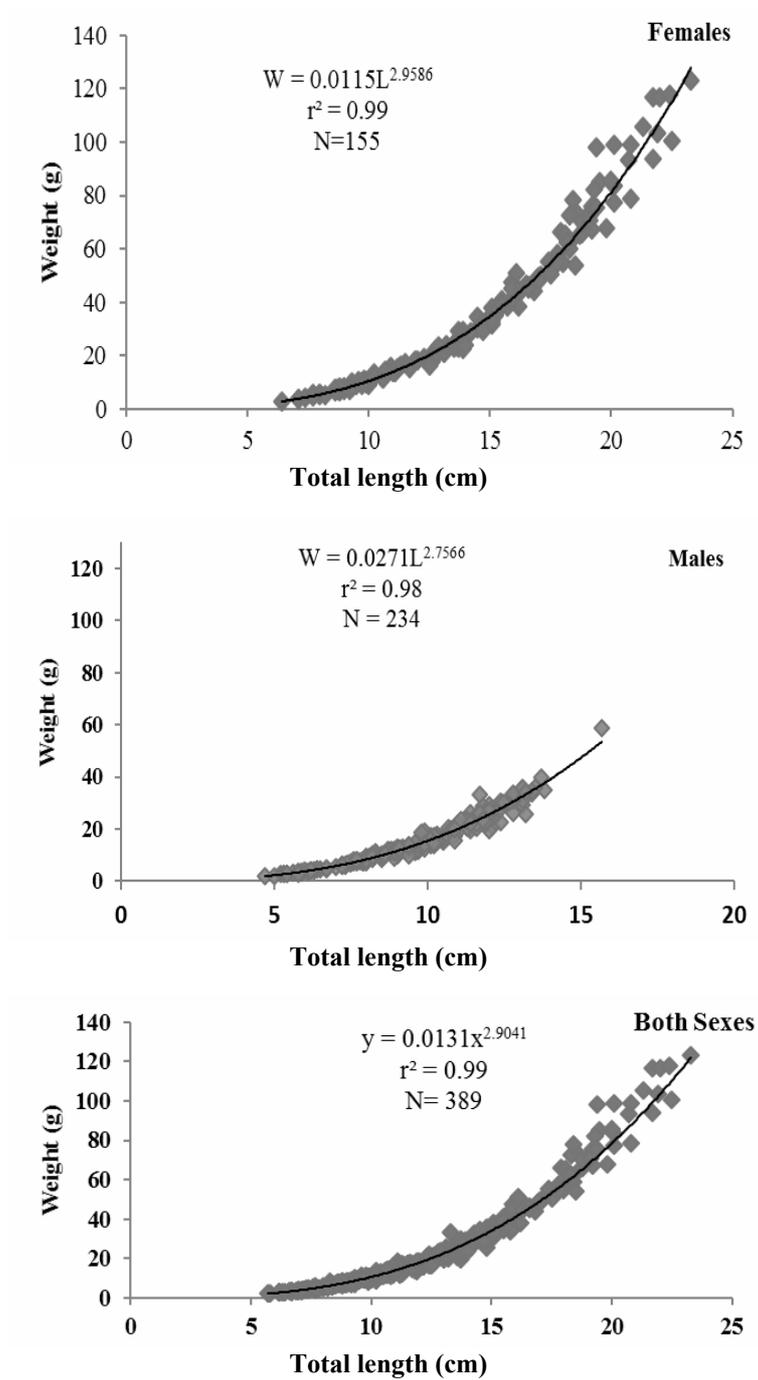


Fig. 1. Length (cm) and weight (g) relationships for females, males and both sexes of *B. lacerta*.

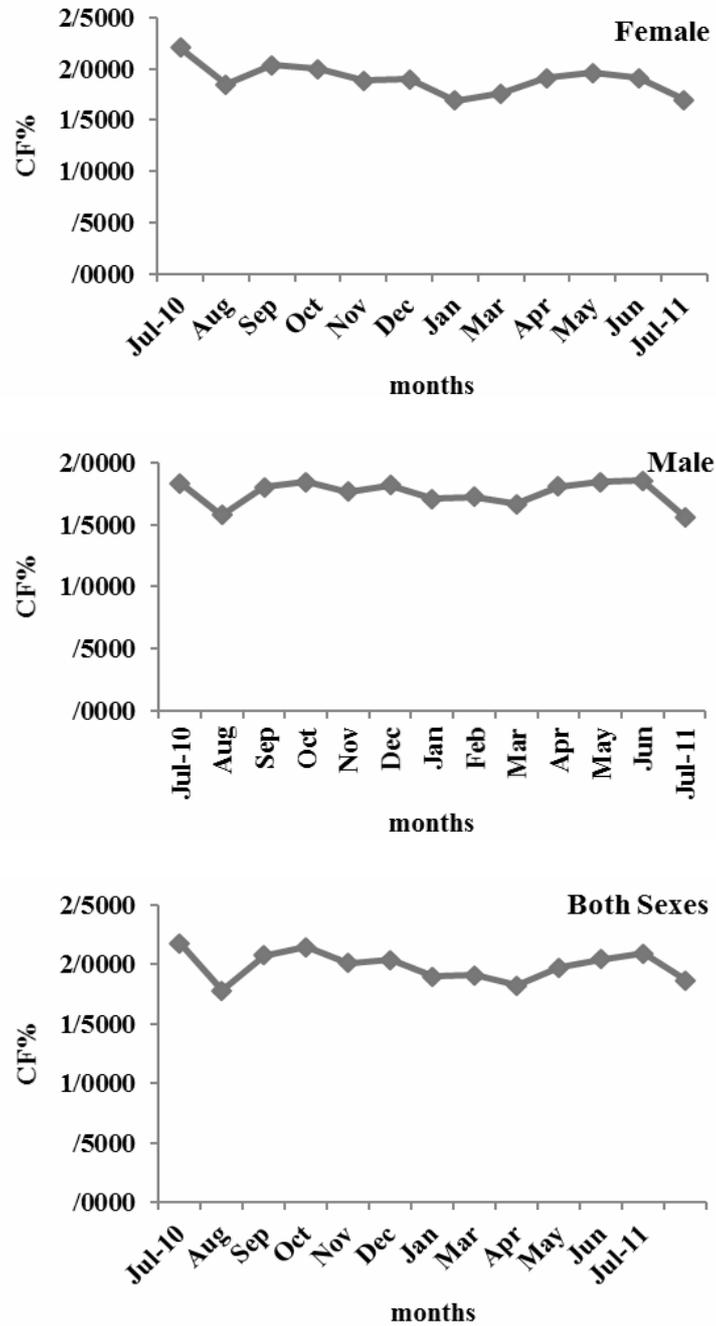


Fig. 2. Monthly variations in the CF% for females, males and both sexes of *B. lacerta*.

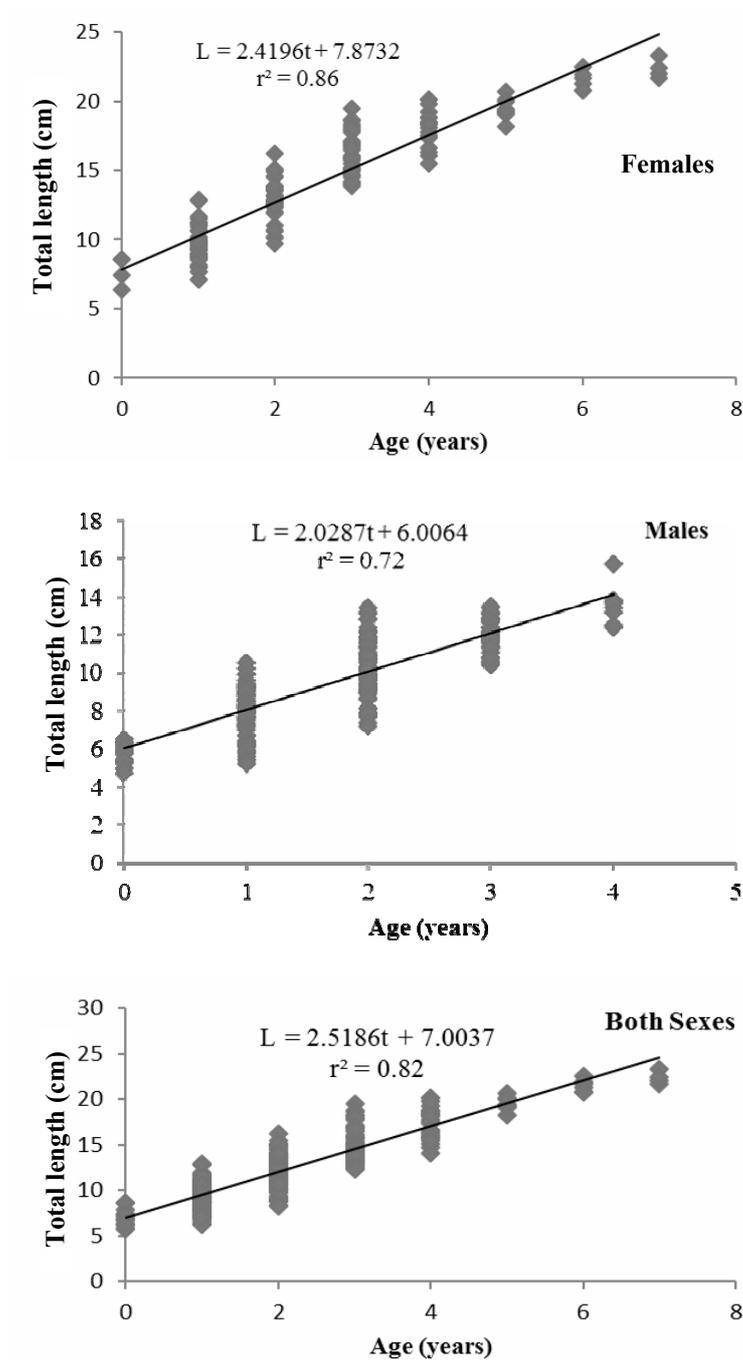


Fig. 3. Length and age relationships for females, males and both sexes of *B. lacerta*.

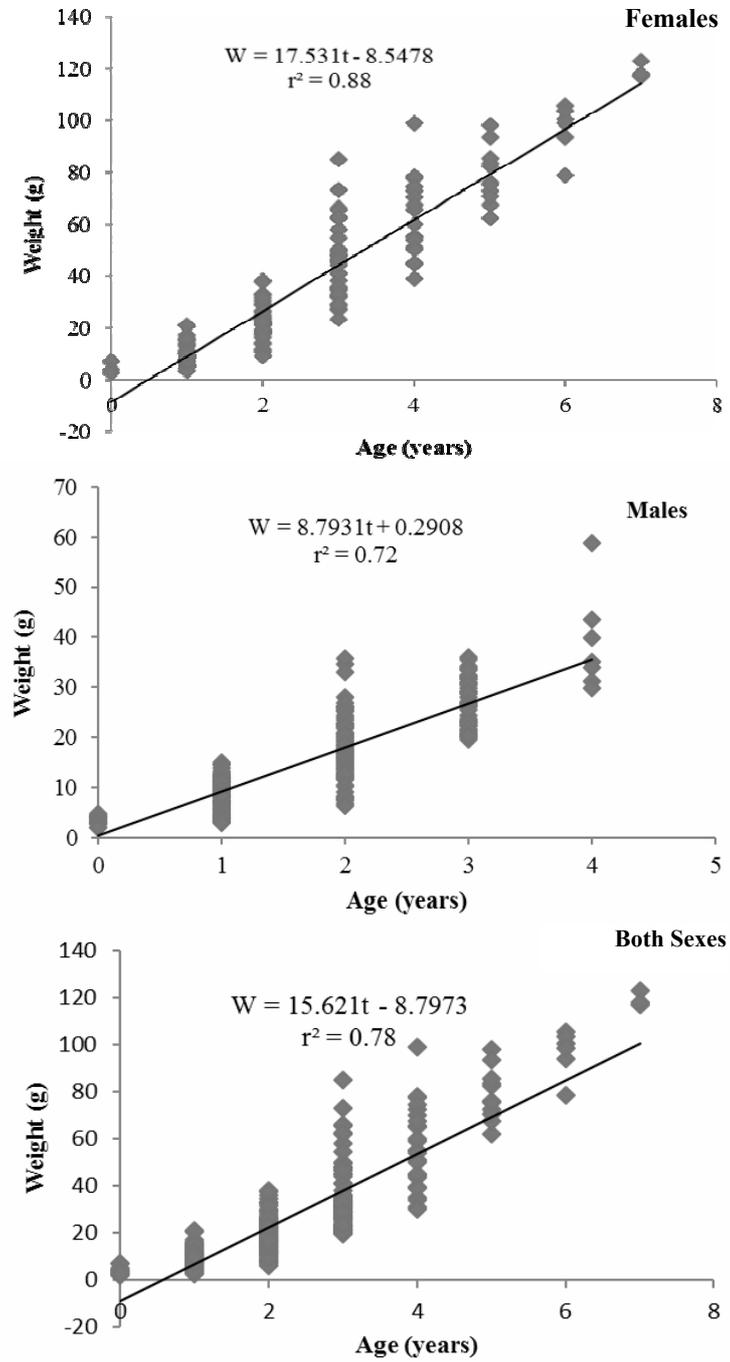


Fig. 4. Weight and age relationships for females, males and both sexes of *B. lacerta*.

