Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 31, issue 3, 2021, pp. 129 - 136

THE IMPACT OF MILITARY TRAINING-RELATED DISTURBANCES IN ZÁHORIE MILITARY TRAINING AREA (WESTERN SLOVAKIA) ON THE DRAGONFLIES DIVERSITY

Zuzana ŠÍBLOVÁ[1,2], Blanka LEHOTSKÁ[3*], Milena MOYZEOVÁ[1]

[1]Institute of Landscape Ecology, Slovak Academy of Sciences, Bratislava, Slovak Republic
[2]Department of Ecology and Environmental Studies, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Nitra, Slovak Republic
[3] Department of Environmental Ecology and Landscape Management, Faculty of Natural Sciences, Comenius University in Bratislava, Bratislava, Slovak Republic

Abstract: The Záhorie Military Training Area (MTA) is characterized not only by the occurrence of rare xerothermic habitats on sand dunes but also by the presence of numerous wetland habitats. The aim of this study was to compare wetland habitats inside and outside MTA and observe whether they are affected by military training activities. For this purpose, we chose dragonflies (*Odonata*) as a model organism, whose different species composition and diversity can indicate different environmental influences. During the seasons 2017 and 2018, we determined a total of 31 species (1431 individuals) at 6 sites outside the MTA and 38 species (2099 individuals) at 6 sites inside the MTA. Data obtained by field odonatology research were evaluated and compared using the Shannon-Wiener index of diversity, equitability, species abundance, the presence and representation of species with high ecological value (e.g. *Leucorrhinia pectoralis*).

Keywords: Military training area (MTA), wetlands, *Odonata*, biodiversity, Borská nížina lowland.

INTRODUCTION

As a result of the growing loss of natural habitats, in recent years attention has also begun to focus on secondary habitats, which are often significantly affected (or directly created) by human activity. Many scientific studies have confirmed that these habitats also have great potential in terms of biodiversity. In the case of dragonflies, the decisive factor is the representation of diverse habitats and their successive stages, to which individual species bind by reproduction (Mazzacano *et al.*, 2014). In such a case, in terms of species abundance, sites created or influenced by human activity may also compete with the natural ones (Simaika *et al.*, 2016).

Military training lands provide a unique opportunity to explore ecosystems and their components without anthropogenic interventions (e.g. urbanization, agriculture, over-tourism) other than military training activities (Quist *et al.*, 2003). Many scientists around the world have researched the impact of military activity on biota in military districts. In Australia, they compared (Lindenmayer *et al.*, 2016) the occurrence of different species of vertebrates (especially birds) in the intervention and non-intervention zone of the Beecroft Weapons Range Military Training Area. They examined not only the direct effects of disturbances such as noise or fire but also secondary effects. These can be, for example, changes in the distribution of vegetation after fires or mechanical damage by military hardware. Their research showed that in terms of overall biodiversity, the compared sites did not differ significantly. Differences in abundance occurred more at the level of some species, with some preferring the non-intervention area but others were more abundant in the intervention zone. The occurrence of ecologically important species was also confirmed in the intervention zone. It follows that, despite or precisely because of the regular disturbances created by military activity, MTAs can be considered valuable for biodiversity and can have great potential for nature conservation (Warren *et al.*, 2007). In Poland, research was carried out on explosion craters in the active military area and their effect on the diversity of vascular plants, bryophytes and lichens species. Research has shown differences in species composition between craters and undisturbed plots, there were also found several species with a strong preference for craters (Krawczyk *et al.*, 2019). In Germany, Reinhardt *et al.* (2019) have proved the importance of MTAs even in connection with the recolonization of wolves.

We carried out our research on the territory of the Military District (MD) Záhorie with an area of 27,650 ha and its immediate surroundings, which extends to the territory of the Borská nížina lowland. This area is specific for the occurrence of large sand dunes and wetlands filling inter-dune depressions. Kalivodová *et al.* (2018) recently wrote about the importance of wetlands in the Borská nížina lowland, studied small terrestrial mammals as a model organism. Gajdoš and Majzlan (2001) researched spiders on sand dunes, the preservation of which in the MTA Záhorie also depends on military training activities. Mišíková and Dobiášová (2014) gave a detailed list of bryophytes from this area in their work. Many rare communities and species of fauna and flora are associated with these types of habitats, several of which are also subject to protection. For MTA Záhorie, the occurrence of up to 19 habitats of community interest and 6 habitats of national interest is reported. The occurrence of the dragonfly *Leucorrhinia pectoralis*, which is a species of community interest, was also confirmed in several sites. Its occurrence was most recently published by Šíblová and Moyzeová (2019). They also confirmed the occurrence of 7 species of national interest – *Aeshna isosceles*, *Anax imperator*, *Brachytron pratense*, *Libellula fulva*, *Orthetrum*

Correspondence: Blanka Lehotská, Department of Environmental Ecology and Landscape Management, Faculty of Natural Sciences, Comenius University in Bratislava, Ilkovičova 6, 842 15 Bratislava, Slovak Republic, e-mail: blanka.lehotska@uniba.sk

coerulescens, *Somatochlora flavomaculata*, and *Sympecma fusca*.

Military training-related activities are often perceived as a negative factor in the natural environment. Activities such as the bombing of training targets or the passage of military hardware result in physical damage to the environment (vegetation loss, change in its distribution, erosion of the soil cover, local fires) (Zentelis *et al.*, 2017). MTA Záhorie is specific for the occurrence of habitats, which, on the contrary, to a reasonable extent, these disturbances can help maintain a favorable state. Military hardware and training bombing here make it possible to preserve rare xerothermic communities on windy sands by preventing ecological succession and the onset of invasive trees by mechanical disturbance. Without this type of disturbance, the known sands would gradually overgrow especially Scots pine (*Pinus sylvestris*), and form expansive grasses with *Calamagrostis epigejos*. During military training activities, depressions are often created, which are transformed into periodic ponds and permanent water areas by capturing rainwater. These then provide a refuge for many freshwater organisms. There are also a high proportion of natural wetland habitats filling the inter-ton depression in the military district. Some of these habitats have become the subject of protection in Natura 2000 sites declared in this area (Šíbl and Klimová, 2011).

According to Harabiš and Dolný (2018), the advantage of these areas is especially their large area with almost zero degrees of urbanization and their isolation. Due to the considerable isolation of the MTA resulting directly from the Act on Military Districts (No. 281/1997 Coll.), these ecosystems are not negatively affected by human activity. The movement of civilians here is limited and subject to certain rules, which precludes excessive tourism. Some zones are permanently inaccessible. Also, the rate of urbanization is almost zero here. This factor is very important because precisely due to the construction of industrial buildings, extensive wetland habitats in the vicinity of the nearby city of Malacky have disappeared. Within the territory of the Borská nížina lowland, there are valuable wetland habitats also outside the MTA Záhorie. However, without management measures, many of them are doomed to gradual extinction by overgrowth, drying out, or extinction due to urbanization.

The aim of this work is to confirm the hypothesis that MTA Záhorie, thanks to military training activities and isolation, can have a positive effect on the creation and preservation of suitable habitats for dragonflies, including species of community interest such as species *Leucorrhinia pectoralis*. We proved this theory by comparing the analysis of data obtained from sites inside and outside the MTA.

STUDY AREA

The research took place in 12 sites located on the territory of the Borská nížina lowland lying in the west of Slovakia, while 6 sites are located on the territory of an active military training area (MTA Záhorie) and another 6 sites near its borders. They are (name, GPS coordinates, altitude, area, and habitat are listed):

1. Amphibian hatchery – N 48.412127° E 17.028548°; 168 m; 1.42 ha – artificial amphibian hatchery,
2. Zelienka – N 48.600098° E 17.165182°; 207 m; 22.5 ha – peat bog,
3. Vanišovec – N 48.612925° E 17.148674°; 194 m; 13.4 ha – peat bog,
4. Dolné Valy 1 – N 48.573340° E 17.112250°; 182 m; 0.49 ha – stream dammed by beaver activity,
5. Jasenácke – N 48.554024° E 17.154518°; 216 m; 9.2 ha – peat bog,
6. Horné Valy – N 48.567509° E 17.123218°; 185 m; 0.95 ha – stream dammed by beaver activity,
7. Orlovské vŕšky – N 48.467678° E 17.059620°; 177 m; 9.05 ha – peat bog,
8. Mešterova lúka – N 48.481530° E 17.063830°; 175 m; 9.44 ha – peat bog,
9. Bežnisko – N 48.534545° E 17.247688°; 206 m; 0.78 ha – flooded depression in a sand dune,
10. Kotlina 1 – N 48.634563° E 17.332106°; 208 m; 0.09 ha; peat bog,
11. Kramárka – N 48.448220° E 17.081220°; 193 m; 0.12 ha – periodically flooded swamp,
12. Kotlina 3 – N 48.631670° E 17.324805°; 215 m; 14.5 ha – artificial pond for fire purposes.