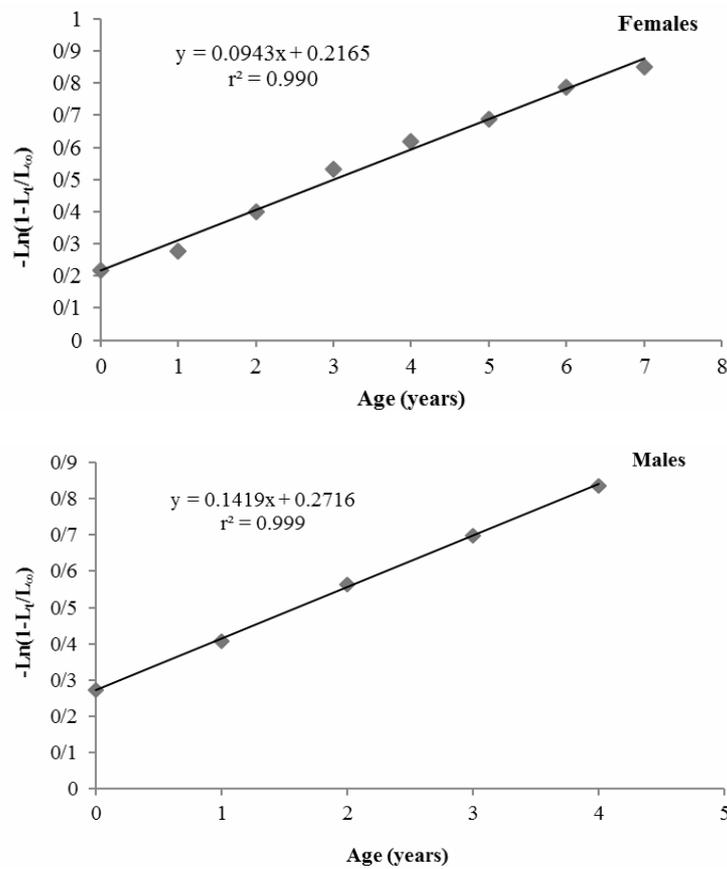


Fig. 5. Relationship between length (cm) and age for females and males of *B. lacerta*.

Table 1
Specific growth rates of *Barbus lacerta* in different ages and sexes

	Age	Mean Weight (g)	Counts	G
Female	0	5.33	4	
	1	9.80	42	0.61
	2	22.36	36	0.82
	3	44.85	34	0.70
	4	62.45	18	0.33
	5	78.83	11	0.23
	6	96.87	6	0.21
Male	7	118.68	4	0.20
	0	3.38	15	
	1	8.57	72	0.95
	2	17.41	89	0.71
	3	26.83	51	0.43
	4	38.86	7	0.37

CONCLUSIONS

The results of this study indicate this species as a slow growing fish with a relatively high mortality rate that could be used in evaluating the relative condition of this fish for conservation purposes and local fisheries management.

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LANDSCAPE CHANGES IN BRĂILA ISLANDS; IDENTIFICATION OF HABITAT AVAILABILITY FOR COLONIAL WATERBIRDS

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The natural river floodplains support one of the most heterogeneous and species-rich landscapes. Wetlands are especially important for colonial waterbirds species providing ideal feeding, nesting and resting habitats for many species. Lower Danube River floodplain has changed dramatically in the past century as a result of hydro-technical works, including the Brăila Islands. The aim of this paper is to analyze the structural pattern of ecological systems from Brăila Islands and spatially assess the provision of supporting habitats for the colonial waterbirds species, based on Geographic Information System methods. The bird – habitat association was evaluated according to the species nesting, resting and foraging needs, and distribution maps were created. Landscape analysis showed that the only area in the region of interest that still preserves the diversity and the capacity to sustain large and complex colonies of waterbirds is the Small Island of Brăila, the last remnant left under natural Danube River flooding regime. Nine fish-eating bird species have been observed at nesting, resting and foraging places: *Phalacrocorax carbo sinensis*, *P. pygmeus*, *Ardea cinerea*, *A. alba*, *Nycticorax nycticorax*, *Ardeola ralloides*, *Egretta garzetta*, *Platalea leucorodia*, *Plegadis falcinellus*. Based on species preferences, the maximum specific diversity for resting areas is found in marshes and in littoral zone of the shallow lakes. The preferred foraging habitats are marshes, littoral zone of the shallow lakes, natural grasslands and riparian areas. Only the two cormorant species are using the open river water and the shallow lakes limnetic zone, when present, as foraging habitats. Based on these findings we are supporting the implementation of research and monitoring programmes in all the areas from the Brăila Islands holding large waterbirds colonies, and conservation and restorations at landscape level, not only in strictly protected areas.

Keywords: colonial waterbirds, landscape indices, Brăila Islands.

INTRODUCTION

The natural river floodplains support one of the most heterogeneous and species-rich landscapes (Ward *et al.*, 1999). Lower Danube River (LDR) floodplain has changed dramatically in the last century as a result of hydro-technical works. Particularly the wetlands, lentic and lotic ecosystems were strongly affected by the construction of dams, embankments, or by the establishment of new areas for agro-systems, the enlargement of the forested area and the creation of aquaculture systems for fishery. Debates about the conversions of LDR floodplain started at the beginning of the XXth century (Antipa, 1910, 1913; Vidrașcu, 1921). Although land

transformations for agricultural use were made, until the 60s the anthropogenic impact over the area was considered low (Gâștescu & Gruescu, 1973; Popp, 1985; Hancu, 2008). The most drastic changes took place between 1960 and 1980 as a result of the implementation of management plans for the conversion of natural wetlands into arable land for intensive agricultural production, monospecific forest plantations and fish ponds designed for semi-intensive and intensive fish farming using alien species with invasive potential (Vădineanu *et al.*, 2004). These modifications resulted in deterioration of the ecological structure (Anastasiu *et al.*, 1971; Vădineanu, 2009) and lead to significant biodiversity changes in the LDR system (Vădineanu *et al.*, 2001). Thus large areas of the present-day LDR floodplain landscape have become homogeneous and the ecological systems reduced their carrying capacity. The continuity of natural systems was disrupted and ecosystem provision of supporting habitats for biological diversity is at risk.

Wetlands are especially important for colonial waterbirds species (Hoffmann *et al.*, 1996; Erwin *et al.*, 1999; Erwin & Beck, 2007), due to the alternation between dry and flooded periods. When flooded they provide ideal feeding, nesting and resting habitats for many species, including cormorants, herons, egrets, ibises and spoonbills. When dry up, grassland vegetation is taking over, growing on a rich substrate formed by the decaying animal and plant species (Rogers & Ralph, 2011) and on re-flooding, the abundance of food offers condition for breeding (Froneman *et al.*, 2001; Bino *et al.*, 2015). In the LDR floodplain (excluding the Delta), both on the Romanian and Bulgarian territory, there are 11 fish-eating birds colonies, located at great distances from each other (Shurulinkov *et al.*, 2007; Giuca, 2012), as river embankment and drainage works applied in the 60s have reduced the wetland area (Cazacu *et al.*, 2010) and the number and surface of potential nesting, resting and feeding places, thereby decreasing the carrying capacity of the landscape. Three of the largest colonies are located in the Brăila Islands area. The aim of this paper is to analyze the structural pattern of ecological systems from Brăila Islands and spatially assess the provision of supporting habitats for colonial waterbirds in the area.

MATERIAL AND METHODS

Study area

Brăila Islands (BrI) area, located in Romania, between 27°48'36"E/28°15'52" longitude E and 45°25'26" N/44°35'18" latitude N, is part of the network of Long Term Socio-Ecological Research (LTSER) sites. The BrI-LTSER site extends along the Danube River and covers the river terrace and a large floodplain. The analysis in this paper is specifically targeted on the floodplain area from BrI-LTSER (Fig. 1), from Giurgeni – Vadul Oii bridge (km 237 upstream) and Brăila municipality (km 175 downstream), with a total surface of 150918.93 ha.

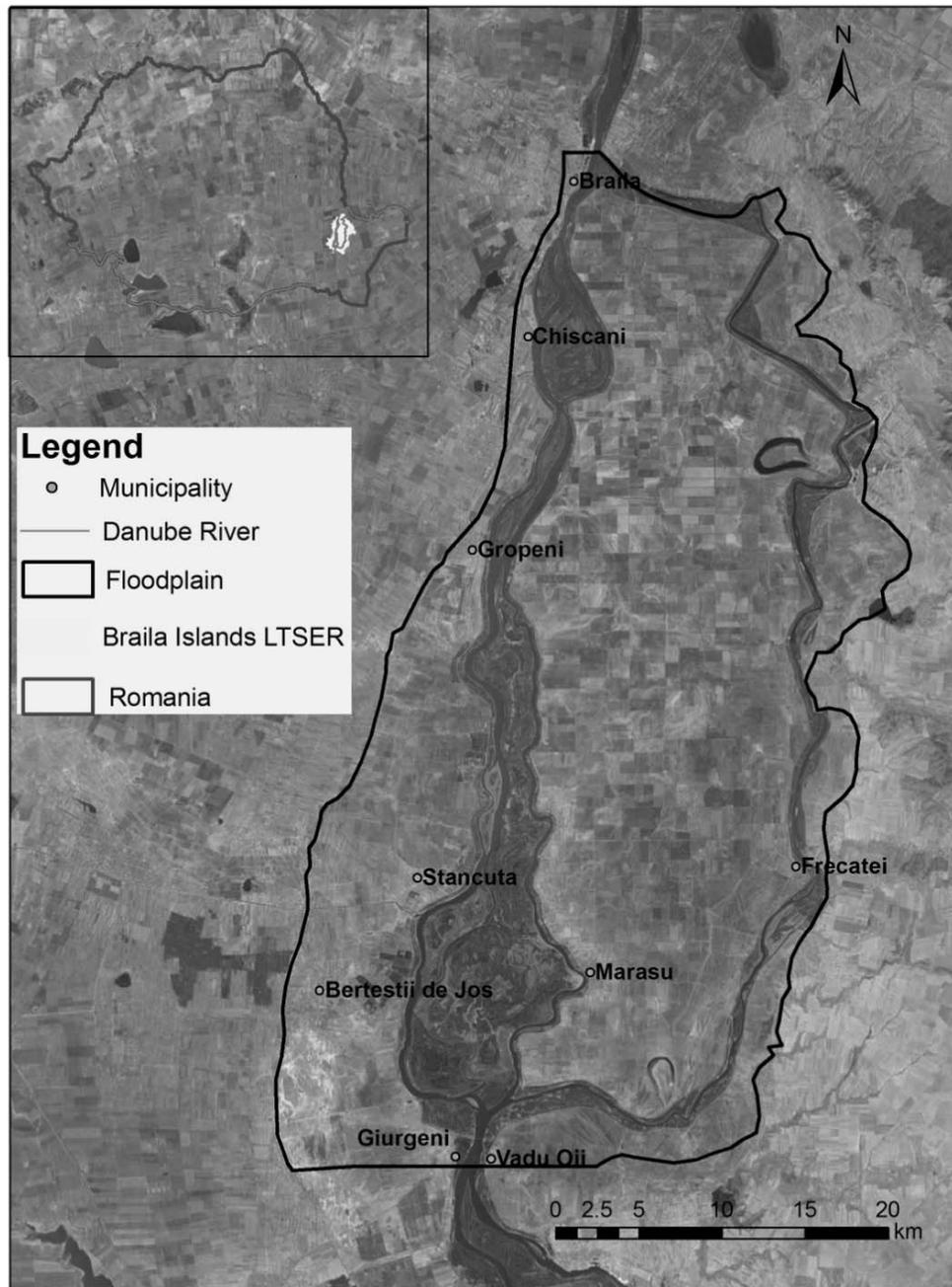


Fig. 1. Location of Danube River floodplain area in the Brăila Islands Long Term Socio-Ecological Research (BrI-LTSER) site, Romania.

Methodology

Landscape patterns are identified in a Geographic Information System (GIS) environment based on spatial configuration of the main ecosystems present in the area. Landscape metrics related to diversity, dominance, form and distribution are used for the characterization of main ecosystem composition, structure and spatial configuration.

Shannon diversity index (Shannon & Weaver, 1971)

$$SHDI = - \sum_{i=1}^n (P_i * \ln P_i) \text{ for } i = 1, 2, \dots, n$$

P_i = proportion of area covered by ecosystem type i ;

n = number of ecosystems;

$SHDI \geq 0$; $SHDI = 0$ when only one type of ecosystem is present; $SHDI$ increases with the incremental of the number of ecosystem types and / or with increase in equitability of areas covered by ecosystem types.

Shannon evenness index (Shannon & Weaver, 1971)

$$SHEI = \frac{- \sum_{i=1}^n (P_i * \ln P_i)}{\ln n} \text{ for } i = 1, 2, \dots, n$$

P_i = proportion of area covered by ecosystem type i ;

n = number of ecosystems;

$0 \leq SHEI \leq 1$; $SHEI = 0$ when only one type of ecosystem is present (no diversity), approaches 0 when the proportion of areas covered by different ecosystems becomes more unequal (dominated by one type); $SHEI = 1$ when the proportion of areas covered by different ecosystem types is equal.

Dominance index (O'Neill *et al.*, 1988)

$$D = \ln n + \sum_{i=1}^n P_i * \ln P_i \text{ for } i = 1, 2, \dots, n$$

P_i = proportion of area covered by ecosystem type i ;

n = number of ecosystems;

$D \geq 0$; larger D values for landscape dominated by one or few ecosystem types; D approaches 0 when the proportion of areas covered by different ecosystems is almost equal.

Edge density (Turner, 1989)

$$D = \frac{P_i}{A_i} \text{ [m / ha]} \quad \text{for } i = 1, 2, \dots, n$$

P_i = perimeter of the area covered by ecosystem type i ;

A_i = area covered by ecosystem type i ;

$P/A > 0$; for a given surface, larger ratio values indicate a complex elongated shape of the border, lower values indicate a compact, simple shape.

Data analysis was accomplished using ArcGIS software and the landscape indexes were calculated for two time moments. The first moment called reference state was considered around the year 1900 due to the fact that the anthropic impact (hydretechnical works) did not yet affect the Danube river system significantly. The reference state was inferred from historical topographical maps at a scale of 1:100,000. The cartographic material was scanned and then georeferenced using the map information and land marks that can be identified on recent existing maps (churches) as ground control points. Major land cover classes were identified from the maps and vectors were extracted by manual digitization. The situation for the recent period (the current state) was obtained by aggregation of the Corine Land Cover datasets (EEA, 2013).

Based on the landscape characterization there were identified areas with a wide range of habitats available to support biological diversity. Furthermore aerial orthorectified photographs of the area at a scale of 1:5,000 were used and field surveys were conducted in three consecutive years (2011-2013) for the description of fish-eating birds colonies in the area. The colonies were defined according to the methodology proposed by the IUCN Cormorants Research Group, which stated that a colony “should be considered separate from another one if it is isolated from other group(s) of nests by at least 2,000 m” (Bregnballe *et al.*, 2012). The size of a colony was assessed by using the apparently occupied nests concept. Bird species presence-absence data were recorded for each colony, and the bird – habitat association was evaluated according to the species nesting, resting and foraging needs. Distribution maps for species – specific habitat associations were created using GIS for the identification of habitat availability for colonial waterbirds.

RESULTS AND DISCUSSION

The main types of ecosystems and their land cover for the reference and current state were identified and the two situations are presented in Figure 2. In the reference period natural and semi-natural ecosystems, especially grasslands (42.92%), aquatic ecosystems (lakes and channels – 23.67%, Danube River –4.91%) and wetlands (16.79%) are dominating the landscape. The reference spatial arrangement

can be seen as a well developed network consisting of Danube River branches, lakes and channel occupying almost the entire area. Here there was the former Balta Brăilei (Gâștescu, 1965), a biodiversity hotspot in the region (Simionescu, 1983). Landscape changed due to anthropic influence the most notable one referring to the increase of surface used for agriculture from 3.29% to 73.78%, followed by a 44.97% (percentage change) increase in land used for forestry. Also, the socio-economical systems tripled their surface comparing with the reference state. These increases were done by reducing the pasture surface to only 2.94%, aquatic ecosystems, especially the lakes and channels, having an almost 100% decrease (-97.85 percentage change) and wetlands shrink about four times.

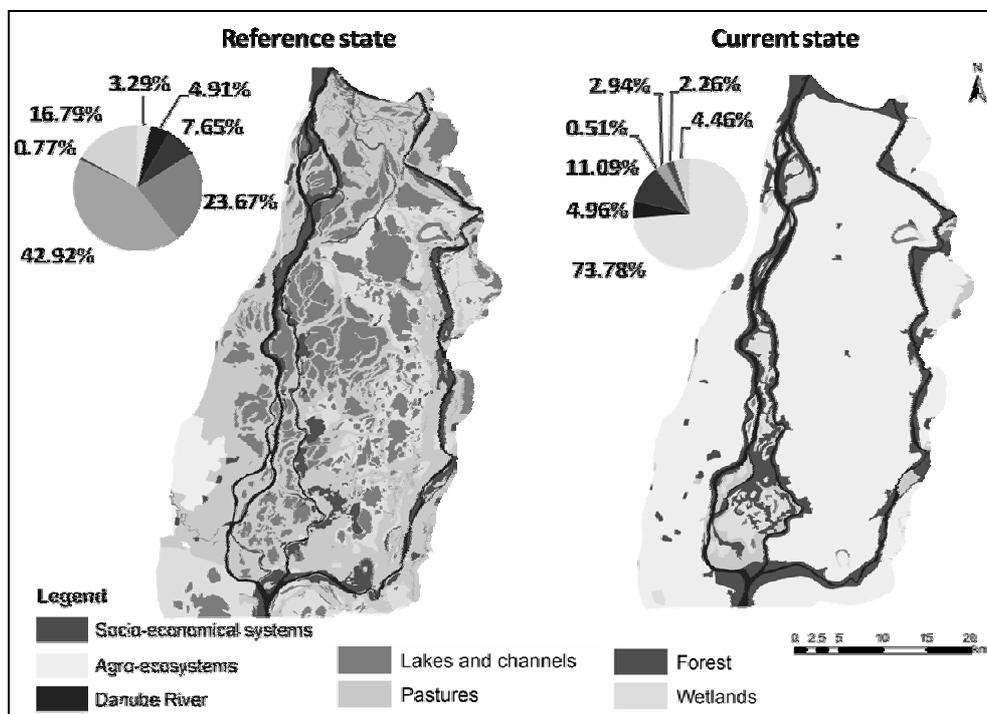


Fig. 2. Distribution of main ecosystem types from Brăila Islands Long Term Socio-Ecological Research (BrI-LTSER) site Danube River floodplain area in the reference and current state.

The landscape level comparison based on diversity indices, dominance and perimeter-area ratio between reference and current state configuration (Table 1) of the study area show that over time the structure became less diverse as the dominance of the agricultural systems increased. Decrease in equitability of areas covered by ecosystem types and the current distribution of the main ecosystem types in simple and compact shape also contributed to landscape simplification. Changes in the structural configuration for the reference state (diverse and multi-functional ecosystems) lead to an increasing share of simplified, mono-functional

ecosystems (Vădineanu, 1998, 2004). The current state presents two very different situations, a homogeneous landscape in the agricultural enclosure of the Big Island of Brăila (resulted from embankment and drainage) and a preservation of the former heterogeneity in the Small Island of Brăila (SIBr) area (still under natural Danube River flooding regime).

Table 1

Values of landscape metrics for reference and current state in the Brăila Islands Long Term Socio-Ecological Research (Bri-LTSEr) site Danube River floodplain area

Landscape indices	Bri-LTSEr floodplain		Big Island of Brăila		Small Island of Brăila	
	reference	current	reference	current	reference	current
Shannon diversity index	1.498	0.972	1.303	0.358	1.365	1.47
Shannon evenness index	0.77	0.5	0.67	0.2	0.702	0.756
Dominance index	0.448	0.974	0.643	1.434	0.58	0.476
Edge density (m/ha)	511040	182312	575779	83170	677642	578862

SIBr is an important wetland area for waterbirds, here nesting, feeding or found their refuge over 136 bird species, of which 47 species are listed in Birds Directive (79/409/EEC) and 34 species in Bern Convention Appendix, and it is a protected area as Natural Park, RAMSAR and Natura 2000 sites. Together with the Danube Delta, SIBr is an important hub on the migration routes of many birds (Vădineanu *et al.*, 2004). On the SIBr territory there were identified three fish-eating birds colonies. The colonies, listed from upstream to downstream, named after the shallow lakes nearby, are as follows: Vulpasu, Cucova and Chiriloaia (Fig. 3A). The key characteristics of fish-eating bird colonies from SIBr area are presented in Table 2 (Onea, 2011; Giuca, 2012, 2013 a, b). The distances between them, according to the nearest neighbour criterion, are approximately 22 km, while the distance to the closest colony located in the LDR floodplain is approximately 70 km and to the nearest Danube Delta colony is about 60 km.

Table 2

Key characteristics of fish-eating bird colonies from Small Island of Brăila (SIBr) area

Colony name	Chiriloaia	Cucova	Vulpaşu
Location SIBr	Fundu Mare Islet/ Chiriloaia Lake	Popa Islet / Cucova Lake	Popa Islet / Vulpaşu Lake
Colony type	Mixt	Mixed	Mixed
Dominant species	<i>Phalacrocorax carbo sinensis</i>	<i>P. pygmaeus</i> , <i>N. nycticorax</i> <i>E. garzetta</i>	<i>Phalacrocorax carbo sinensis</i>
Minimum no. of species	6	4	8
Maximum no. of species	9	9	9
Substrate	<i>Salix sp.</i>	<i>Salix sp.</i>	<i>Salix sp.</i>
Area (ha)	6	4	9

Data sources: Giuca, 2012, 2013 a, b.

Chiriloaia colony is located on Chiriloaia Lake, in the Fundu Mare Islet. The *Salix* spp. trees constitute the substrate for the colony, being distributed over a stretched area of approximately 6 hectares from southwest to the northeast. The oldest trees are located in the north-eastern and central parts while the younger trees are located in the south-western extremity. During spring floods, the ground area under the colony is covered by water, thus providing protection against potential terrestrial predators. The nests are located in 238 trees or groups of trees, distributed mainly in the central area. The pairs of *Phalacrocorax carbo sinensis* nest in the centre and in the far northeast; those of *P. pygmeus* occupy the central area and the south-western extremity, while the *Nycticorax nycticorax* pairs are nesting throughout the colony. Regarding the colony height distribution, the *Phalacrocorax carbo sinensis* and *Ardea cinerea* nests are located in the upper tree layers, while *Phalacrocorax pygmeus* nests are found in the median layers, alongside *Platalea leucorodia* and *Plegadis falcinellus* nests. *Nycticorax nycticorax* uses all tree layers for nesting, but mostly the median one. The lower layers are mainly occupied by pairs of *Ardeola ralloides*.