Habitats of natural and anthropogenic origin, with and without territorial protection, large and small, and isolated and influenced by human activity are evenly represented in the compared areas. The location of the research sites is shown in Figure 1. The border of MTA Záhorie is marked in orange. Sites 1–6 located outside MTA Záhorie are marked in green, sites 7–12 located in the MTA are marked in red.

MATERIAL AND METHODS

Odonatological research was performed at the studied sites during the season from May to August in 2017 and 2018. The research took place only on clear and sunny days without precipitation and strong winds when the air temperature was not lower than 20 °C. We identified the adult individuals (imagos) that we captured using the entomological net and determined them into species using the Waldhauser and Černý (2014) identification key. After determination, the captured individuals were released into the original environment. The capture took place during the day between 9:00 and 17:00, with the length of time spent on the site depending on its size.

The obtained data for both areas of interest on the basis of ideas of diversity and abundance of species (species of community and national interest were also evaluated separately) were evaluated and compared. The PAST program (Hammer *et al.*, 2001) was used to calculate diversity indices and abundance indices (Fig. 3, 4). We used a bar graph to compare the representation of ecologically important species and the results of the calculated indices (Fig. 2–4).

To calculate species diversity, we used the Shannon-Wiener index, the taxonomic diversity index (Table 1 and 2), and equitability (Whittaker, 1972). Degree of species dominance was evaluated as follows:

eudominant (Eu) represent > 10%, dominant (Do) 5.0 to 9.9%, subdominant (Su) 2.0 to 4.9%, recedent (Re) 1.0 to 1.9% and subrecedent (Sr) < 0.9%.