Cucova colony is located on Cucova Lake, in Popa Islet. The nests are set in young *Salix* spp. trees which occupy a relatively compact area of about four ha. During spring flood, the ground area under settlement is covered by water, providing the birds with protection from predators. Within the colony area, the species present a uniform nest distribution, but with height segregation, pairs of *Phalacrocorax pygmaeus* and *Ardea cinerea* occupying the upper layers of the canopy trees, while the other species are stationed mainly in middle layers.

Vulpașu colony is located on Vulpașu Lake, in Popa Islet. The nests are set in trees of *Salix* spp., on a relative compact area of approximately nine ha. In the north part, the supporting trees for the colony have dried due to bird droppings. During heavy spring floods, the ground area under settlement is covered by water. In terms of nests distribution inside the colony, the pairs of *Phalacrocorax carbo sinensis* occupy mostly the northern area, while pairs of *P. pygmeus* are located in the central and southern areas. Likewise the central area is occupied by pairs of *Platalea leucorodia* and *Plegadis falcinellus*. The other's species individuals are spread inside the colony with no particular preference for a certain area. *Phalacrocorax carbo sinensis* and *Ardea cinerea* nests are placed in the upper tree layers, while *P. pygmeus* nests are placed in the median layers, alongside *Platalea leucorodia* and *Plegadis falcinellus* nests. *Nycticorax nycticorax* uses all tree layers for nesting, but mostly the median one. The lower tree layers are occupied especially by pairs of *Egretta garzetta* and *Ardeola ralloides*.

Bird species presence-absence data in the colonies from SIBr area, recorded in 2011, 2012 and 2013 field survey, are presented in Table 3. All the colonies are

mixed, during the study period being identified a maximum number of nine fish-eating bird species for Vulpașu colony: *Phalacrocorax carbo sinensis* (Great Cormorant), *Phalacrocorax pygmeus* (Pygmy Cormorant), *Ardea cinerea* (Grey Heron), *Nycticorax nycticorax* (Night Heron), *Ardeola ralloides* (Squacco Heron), *Egretta garzetta* (Little Egret), *Platalea leucorodia* (Spoonbill), *Plegadis falcinellus* (Glossy Ibis), *Ardea alba* (Great Egret), and eight for Cucova and Chiriloaia colonies, from the above listed species missing the Great Egret. In previous years it was observed in Cucova and Chiriloaia colonies, but only sporadically and in few breeding pairs (BP) (Onea, 2011).

Table 3
Occurrence of bird species in Chiriloaia, Cucova and Vulpașu colonies (2011-2013)

Colony Year	Chiriloaia			Cucova			Vulpașu		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Species									
<i>Phalacrocorax carbo sinensis</i>	+	+	+	-	-	+	+	+	+
<i>Phalacrocorax pygmeus</i>	+	+	+	+	+	+	+	+	-
<i>Ardea cinerea</i>	+	+	+	+	+	+	+	+	+
<i>Nycticorax nycticorax</i>	+	+	+	+	+	+	+	+	-
<i>Ardeola ralloides</i>	+	+	+	-	+	+	+	+	-
<i>Egretta garzetta</i>	+	+	+	+	+	+	+	+	-
<i>Platalea leucorodia</i>	+	-	-	-	-	+	+	+	-
<i>Plegadis falcinellus</i>	+	-	+	-	+	+	+	+	-
<i>Ardea alba</i>	-	-	-	-	-	-	+	+	-

By far, the most abundant species nesting in the SIBr is the Great Cormorant (481 BP), being followed by the Night Heron (259 BP) and the Little Egret (224 BP). Vulpașu is the biggest colony from the studied area, holding up to 900 BP of different colonial nesting waterbirds. On the second place comes Chiriloaia colony, with up to 700 BP. Cucova is the third, with up to 500 BP. All species have been observed at nesting, resting and foraging places. Based on their preferences for specific habitats, like willow forest, littoral zone or open water in shallow lakes, marshes, pastures, riparian areas or open waters of the Danube River the habitat distribution maps for each species were made (Fig. 3B). The maximum specific diversity for resting areas is found in marshes and in littoral zone of the shallow lakes. Based on the high species diversity recorded, the preferred foraging habitats are marshes, littoral zone of the shallow lakes, natural grasslands and riparian areas. Only the two cormorant species are using the open river water and the shallow lakes limnetic zone, when present, as foraging habitats. Even though inside the SIBr Natural Park there are only two strictly protected areas, the breeding colony from Vulpașu and the feeding area from Jigara Lake, the whole area is of great conservation importance because it is providing feeding, resting and nesting habitats for the waterbirds populations.

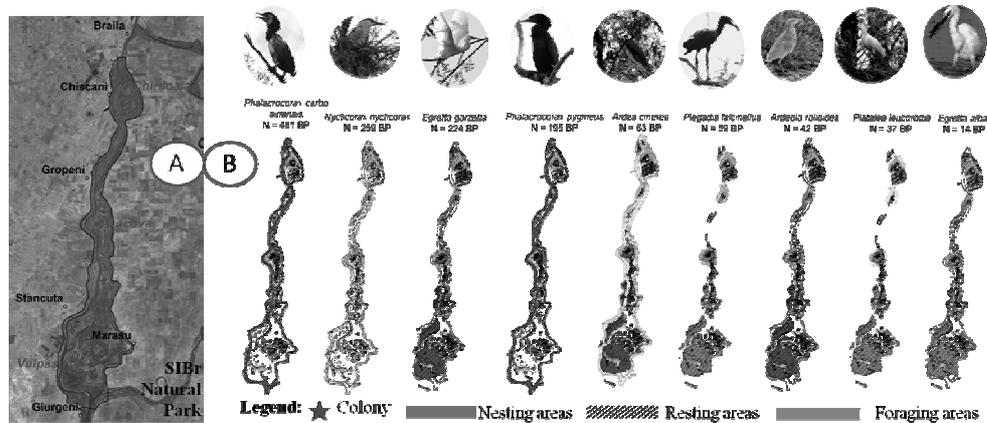


Fig. 3. Location of Vulpășu, Cucova and Chiriloaia fish-eating bird colonies (A) and habitat distribution maps for colonial waterbirds species (B) in Small Island of Brăila (SIBr) Natural Park.

CONCLUSIONS

Compared with the reference state a simplification of the overall landscape structure was observed for the BrI-LTSER site.

The only area in the region of interest that still preserves the diversity and the capacity to sustain large and complex colonies of waterbirds is SIBr.

The alternating flood-dry periods (natural flooding regime) as well as the high diversity of ecosystem types assures the needed spatial complexity for breeding, feeding and resting for large colonial birds ensuring at the same time an important connectivity area.

Based on these findings we are supporting the implementation of research and monitoring programmes in all the areas from BrI-LTSER floodplain holding large waterbirds colonies, and conservation and restorations at landscape level, not only in strictly protected areas.

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ESCAPE BEHAVIOURS OF CORVIDAE IN AN URBAN ECOSYSTEM OF ZHYTOMYR (UKRAINE)

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The paper presents the results of research on the tolerance of Corvidae on human behaviour and human pressure in Zhytomyr city (Ukraine) conducted in 2009-2012. *Corvus frugilegus* L., *Corvus monedula* L. and *Corvus cornix* L. were selected as model bird species. Although these species vary in their relatedness between cities, for our purposes here they fall into same functional group: they are large birds that are generally disliked by humans. Therefore, we selected these species in part because of typical human attitude toward them, as well as because they occur across the urbanization gradient on all the study sites in their respective cities. We determined that flight initiation distance of rooks varied in range from 0.5 to 21.5 m, hooded crows – from 0.8 to 19 m, jackdaws – from 0.5 to 16.3 m. We found that the degree of Corvidae tolerance to human disturbance in urban habitat depends on the intensity of human pressure. Flight initiation distance of Corvidae correlates negatively with intensity of urbanization. The principal factors determining flight initiation distance were the type of habitat (most significant factor), number of birds in a group, direction and parameters of human influence and season of the year.

Keywords: Corvidae, flight initiation distance, anthropogenic tolerance, urban ecosystem, Zhytomyr, Ukraine.

INTRODUCTION

In particular, urbanization affects species survival, population structure, expands worldwide, an understanding of how animals respond to the conversion of wild, rural areas to human-dominated landscapes is necessary to successfully conserve biodiversity. These modifications in land cover also provide a natural experiment for exploring how animals respond to modified environments. Thus, urbanization provides a unique venue for applied and basic theoretical research on natural selection. Birds are particularly well suited for such study in that they are ubiquitous worldwide and responsive (both positively and negatively) to human action reproduction, and behavior (Knight & Fitzner, 1985; Lima, 1987; Kramer & Bonenfant, 1997).

Urban environments have a number of characteristics that might enhance the establishment of certain species. First, urban areas have a longer growing season, which might facilitate species with multiple broods per year. Second, urban environments are characterized by specific habitats that might be suitable for certain species (Rodgers & Smith, 1997; Swarthout & Steidl, 2001; Seltmann *et al.*,

2012). Third, urbanized areas are characterized by high resource abundance that might support species that are able to exploit anthropogenic food. Fourth, urbanization is associated with the proximity of humans and, therefore, species with high thresholds for fear and short flight initiation distances might have selective advantages (Shochat *et al.*, 2006; Møller, 2008, 2010; Møller & Tryanowski, 2014; Møller *et al.*, 2015).

One of the variables used to quantify bird tolerance towards humans is flight-initiation distance (here FID). It is the distance (from bird to approaching human) when the bird takes flight or otherwise flees. In addition to the FID the alert distance (here AD) has also implemented another variable useful in the measurement of bird tolerance towards humans. The AD measurement related to the distance when the bird becomes alert and aware of approaching human (Møller, 2008; Blumstein, 2014).

In the conditions of intensive transformation of natural landscapes the corvids become the obligatory constituent of urban bird communities. In places with permanent concentrations of birds they change physical and chemical properties of soil, microbiological processes, composition, and structure of phytocoenosis (Fernandez-Juricic *et al.*, 2001, 2004; Blumstein, 2003; Fernandez-Juricic & Schroeder, 2003).

Although corvids vary in their relatedness between cities, for our purposes here they have same functional features: they are large birds that are generally disliked by humans. Therefore, we selected these species in part because of typical human attitude toward them, as well as because they occur across the urbanization gradient on all the study sites.

The abundance of corvid species and the number of occupied habitats is progressively increased from common raven, to jackdaw, to rook, to Eurasian jay, to black-billed magpie and to hooded crow (Otto & Witt, 2002) (Table 1). It suggests that hooded crow and black-billed magpie are more successful in establishing in urban environments compared to other corvid species. However, patterns of abundance and distribution can differ between cities as corvid species colonize European cities with different success. Therefore, the goal of this article is to identify human tolerance differences that might explain differences in the establishment success of corvids in urban areas (Mazgajski *et al.*, 2008; Źmihorski *et al.*, 2010).

Several factors influence the human tolerance of Corvidae: closeness of human population, intensity of human motion through habitat, direction of motion and conduct of observer, starting distance of observer, period of year, time of day, size of groups the observer approaches. In the present research we tested the influence of type of habitat, size of groups, speed and direction of observer approach on the flight initiation distance of Corvidae.

MATERIAL AND METHODS

Researches of AD and FID were conducted for three bird species: rook (*Corvus frugilegus*), jackdaw (*C. monedula*) and hooded crow (*C. cornix*) by Blumstein (2003) in Rezanov (2006) modification, who suggested to distinguish the behavioural

bird reactions and scale them (Table 1). All measurements were performed for corvids of Zhytomyr city (NW of Ukraine, 50°16'N 28°40'E, area of 65 km², 226 m a.s.l. The current estimated number of residents 271.172).

FIDs were determined in a standardized manner by first ensuring that the focal individual (a bird foraging on a ground) had noticed the approaching researcher, and then walking towards it following a direct trajectory at a constant low speed, and with no obstacles blocking the view between the bird and the observer. FIDs were always determined by the same observer wearing the same clothes to avoid bias resulting from differences in the physical appearance of investigators (Seltmann *et al.*, 2012; Öst & Jaatinen, 2013). Walked distance is approximately equal to the number of meters according to comparisons with measured distances (as suggested by Mikula, 2014), so we accepted that there is no significant difference between number of steps and number of measured meters.

We considered the distance of reaction to be the distance from a bird to the observer at the moment of beginning any type of protective reaction by the bird. All spectra of protective reactions of birds towards observer were divided into five groups and presented by 0-3 scale (Table 1). Escape distance is the distance of protective reaction of bird and corresponds to 2-3 score (jump-off and take-off).

Table 1
Categorization of behaviours exhibited by Corvidae species
in response to human approach

Type of reaction	Response categories
No visible reaction	0
Forward branch hop	0,5
Alarm call	1
Walking aside from an observer or jump-off	2
Take flight	3

During registration of AD we estimated the direction of approach in relation to the bird – direct approach (motion is straight on a bird) and indirect approach (motion at an angle to a bird) (Rodgers & Smith, 1995, 1997); human traffic and character of habitat; number of birds in groups; season of year. The individual was approached by one observer in one of three ways that were randomly alternated: (1) ‘Not looking’: the observer approached at a slow walking pace (c. 1ms⁻¹) with the face and eyes averted from the closest bird. (2) ‘Looking’: the observer approached at a slow walking pace with the face and eyes (i.e. gaze) directed towards the closest bird, looking steadily, intently and with attention fixed on the animal. While head and gaze orientation differed between ‘not looking’ and the ‘looking’ treatments, body position was not different. (3) ‘Looking and fast walk’: we also tested how the birds’ reactions changed if the approaching person altered his behaviour once noticed. We tested the effect of increased approach speed, as we supposed that the birds could fly more quickly from people running or jogging past them than to those who walked. We did not carry out a not looking and fast walk

treatment because it was not possible to correctly ascertain the birds' behaviour when walking quickly without looking at them. At direct approach we estimated FID (score 2 or 3) on condition of motion straight on a bird. At indirect approach we estimated FID on a perpendicular: distance was a perpendicular from the transect of observer motion to the bird location (Swarthout & Steidl, 2001). The estimation of disturbing factor was conducted taking into account the type of habitat.

We suggested some six urban habitats that were ranged in order of human traffic intensity:

- 1) central streets of city, squares of public transport;
- 2) places of public amusements (parks, public gardens, boulevards);
- 3) multi-store buildings;
- 4) cottage sector;
- 5) ruderal and industrial landscapes (dumps, abandoned lots, garage cooperative stores, industrial area);
- 6) suburban "green belts".

We used a *Stanley TLM 160i* Laser Rangefinder to record FID (± 1 m). FIDs were assessed 684 times between 2009 and 2012. We divided the year into two distinct seasons (autumn and winter; spring and summer) to account for different cohorts (with more naive juveniles in autumn than in spring). We collected flight initiation distances (FIDs) between 1000 and 1700 h across 2 d at each urban habitats. We used the Kolmogorov-Smirnov test for determination of normality of distribution. The estimation of neighboring linear dependence was carried out by means of Pearson cross-correlation analysis. For establishment of the authenticity of statistical difference between samplings we applied Student t-criteria for independent samplings and Fisher criterion. We used Mann-Whitney U-test for non-normal sampling distribution. The univariable analysis was conducted by one-way ANOVA. We determined the significance of variations by post-hoc comparisons methods, i.e. we performed the comparative analysis of means by LSD test of planned comparisons. Summary statistics is presented as mean and standard deviation.

RESULTS AND DISCUSSION

We approached rook ($n = 341$), jackdaw ($n = 190$), and hooded crow ($n = 153$). Study site, number of conspecifics, starting distance, distance to cover, and the three environmental variables did not have a significant effect on FID (all p values > 0.05).

In these particular conditions the rooks and crows do not react to the presence of observer at the distance up to 8 m. They show the first signs of disturbance at 7 m, and at the distance of 6 m the birds jump away aside from observer. The average take-off distance varies from 4.9 to 5.5 m (Table 2). The means of AD and FD are differed for the rooks ($p = 0.72$, Mann-Whitney U-test, $Z = 16882$), hooded crows ($p = 0.90$, $Z = 2521.5$), and jackdaws ($p = 0.57$, $Z = 21$), but there was no significant difference between them.

Table 2
Average alert and flight initiation distances (mean and SD, m)
of Corvids in Zhytomyr (2009-2012)

Species	Bird response categories*				
	0	0,5	1	2	3
<i>Corvus frugilegus</i>	7.8 ± 0.3	6.7 ± 0.3	5.8 ± 0.3	5.3 ± 0.3	5.2 ± 0.2
<i>Corvus monedula</i>	8.0 ± 0.7	7.7 ± 0.9	6.4 ± 0.5	5.7 ± 0.5	4.9 ± 0.2
<i>Corvus cornix</i>	8.4 ± 0.5	7.0 ± 0.5	6.0 ± 0.5	5.9 ± 0.7	5.5 ± 0.3

* Here grades 0-2 refer to AD and 3 to FID.

We found that AD had greater variation than FID and ranged from 0.5 to 21.5 m for rooks; from 0.8 to 19 m for hooded crows; from 0.5 to 16.3 m for jackdaws (Fig. 1).

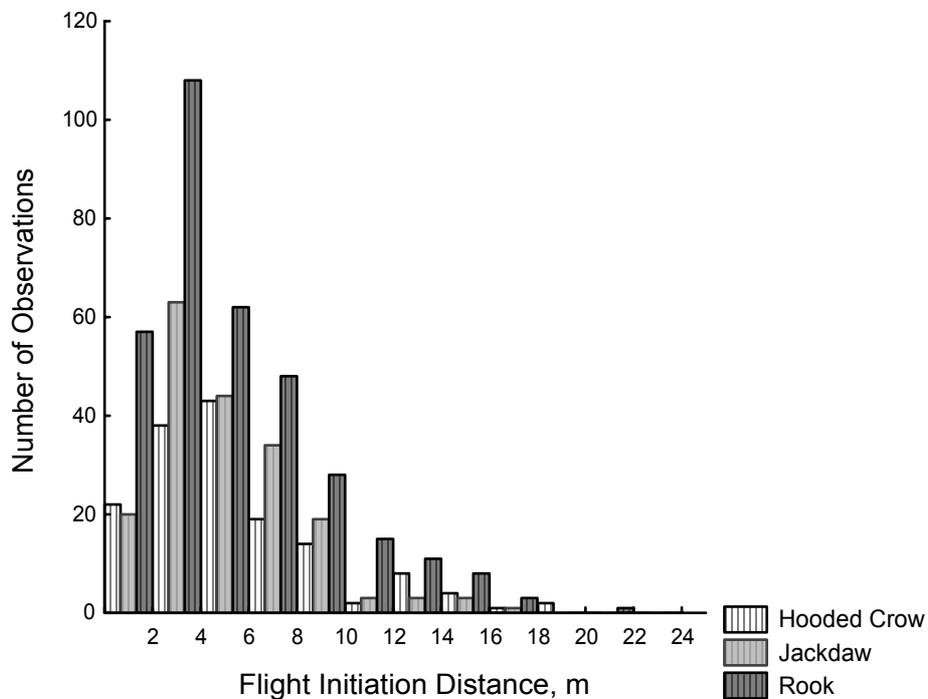


Fig. 1. Distribution of *Corvidae* flight initiation distance (Zhytomyr, 2009-2012).

The FID for Rooks and jackdaws mostly corresponds to the distance of observer from 2 to 4 m (31.7% and 33.2% of all individuals); for hooded the FID was registered in a range of 4-6 m (28.1% from total individuals). FID of 2 m was registered for 16.7% of rooks, for 10.5% of jackdaws, and for 14.4% of hooded crows. The FID was more than 10 m for 11.1% of rooks, for 5.3% of jackdaws, and in 11% of hooded crows (Table 3).

Table 3
Flight initiation distance in various habitats in three bird species, m (mean and SD)

Habitat	Species		
	<i>C. frugilegus</i>	<i>C. monedula</i>	<i>C. cornix</i>
Central streets	2.7 ± 0.2	3.8 ± 0.4	3.2 ± 0.2
Public amusements	4.7 ± 0.3	4.4 ± 0.4	4.9 ± 0.4
Multi-store buildings	4.5 ± 0.3	4.7 ± 0.3	4.3 ± 0.4
Cottage sector	4.7 ± 0.4	5.3 ± 0.5	4.4 ± 0.3
Ruderal and industrial landscapes	8.3 ± 0.6	8.2 ± 0.2	11.6 ± 0.8
Suburban green belts	9.3 ± 0.9	–	8.8 ± 1.1

FID of rooks depends on the habitats ($p < 0.05$; $F = 26.7$; $df = 339$), however, their FID is not strongly dependent on pattern of city buildings ($p = 0.754$ for multi-store and single-store buildings, post-hoc comparisons). FID also almost equal in ruderal landscapes and suburban green belts ($p = 0.17$) – see Table 3. FID of rooks positively correlates with the habitat factor ($r = 0.48$, $p < 0.05$) that testifies the adaptation of birds to the presence of non-aggressive people in their habitats.

Type of habitat influences the FID of jackdaws ($p < 0.05$, $F = 14.7$), although statistically significant differences were only marked between the birds from ruderal landscapes and all other types ($p < 0.05$, LSD test of planned comparisons = 0.636). There is an insignificant correlation between FID of jackdaw and degree of the anthropogenic load on habitat ($r = 0.44$, $p < 0.05$).

The FID of hooded crows varied in different habitats ($p < 0.05$, $F = 40.7$). However, FID on central streets, in the quarters of multi-story and private buildings differ insignificantly ($p < 0.05$), that testifies to the nearly identical degree of human disturbance in these urban systems. There was a strong correlation between hooded crows FID and anthropogenic loading on habitat ($r = 0.64$, $p < 0.05$).

The direction of observer approach towards the bird had significant influence of FID ($p < 0.05$, for rook $F = 69.2$, for jackdaw $F = 58.5$, for hooded crow $F = 15.9$). If a man moves straight on a bird, the FID was usually higher than when an observer goes by a bird. Thus average FID of rook at direct approach was 6.2 ± 0.2 m ($n = 248$, $SD = 3.8$ m, range 1-21.5 m), at motion by bird (indirect approach) it was 2.9 ± 0.2 m ($n = 93$, $SD = 1.8$, range 0.5-10.5 m). Average FID of jackdaw at direct approach was 6.0 ± 0.2 m ($n = 140$, $SD = 2.9$, range 1.7-16.3 m), and at indirect approach it was 2.7 ± 0.2 m ($n = 50$, $SD = 1.7$, range 0.5-7.4 m).

FID of hooded crow at direct approach was 6.3 ± 0.4 m ($n = 108$, $SD = 3.7$, range 1.2-19 m), at indirect – it was 3.7 ± 0.6 m ($n = 45$, $SD = 3.7$, range 0.8-15.6 m).

The smaller values of FID at indirect approach testify that corvids, with high cognitive capabilities, are able to rapidly assess a situation and degree of risk from human interaction. This interesting observation could also be explained by the anatomy of birds – perhaps when facing an observer a bird can assess the distance better than when looking at the observer with one eye.

The speed of observer approach also influenced the FID of Corvidae (Table 4).