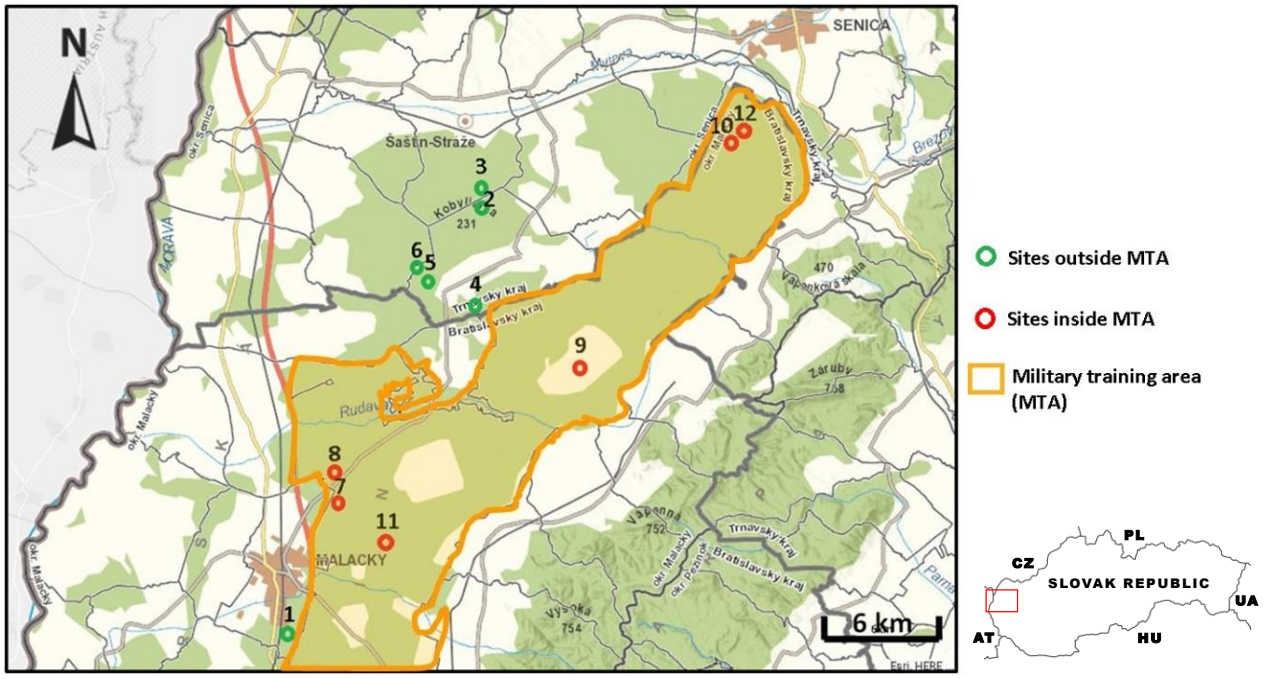

Fig. 1. Location of the research sites and the border of MTA Záhorie. Source of map material: https://zbgis.skgeodesy.sk (available: 20. 10. 2020), graphic design of the map: Zuzana Šíblová and Blanka Lehotská 2020.

RESULTS AND DISCUSSION

During the season in 2017 and 2018, we determined a total of 31 species and 1431 individuals at sites outside the MTA (Tab. 1) and 38 species and 2099 individuals at sites in the MTA (Tab. 2). In the case of dragonflies, the heterogeneity of their habitat might have a significant effect on the number of species, as each species has slightly different ecological requirements (Lindenmayer *et al.*, 2016). Therefore, sites with the occurrence of a larger number of different successional stages also have a higher number of species. The sites of the compared areas were selected so as to represent similar types of habitats, degrees of succession, and have a similar area. Nevertheless, we recorded a higher number of species and individuals in the sites in the MTA. We assume that in the case of sites located in the MTA, the number of species was affected by the combination of area and heterogeneity of the habitat. The highest species abundance was recorded in the two largest sites Mešterova lúka (site 8) and Orlovské vŕšky (site 7), which are also characterized by a high degree of habitat heterogeneity. On the contrary, the lowest number of species was in the area of smaller sites Kramárka (site 11) and Bežnisko (site 9), where not so many diverse successional stages were represented.

In the case of sites located outside the MTA, the heterogeneity of the habitat had a decisive influence on the number of species. The largest sites were Zelienka, Vanišovec, and Jasenácke (sites 2, 3, 5). Nevertheless, a higher number of species had smaller site Horné Valy (site 6) and an artificially created amphibian hatchery (site 1), which lies in close proximity to the IKEA Components industrial zone. Both of these sites are at the same time without any territorial protection. However, they are characterized by different stages of succession and a rich representation of coastal vegetation and aquatic macrophytes, which are essential for the reproduction of a large number of dragonfly species. The amphibian hatchery was also established in relatively recent times, and the initial stages of succession are still active on the sandy substrate. There are hatcheries of various depths, wide, overgrown with an open water surface. All these factors, together with the close location to the protected area of Marhecké rybníky, give a presumption to a higher number of dragonfly species in comparison with more important natural sites. The lowest number of species was recorded in the site Jasenácke, despite the large area. We assessed that this was caused by a fluctuating water level regime, which could not be adjusted even by previous revitalization measures.

Species of community and national interest were identified for both compared areas (Fig. 2). We found that there were more ecologically important dragonfly species (2 species of community interest and 7 species of national interest, tab. 2) in the sites located directly in the MTA than in the sites located outside the MTA territory (1 species of community interest and 6 species of national interest, tab. 1). Examples were the sites of Mešterova lúka and Orlovské vŕšky, which became a refuge for a species of community interest *Leucorrhinia pectoralis*. We also confirmed its occurrence in sites located outside the MTA – Zelienka, and Vanišovec. In the case of this species, the main criterion for its occurrence is the presence of suitable habitat. It is almost exclusively a lymphophilous species requiring the presence of a combination of littoral vegetation with higher vegetation around the water surface and also a

sufficient representation of the open water surface (Dolný et al. 2008). The sites where we recorded it met these ecological requirements, mainly due to the implementation of previous revitalization measures, which helped to restore the natural water regime. Another factor is the degree of territorial protection under which all the mentioned sites fall. In addition to legislative protection, a higher degree of isolation (unavailability) of these areas also contributes. For these reasons, we conclude that the occurrence of this species is not directly affected or linked to military activities taking place in MTA Záhorie. In MTA (site 12) we also observed a species of community interest *Cordulegaster heros*. However, it was only one individual, we could not record its stable population. Most likely, it was an accidental flight of this individual from a nearby stream, which represents its more typical habitat.