Table 4
Dependence of Corvidae flight initiation distance (m)
on approaching person pattern (mean and SD)

Human approach pattern	Species		
	<i>C. frugilegus</i>	<i>C. monedula</i>	<i>C. cornix</i>
Fast walk	7.2 ± 0.4	6.7 ± 0.3	7.4 ± 0.5
Slow walk	4.7 ± 0.3	3.5 ± 0.3	3.3 ± 0.4
Slow and not looking walk	4.3 ± 0.3	5.6 ± 0.5	3.9 ± 0.4

The FID increases with the speed of approach and were almost twice as great at fast step than at slow step. From our data, FID for single rooks on average was higher (5.8 ± 0.3 m, $p < 0.05$, $F = 6.6$, $n = 191$, $SD = 3.9$), than for rooks in groups (4.8 ± 0.2 m, $n = 150$, $SD = 3.1$). We suppose that rooks feel themselves more safe in groups ($p < 0.05$, $F = 1.6$). FID of hooded crows also was higher for single birds (6.3 ± 0.4 m, $n = 103$, $SD = 3.7$), than for groups (4.2 ± 0.6 m, $n = 50$, $SD = 3.9$). Nevertheless, we did not find significant correlations between the number of individuals in a group and birds' FID ($p < 0.05$, $r = -0.15$). Being in group or singular does not have substantial influence on man-impact tolerance of jackdaws ($p = 0.223$, $F = 1.5$). The same was registered for number of birds in group ($p = 0.16$, $F = 1.5$). FID were lower for single jackdaws (4.9 ± 0.2 m, $n = 107$, $SD = 2.4$, $p < 0.05$) in comparison with groups (5.2 ± 0.4 m). This can be explained by behavioral pattern and triggering of quiet birds by more fearful individuals ($n = 83$, $SD = 3.6$, $p < 0.05$).

We determined the seasonal variation of FID and found that it was higher in winter than in summer (four winter and summer seasons, $p \leq 0.05$, $F = 7.7$), and have higher fluctuations. The mean FID of rooks in winter was 5.7 ± 0.3 m ($n = 208$, $SD = 3.6$; range 0.5-21.5 m), in summer it was 4.7 ± 0.3 m ($n = 133$, $SD = 3.5$, range 0.9-16.6 m).

FID of jackdaws in winter was on average 5.7 ± 0.3 m ($n = 106$, $SD = 3.3$, range 0.5-16.3 m), in summer 4.3 ± 0.3 m ($n = 84$, $SD = 2.3$, range 0.5-10.2 m) this difference was significant ($p \leq 0.05$, $F = 10.8$).

A difference in FID values for hooded crows between winter and summer period was not significant ($p = 0.38$, $F = 0.77$), although FID in winter was somewhat higher than in summer, namely 5.8 ± 0.5 m ($n = 86$, $SD = 4.4$, range 0.8-19 m) and 5.3 ± 0.4 m ($n = 67$, $SD = 3.1$, range 1-15 m) correspondingly.

Such seasonal variation could be explained by differences at bird subpopulations level or seasonal adaptations of wintering groups. Final regressive model of Eurasian Jackdaw FID considers type of habitat (H), number of birds in a group (N), direction (D) and parameters of approach (P) and season of year (S). All these variables, except for the season of the year, had a significant influence on FID values and explain 64.2% of its general variation. The most influential factors were type of habitat ($r = 0.44$, $F = 25.75$; $df = 201$; $t = 6.17$) and direction ($r = -0.49$, $F = 25.75$; $df = 201$; $t = -6.1$).

Equation of regression of FID from variables for Eurasian Jackdaw looks like:

$$\text{FID} = 7.21 + 0.23\text{N} + 0.81\text{H} - 2.43\text{D} - 0.94\text{P} \quad (1)$$

We found that all these variables influenced on FID values of Rook and explain 64.5% of its general variation. The most influential factors were type of habitat ($r = 0.48$, $F = 47.35$; $df = 341$; $t = 9.34$), direction ($r = -0.41$, $F = 47.35$; $df = 341$; $t = -6.4$) and parameter of approach ($r = -0.30$, $F = 47.35$; $df = 341$; $t = -6.95$).

Equation of regression which represents factors influence on FID of Rook is:

$$\text{FID} = 9.36 - 0.1\text{N} + 1.02\text{H} - 1.22\text{S} - 2.25\text{D} - 1.23\text{P} \quad (2)$$

Habitat ($r = 0.64$, $F = 30.18$; $df = 153$; $t = 8.77$), direction ($r = -0.31$, $F = 30.18$; $df = 153$; $t = -2.08$) and parameters of approach ($r = -0.43$, $F = 30.18$; $df = 153$; $t = -4.53$) influenced the FID of Hooded crow and explained 71.2% of general variation of flight initiation distance.

$$\text{FID} = 5.63 + 1.23\text{H} - 0.97\text{D} - 1.42\text{P} \quad (3)$$

DISCUSSION

We found that the degree of bird tolerance is based on habitat as a result of bird adaptation to the human presence as in urban habitats the FID of Corvidae negatively correlates with the increase of intensity of disturbance. Thus, we supposed that the degree of landscape transformation does not have significant influence on forming of rook tolerance, but the intensity of anthropogenic load, i.e. the number of people passing through the habitat.

The birds react insignificantly on the presence of man on the central streets of city and in public amusements, which could suggest the successful bird adaption to intensive human traffic is triggered by positive contacts with people (for example, by bird feeding). The highest values of FID were obtained in rural, industrial habitats, and green city belts characterized by intensive human traffic.

We also found out the impact of group size on FID. Birds' disturbance reaction was mostly asynchronous at observer approaching to the group of few rooks or jackdaws. This feature was well-proven for hooded crow (Rezanov, 2006; Halupka & Osinska, 2013).

CONCLUSION

The values of FID depend on habitat type, amounts of birds in a group, direction and parameters of observer approach, season of year. The most significant factor is habitat.

We suggested that the human traffic intensity had greater influence on rooks FID in habitats. The FID more depended on bird group size for hooded crows and less for jackdaws and rooks. The seasonal variation of FID was registered for the rooks: in winter FID were certainly much higher than in summer and characterized by greater variation. We supposed that the increasing of flight initiation distances in winter was caused by differences at bird subpopulation level or seasonal adaptations of wintering groups of Corvidae.

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ECOLOGICAL NICHE MODELLING OF *FRINGILLA COELEBS* LINNAEUS, 1758 (COMMON CHAFFINCH) USING GIS TOOLS

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Ecological-Niche Factor Analysis of finches showed that this species has a high marginality in relation to such ecogeographical variables as: the normalized difference vegetation index, the green NDVI, altitude, diffuse insolation, the activity of chlorophyll, the index of wind influence. This species is highly specialized in relation to various vegetation indices. Based on the habitat preference map, we found that *Fringilla coelebs* does not use all its potential pro-spatial niche. In this work a new approach to the study of the ecological niche of the species by using different levels of scale is proposed. Considering the ecological niche of common chaffinch on different levels of scale, we noticed certain features: first, a list of factors that influence the distribution of common chaffinch was significantly altered by changing the scale, secondly, the finer details of relief come to the forefront when scaled down; third, specialization of finch does not change with zooming.

Keywords: *Fringilla coelebs*, Ecological-Niche Factor Analysis, ecogeographical variables, marginality, specialization.

INTRODUCTION

Species-habitat interaction is a main subject of present-day biology and ecology. From the ecological perspective these relationships are formalized through the concept of ecological niche (Hutchinson, 1965). Distribution and niche modelling can unravel species-environment relationships (Guisan & Zimmermann, 2000; Mateo *et al.*, 2010; Peterson *et al.*, 2011) and provides a useful instrument in conservation biology, evolutionary ecology, and biogeography (Koper & Manseau, 2009; Durant *et al.*, 2010; Dolgener *et al.*, 2014).

Ecological-Niche Factor Analysis is based on the assumption that a species is not randomly distributed with regard to eco-geographical variables (Chase & Leibold, 2003; Goberville *et al.*, 2015). A focal species may be characterized by some marginality (expressed by the fact that the eco-geographical variable of the species mean differs from the global mean) and some specialization (expressed by the fact that the species variance is lower than the global variance) (Hirzel & Guisan, 2002; Reineking & Schröder, 2006).

Modern techniques of ecological niche studies provide cues to a number of issues; namely, evolutionary processes, competition, predator distribution and population dynamics. Additionally, the recent 15 years have witnessed an increased

number of studies in habitat-suitability modeling, which are aimed at predicting a reasonable probability of a species occurrence with respect to eco-geographical variables (Hirzel & Guisan, 2002; Bütler & Lachat, 2009). Predictive models of species distribution within large geographical areas, with reference to a species' requirements, are recognized to have a wide range of application in landscape ecology, nature conservation biology and wildlife management (Franklin, 2000; Stauffer, 2002; Trigg *et al.*, 2006; Wisz *et al.*, 2008; Zurell *et al.*, 2009).

Ecological – Niche Factor Analysis (ENFA) is a modeling technique based exclusively on the presence data (Hirzel & Guisan, 2002; Fonderflick *et al.*, 2015). It may be employed to determine correlations between eco-geographical variables (EGV) and species distribution patterns, and also to evaluate habitat suitability. In our research, ENFA was used to evaluate a habitat suitability for a certain bird species, namely, common chaffinch (*Fringilla coelebs* Linnaeus, 1758).

ENFA compares in the multi-dimensional space of ecological variables, the distribution of the localities where the focal species was observed, to a reference set describing the whole study area. ENFA generalizes several EGVs into a number of non-correlative factors without losing too much information. Thus, ENFA estimates a species' niche-suitability functions by comparing a species' distribution in the EGV space to that of the whole set of cells (Austin, 2002; Soares & Brito, 2007).

An ecological niche description may be based on the occurrence frequency or vital activity traces of species representatives, together with radio tracing and satellite navigation.

This study focuses on the *F. coelebs* occurrence frequency on the routes of observation. *F. coelebs* is a songbird, from the genus *Fringillidae*, which is quite numerous and widely spread in Ukraine, nesting throughout the country in localities with an abundance of trees. Its biotope is diverse, including man-made landscapes (gardens, parks, orchards, boulevards, cemeteries); light oak forests; birch, willow and pine groves; flooded non-dense forests and island-type forests in the grasslands. *F. coelebs* tends to avoid large wet dark coniferous forests, restricting its habitats to their edges (Fesenko & Bokotej, 2002).

This paper is concerned with the *F. coelebs* ecological niche, viewed on the landscape level in terms of ENFA and EGVs, which were determined through the Earth remote sensing. Here we propose a new approach to the ecological niche analysis, namely, the one based on different scale levels.

MATERIAL AND METHODS

The data were collected by seasonal observations in 2011-2014 on an ecological profile Dnipropetrovsk National University Ecological Station (Ukraine).

The area of the referent polygon, which includes all the basic biogeocenosis types of the study site, constitutes 38.35 km². The area of the curved polygon,

where birds were recorded, is 5.23 km². The area covering the cells of pseudo-absence varies depending on their proximity to the presence cells; with this distance being not less than 100 meters, the area is 6.44 km², with a distance of 200 meters, the area is 8.39 km², 500 meters – 11.96 km², 1000 meters – 20.25 km².

To study the birds-habitat relationships time-keeping (Dolnik, 1982) was employed. Employing this tool we used visual observation to keep time of the birds' activity for each sample in a tree stand. Bits of activity registered were not less than 30 meters apart, which correlates with 1 pixel in satellite imagery.

To employ a bird observation technique one should obtain the following data:

- 1) the bird species;
- 2) the tree species, whose crown the bird occupied;
- 3) the determinant tree characteristics (age, height, crown size);
- 4) the bird's position:
 - a) within the vertical and horizontal systems of a tree structure;
 - b) within the substratum gradation system;
 - c) within the Biallovich biogeohorizon system;
- 5) functional interaction with a certain tree sample with respect to the consortive relationships: a) trophic; b) topic; c) productive; d) phoric;
- 6) duration of the interaction (sec);
- 7) coordinates (in this research GPS Garmin E – trex was used after the activity was successfully recorded and the bird flew away).

Multichannel space survey and three-dimensional relief models open new possibilities for a species-habitat interaction research and evaluation of growing conditions (Dolgener *et al.*, 2014). This paper is based on the data obtained by Operational Land Imager (OLI), installed on Landsat 8 (<http://purl.access.gpo.gov/GPO/LPS82497>). The survey was done on May 16, 2014. Coordinates of bird locations are given in Universal Transversal Mercator (UTM), which projects the Earth spherical surface into two-dimensional Cartesian coordinates.

In the context of ENFA, an ecological niche is assumed to be a subset of cells in the ecogeographical space within which the focal species is expected to occur with reasonable probability. This multivariate niche can be quantified on any of its axes by an index of marginality and specialization (Hirzel & Guisan, 2002).

The coefficients m_j of the marginality factor express the marginality of the focal species on each EGV in units of standards deviations of the global distribution. The higher the absolute value of the coefficient m_j , the further the species optimum departs from the mean of the corresponding variable within the study area. Negative coefficients indicate that the focal species prefers values that are lower than the mean with respect to the study area, while positive coefficients indicate preference for higher-than-mean values (Hirzel & Guisan, 2002).

The coefficients of the other factors (specialization ones) receive a different interpretation: the higher the absolute value, the more restricted is the range of the

focal species on the corresponding variable. The eigenvalue λ_i associated to any specialization factor expresses the amount of specialization it accounts for, i.e. the ratio of variance of the global distribution to that of the species distribution. Eigenvalues usually rapidly decrease, so that a few initial factors are sufficient to evaluate the species habitat suitability (Demidov *et al.*, 2013).

Accuracy, or adequacy, of the model obtained may be estimated by a degree of its deviation from a randomly chosen alternative. To achieve this, the Monte Carlo method was used. Thus, 300 random distributions, generalized within the study area, were compared to the ENFA data (marginality and specialization). This gave an estimate of the deviation probability between the focal structure and the random alternative.

The digital relief model (Earth Explorer Aster Global DEM) allowed to compute the following derived geomorphological parameters within area studied: Topographical Wetness Index according to SAGA algorithm (TWI-Saga); Topographical Ruggedness Index (Ruggedness); Profile curvature (Prof. curv.), Planar curvature (Plan. curv.); Mass-balance Index; Slope length factor (LS, ls-factor) of the Universal Loss Soil Equation (USLE).

Other abbreviations: NDVI – Normalized Difference Vegetation Index – net production, transpiration; VI – Vegetation Index (biomass and vegetation types); Green NDVI – extremely sensitive to chlorophyll concentration; NDWI – Normalized Difference Water Index (water content in biomass); NDB4 – chlorophyll activity; GR – green; DEM – elevation; TWI – Topographical Wetness Index; Slope – angle the relief slope; W – wetness; direct_insol – direct insolation; diffuse_insol – diffuse insolation; mrrtf – multiresolution index of the ridge top flatness; mrvbf – Multiresolution Index of Valley Bottom Flatness; wind – Livard wind influence index; altitude – altitude above the canal network (Friedrich, 1998).

The originality of the present approach lies in the fact that an ecological niche is described at different scale levels. ENFA provides quantitative estimates of an ecological niche comparing the EGVs in the species presence cells to those of the reference area, within which pseudo-absence cells are artificially distributed (Hirzel & Zimmermann, 2000). Generally, the size and configuration of the reference area are chosen at random. In this respect, features of the surveyed ecological niche were obtained at different ranges of proximity between the pseudo-absence cells and the curved polygon where the species was recorded.

For this purpose, the pseudo-absence cells were distributed at distances which do not exceed 1000 meters, 500 meters, 250 meters, 100 meters from the *F. coelebs* presence cells. Statistical computation was implemented in the software Project R “R: A Language and Environment for Statistical Computing” (<http://www.R-project.org/>). For graphical data Surfer 11 was used.

RESULTS

Spatial distribution of *F. coelebs* within the study area is given in Fig. 1. ENFA provides the *F. coelebs* ecological niche with respect to two factors: marginality and specialization regarding various EGVs.

We project the used and available points in the ecological space on the plane defined by the marginality axis and one specialisation axis (Fig. 2). The environmental variables are represented by an arrow with two components of importance: the length and the direction. The length of the arrow identifies the contribution of a given environmental variable to the definition of the axes of the ENFA, *i.e.*, their influence on the position and volume of the ecological niche within the available habitat. The direction measures how this contribution is decomposed on the marginality or specialization axes. EGVs, mostly associated to the *F. coelebs* presence in relation to the marginality factor (Mar), include: NDVI, Green NDVI, Dem, Diffuse_insol, NDB4, wind (Table 1; Fig. 2).

Our modelling showed that *F. coelebs* gives preference to habitats with higher vegetation, wetness and direct insolation indexes than those of the study area mean, while its optimal diffuse insolation and wind indexes are lower than those of the area mean values. With respect to the altitude above the sea level, *F. coelebs* tends to inhabit sites that are lower than the mean (Table 1).

The next factor, specialization (Spel), shows that *F. coelebs* is essentially linked to various vegetation indexes: GVI (Ratio VI), NDB4 (chlorophyll activity), GR (Table 1). The distance between the centroid of the ecological niche of *F. coelebs* and the centroid of the available habitat was quite high, resulting in a pronounced marginality (X-axis, Fig. 2), *i.e.*, the optimum of *F. coelebs* was rather different from the mean available conditions.

The Monte-Carlo test shows that, statistically, with regard to the focal niche both marginality and specialization axes are likely to differ from a random alternative (Mar = 11.22, $p = 0.003$; Spel = 237.25, $p = 0.01$) (Fig. 3).

The *F. coelebs* preference map was computed from ENFA. The habitat suitability map is a grid, with each cell ranging in value from 0 to 100, which correlates with a zero to a high habitat suitability (Fig. 4). The habitat suitability map shows that the *F. coelebs*' most favourable conditions are situated in the centre of the study area.

Distribution of resources used by *F. coelebs* differs from the distribution of resources within the area, especially in relation to such variables as: altitude above the sea level, normalized difference vegetation index, leeward wind influence index, etc. (Fig. 5).

Table 1
ENFA results with regard to the *F. coelebs* ecological niche

Ecological geographic variables	Within area studied		Scaling levels							
			1000 M		500 M		250 M		100 M	
	Mar	Spe1	Mar	Spe1	Mar	Spe1	Mar	Spe1	Mar	Spe1
NDVI	0.30	-0.11	0.29	-0.06	0.22	-0.01	0.18	0.12	0.17	0.17
NDWI	-0.28	0.14	-0.32	-0.43	-0.25	-0.31	-0.18	-0.08	-0.09	-0.08
GR	0.30	0.28	0.23	-0.02	0.15	0.01	0.11	-0.07	0.09	-0.04
GreenNDVI	0.31	-0.03	0.25	-0.10	0.18	-0.08	0.16	0.00	0.15	-0.07
GVI	-0.25	0.81	-0.21	-0.66	-0.15	-0.67	-0.11	-0.70	-0.09	-0.67
NDB4	0.28	0.39	0.17	-0.50	0.11	-0.62	0.10	-0.65	0.10	-0.67
VI	-0.23	-0.25	-0.27	0.16	-0.24	0.18	-0.19	0.22	-0.18	0.21
W	0.21	0.06	0.35	-0.28	0.29	-0.17	0.18	0.02	0.06	0.01
Dem	-0.33	-0.09	0.17	0.02	0.20	0.03	0.12	0.04	0.07	0.06
Twisaga	0.22	-0.03	-0.06	-0.04	-0.10	-0.03	-0.07	-0.01	0.06	0.09
TWI	0.05	0.00	-0.11	0.00	-0.12	0.00	-0.15	0.00	-0.30	-0.01
Slope	0.11	0.03	0.03	0.03	0.01	0.04	0.02	0.04	-0.13	0.09
Ruggedness	0.03	0.01	0.08	-0.01	0.07	0.00	0.10	0.00	0.00	0.02
Prof_curv	-0.15	0.01	0.25	0.00	0.32	0.00	0.44	0.01	0.43	0.02
Plan_curv	-0.06	0.00	0.21	0.00	0.26	0.00	0.32	0.00	0.29	0.00
Mass_balance	-0.06	0.00	0.12	0.00	0.15	0.00	0.20	0.00	0.22	-0.01
Ls_factor	0.20	-0.01	-0.03	-0.05	-0.07	-0.05	-0.05	-0.04	-0.19	-0.04
Direct_insol	0.13	0.00	0.19	0.00	0.29	0.01	0.38	0.01	0.42	0.02
Diffuse_insol	-0.23	0.02	0.08	-0.01	0.13	-0.01	0.07	0.00	0.16	0.02
Altitude	-0.14	-0.02	0.17	-0.02	0.24	-0.02	0.19	-0.02	0.12	0.01
Mrrtf	-0.15	0.04	-0.07	0.01	-0.06	0.01	-0.09	0.01	-0.12	0.01
Mrvbf	-0.08	-0.01	0.12	0.01	0.16	0.02	0.15	0.02	0.24	0.02
Wind	-0.23	0.00	0.41	-0.04	0.46	-0.03	0.45	-0.03	0.36	-0.01

Legend: Mar – marginality axis. Spe1 – specialization axis.

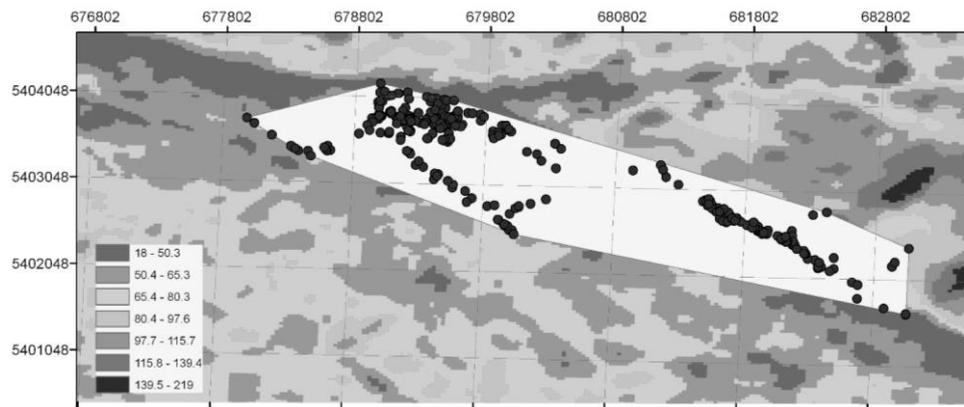


Fig. 1. Spatial distribution of *F. coelebs*. Symbols: coordinates are given in UTM (Zone 36); grey scale shows the altitude above the sea level (m); curved polygon shows the zone where the focal species was recorded during route observations.

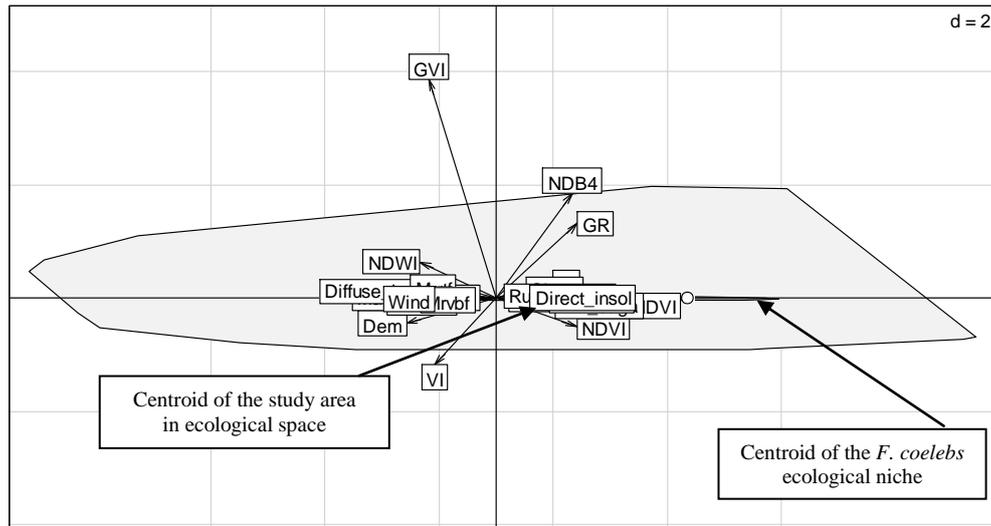


Fig. 2. The ENFA results for the *F. coelebs* ecological niche.