From species with high ecological value, we further confirmed the occurrence of 7 species of national interest (together from all sides) – *Sympecma fusca*, *Aeshna isosceles*, *Anax imperator*, *Brachytron pratense*, *Somatochlora flavomaculata*, *Libellula (= Ladona) fulva*, and *Orthetrum coerulescens*. The abundance of these species was also mostly higher inside the MTA (tab 1., tab. 2.). The overall abundance of *Leucorrhinia pectoralis* was higher outside the MTA, however, it was significantly influenced by the site Vanišovec (site 3), where we recorded up to 54 individuals. The number of individuals of the species *Orthetrum coerulescens* is also significant, which we recorded only in the area in the MTA, mainly in the peat bog on Kotlina 3 (site 12). We also compared species included in the Slovak red list of dragonflies (David, 2001). Figure 2 shows, that more or comparably many such species were in the sites in the MTA, while species *Lestes virens*, *Aeshna mixta*, *Orthetrum coerulescens*, *O. brunneum*, *Sympetrum danae* and *S. meridionale* were recorded only inside the MTA.

One of the results of our research was the confirmation for the territory of the Borská nížina lowland of the species *Orthetrum brunneum*. This species is relatively common for the territory of Slovakia, nevertheless, the mention of its occurrence in this specific area has not been published for the last 20 years. However, from our research, we believe that it was also present during an earlier period. We recorded its occurrence in the sites Bežnisko and Kotlina 1 directly in the MTA. Both sites are also part of the territory of community interest. In the case of the Bežnisko site (site 9), the hypothesis was confirmed that disturbances caused by military training activity may have a positive effect on the biota. Thanks to the regular passage of military hardware through a part of this site, the water surface is systematically deepened and the onset of succession is prevented. This has increased the overall diversity of habitats in the site, which provides a refuge for a wider range of aquatic organisms, including dragonflies. One of the main problems in the protection of freshwater habitats located in military training areas is, paradoxically, the cessation of military activity (Harabiš and Dolný, 2018). Jentsch *et al.* (2009) also pointed out in their study the problems associated with the disappearance of regular disturbances in abandoned MTAs. Today, these activities replace the once naturally occurring disturbances, and without their action, many habitats would have disappeared due to the onset of succession (Cizek *et al.*, 2013). The site Kotlina 1 (site 10) has a completely different character. It is formed by an extremely important and preserved natural peat bog. We can assess that isolation has the most favorable effect for this type of habitat. It is located in close proximity to the impact part of the shooting range and the impact of human activity right on the site is minimal. In the years 2007–2008, the site was part of the revitalization project LIFE WETREST – Restoration of wetlands in the Záhorská nížina lowland. Following the implementation of management measures taken to restore the natural water regime, the site was left to self-development. Even after more than 10 years from the implementation, we can consider the current state as favorable, which was also confirmed by the occurrence of ecologically important species of dragonflies.

We also recorded differences in the compared areas after calculating the diversity indices, which allowed us to compare whole zoocenoses. From the values of the Shannon-Wiener index (Fig. 3), we can see that the highest diversity was recorded in site inside the MTA (sites 8) providing more diverse types of habitats for dragonflies.

The total equitability (Fig. 4), which expresses the balance of species, is similar for both territories. It can be said that the closer it is to the numerical value of 1, the fewer species dominate compared to others in a given site. If the value of equitability were exactly 1, it would mean that all species in this site are represented by the same number of individuals. We calculated the lowest for site Kotlina 3 (site 12). It is an anthropogenically created fire water tank in the MTA. The number of species and individuals was relatively high for such a small site, however, from the low value of equitability, we see that one species (*Coenagrion puella*) significantly dominated over the others.

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 31, issue 3, 2021, pp. 129 - 136

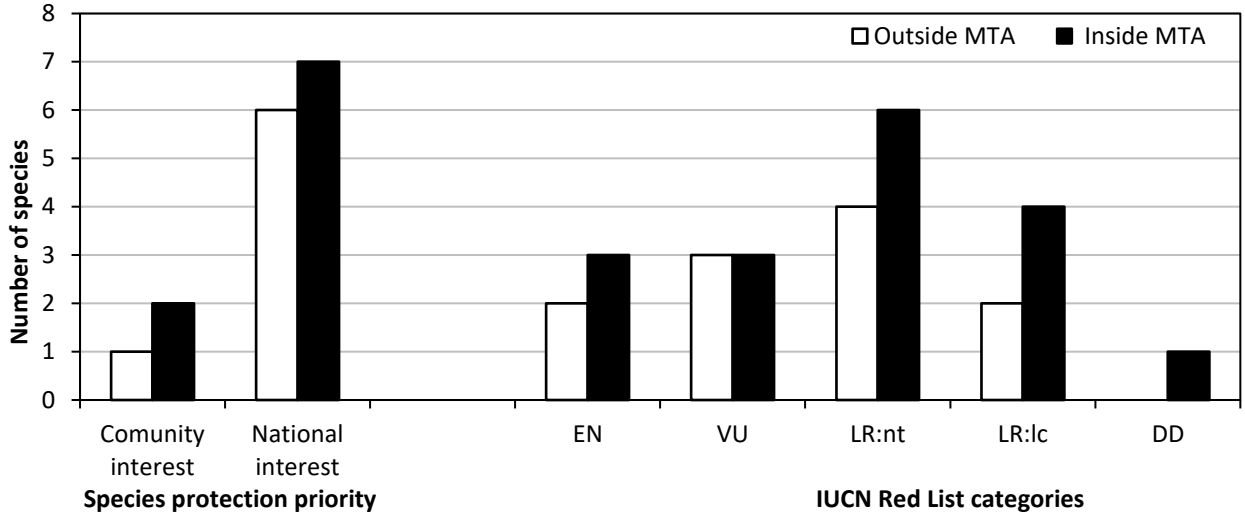

Fig. 2. The abundance of ecologically important species (species of community and national interest and species from Slovak red list of dragonflies) in sites inside and outside the MTA Záhorie.

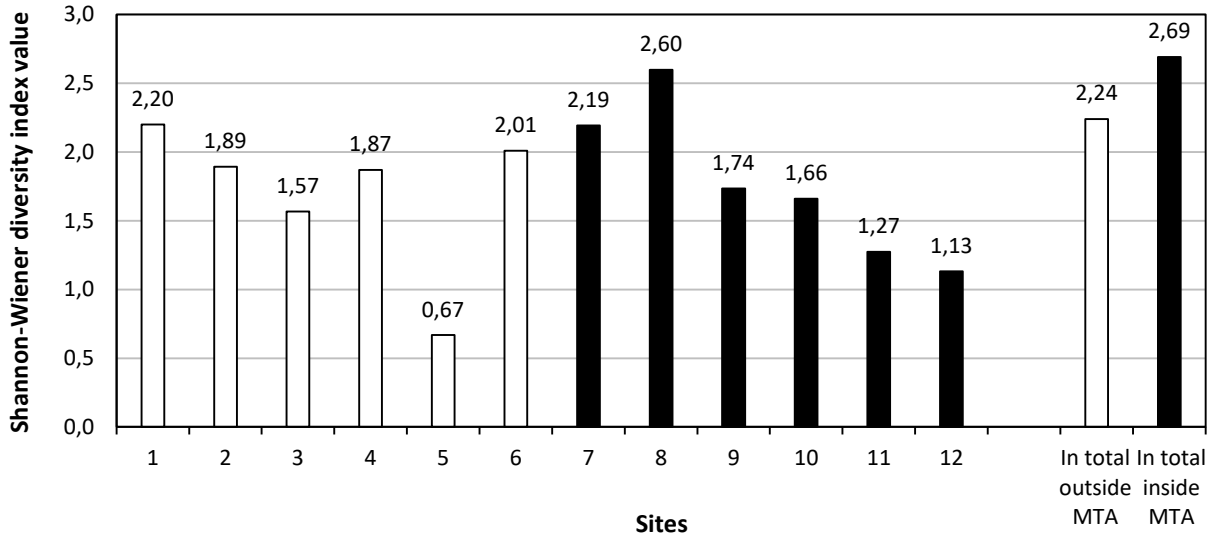

Fig. 3. Comparison of sites evaluation by Shannon-Wiener diversity index.