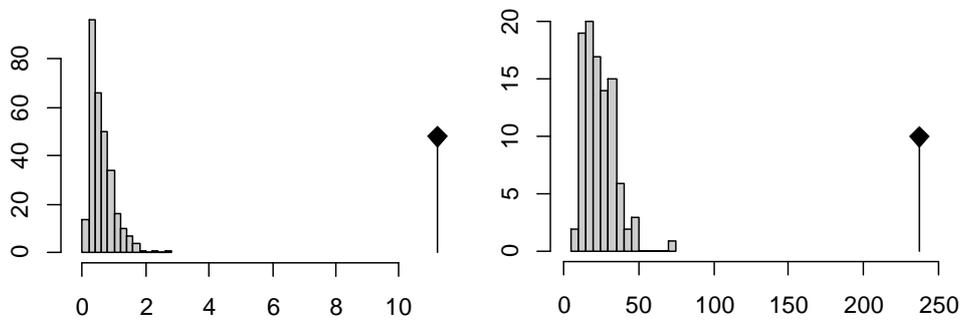


Fig. 3. Simulation results (through the Monte Carlo method) of the marginality (on the left) and specialization (on the right) indexes. Histograms – values of the correlative statistics for the random data; rhombus-containing lines – observed statistics for the experimental data.

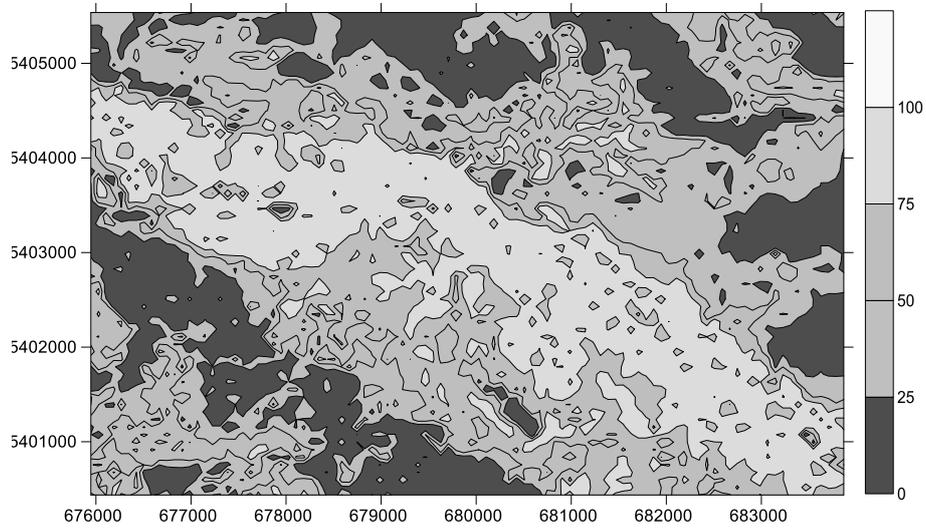


Fig. 4. The *F. coelebs* habitat-preference map (100 – maximal preference, 0 – minimal preference). Symbols: coordinates are given UTM (Zone 36).

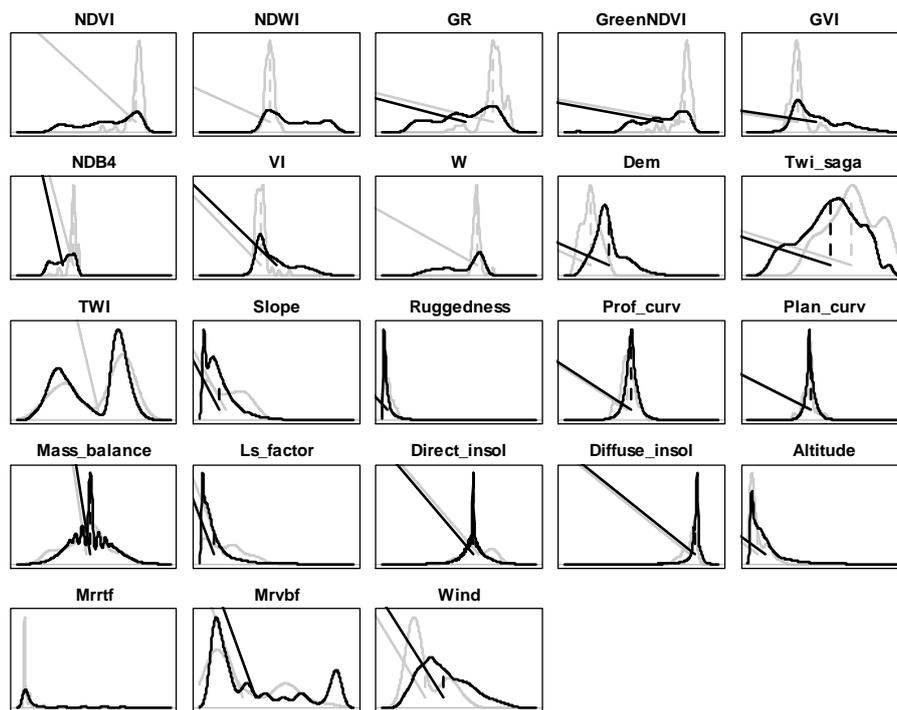


Fig. 5. Distribution of resources (black line) and distribution of used resources (grey lines). The variables values are normalized to 1 which equals the width of the corresponding graph.

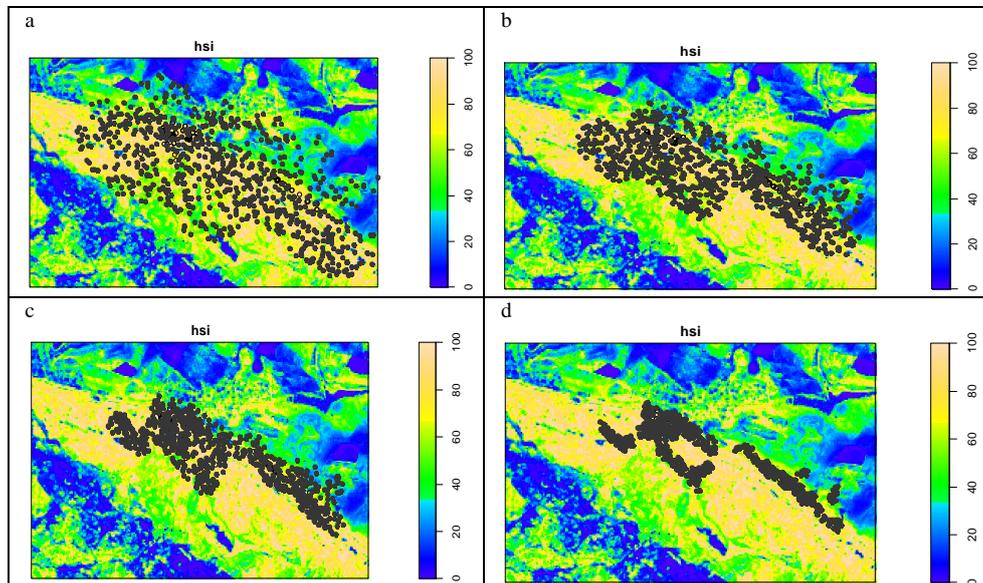


Fig. 6. Distribution of pseudo-absence cells: a – distance to the presence cells not exceeding 1000 meters; b – distance to the presence cells not more than 500 meters; c – distance to the presence cells not exceeding 250 meters; d – distance to the presence cells not more than 100 meters. The scale gradation – see Fig. 4.

The ecological niche of *F. coelebs* was evaluated through the distribution of the pseudo-absence cells at distances not less than 1000 meters, 500 meters, 250 meters, 100 meters from the bird's presence or registration cells (Fig. 6). With scale decrease the significance of all vegetation indexes lessens, i.e. they become less crucial for *F. coelebs*' distribution. By contrast, *F. coelebs*' marginality with respect to the direct insolation variable is gradually increasing with the scale reduction. Further, *F. coelebs* loses its marginality with regard to the altitude above the sea level.

With the more general survey of the study area, the species gives preference to the lower patches of the referent site. At the scale of 500 meters from the presence cells, the species marginality remains positive, i.e. the species prefers higher patches and, with the further decrease of scale, the influence of this factor becomes less significant, though still positive. Likewise, marginality regarding the diffuse insolation index changes from the negative values, when surveyed from a more general level, to the positive ones with scale decrease. Quite the opposite tendency is displayed by the topographical wetness index, which at the largest scale has positive marginality, i.e. *F. coelebs* prefers habitats with greater mean wetness, whereas with scale reduction, marginality acquires positive values. *F. coelebs*' response to wind changes from negative marginality at the largest scale to positive

values, if the scale is reduced; incidentally, the maximal marginality with respect to the wind influence index is registered at the scale of 500 meters from the presence cells (0.46) (Table 1).

Marginality of such variables as Prof_curv, Slope, Mass-balance index (used to assess erosion processes), etc. increases with scale decrease (Table 1).

Specialization remains practically the same with respect to all the variables, except for NDWI, NDVI, W (wetness), even if the scale of observation is changed.

DISCUSSION

This study is the first attempt to understand *F. coelebs* habitat preferences using the environmental niche factor analysis (ENFA) approach. The ENFA provides a suitable way to measure habitat selection under a large range of ecological contexts (Calenge, 2008). *F. coelebs*' high marginality in relation to NDVI, Green NDVI, Dem, Diffuse_insol, NDB4, wind proves that these factors are crucial for the species distribution.

The most important specialization factors are various vegetation indices (GVI (Ratio VI), NDB4 (chlorophyll activity), GR). This proves that *F. coelebs*' distribution largely depends on vegetation abundance and its habitats are restricted within a small range of shifts on these variables (Fesenko & Bokotej, 2002).

Computing habitat suitability maps allow us to identify those suitable areas that are not yet or no longer colonized and those critical areas that need to be preserved, such as faunistic corridors (Abade *et al.*, 2014).

On the basis of the niche spatial parameters we may depict a patch most suitable for *F. coelebs*, lighter shades marking the highest degree of suitability. The optimal preference zone may be viewed as a potential niche (Hutchinson, 1965) and the locations where the focal species was observed and registered – as a realized niche. Obviously, not the entire potential niche of *F. coelebs*, with regard to its spatial parameters, is likely to be realized (Fig. 4).

Every species tends to occupy its own inherently suitable habitat, stipulated by its specific requirements to the environment (Hirzel & Guisan, 2002). Thus, since any area proves to provide a number of available resource units, any species may be characterized by a certain degree of use of these resources (Fig. 5).

“Weight of resource availability” is a portion of a study area containing the corresponding EGV. Total_weight of availability constitutes distribution of available resources. Weight of use describes how intensively a species uses resource units. This weight of use may be described as a portion of a species' occurrences, from their total quantity, within the area with the given EGV. Aggregate utilization weight represents the distribution of resources used (Demidov *et al.*, 2013). Therefore, distribution of resources used by *F. coelebs* differs from the distribution of resources within the area.

A new technique proposed in this paper and based on the scale changes enables a researcher to evaluate an ecological niche at different levels of survey.

The *F. coelebs* ecological niche surveyed at different scale levels allows us to make a number of points. First, a list of factors influencing the *F. coelebs* distribution changes essentially at different scale levels. Thus, with scale decrease the significance of all vegetation indexes reduces, i.e. they become less crucial for the *F. coelebs* distribution. This may be explained by the fact that the study area becomes more homogeneous.

Second, with scale decrease there come to the forefront finer details of the relief, which are not evident when the scale is higher. Therefore, decreasing the scale we may evaluate how the ecological niche is influenced by the variables: Prof_curv, Slope, Mass-balance index (used to assess erosion processes), etc.

Third, *F. coelebs*' specialization does not respond to the scale change. This proves that *F. coelebs*' distribution largely depends on vegetation abundance.

A new technique proposed in this paper proves fruitful from an ecological perspective, as it makes it feasible for observers, being on the same level with an object, to change their point of observation while performing their wildlife survey. Different scale levels reveal certain regularities with respect to the species distribution both locally and globally.

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