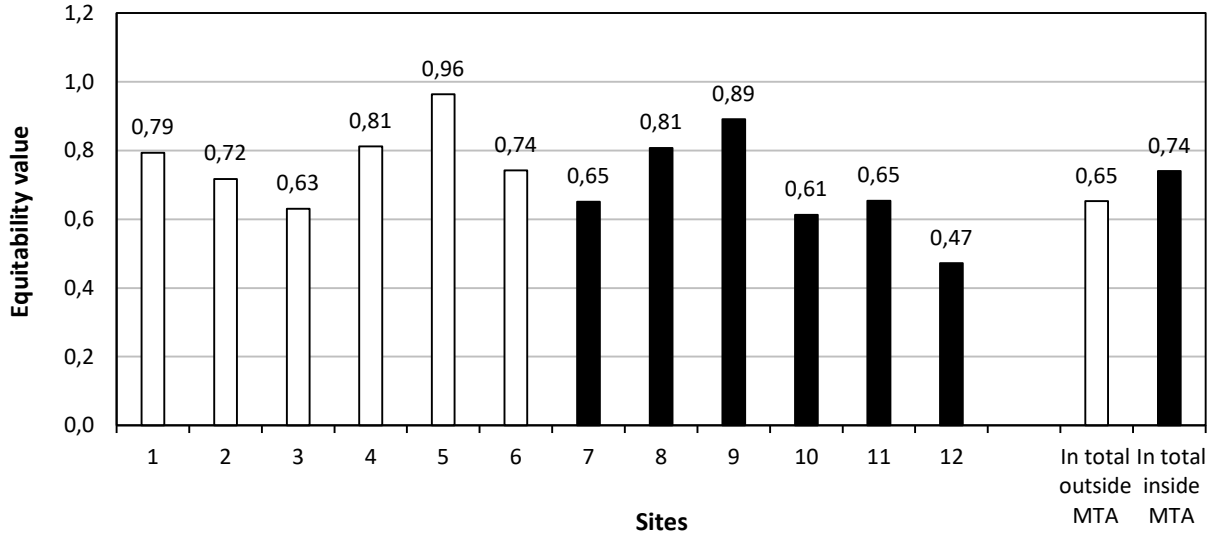

Fig. 4. Comparison of sites evaluation by equitability.

Table 1.

Systematic overview of the determined material of dragonflies in sites outside the MTA

Species / Sites outside the MTA	1	2	3	4	5	6	∑N	D (%)	RL SR
Calopteryx splendens	1					6	7	0.49 (Sr)	-
Calopteryx virgo			1				1	0.07 (Sr)	-
Lestes dryas	6		33	2		1	42	2.94 (Su)	-
Lestes sponsa	7	33	35			4	79	5.52 (Do)	-
Lestes viridis						3	3	0.21 (Sr)	LR: nt
*Sympecma fusca**	4						4	0.28 (Sr)	LR: nt
Ischnura elegans	57	45					102	7.13 (Do)	-
Ischnura pumilio	24						24	1.68 (Re)	LR: nt
Erythromma najas						17	17	1.19 (Re)	-
Erythromma viridulum	1						1	0.07 (Sr)	LR: lc
Coenagrion puella	12	113	199	28		20	372	26.00 (Eu)	-
Coenagrion pulchellum		2	2			1	5	0.35 (Sr)	-
Pyrrhosoma nymphula			4	3		3	10	0.70 (Sr)	-
Platycnemis pennipes	11	1		1		10	23	1.61 (Re)	-
Aeshna affinis					11		11	0.77 (Sr)	LR: nt
Aeshna cyanea						1	1	0.07 (Sr)	-
*Aeshna isosceles**		2	5				7	0.49 (Sr)	VU
*Anax imperator**	3	9					12	0.84 (Sr)	-
*Brachytron pratense**		9	7	9		2	27	1.89 (Re)	VU
Cordulia aenea		5					5	0.35 (Sr)	-
*Somatochlora flavomaculata**		1	16	5		30	52	3.63 (Su)	VU
Libellula depressa	6			18			24	1.68 (Re)	-
Libellula quadrimaculata	3	17	22	8			50	3.49 (Su)	-
*Libellula fulva**						3	3	0.21 (Sr)	EN
Orthetrum cancellatum	10						10	0.70 (Sr)	-
Orthetrum albistylum	7						7	0.49 (Sr)	-
Crocothemis erythraea	2	4					6	0.42 (Sr)	LR: lc
Sympetrum sanguineum	5	57	309	22	7	52	452	31.59 (Eu)	-
Sympetrum striolatum						1	1	0.07 (Sr)	-
Sympetrum vulgatum				1			1	0.07 (Sr)	-
*Leucorrhinia pectoralis***		8	64				72	5.03 (Do)	EN
∑N	159	306	697	97	18	154	**1431**		
∑S	16	14	12	10	2	15	**31**		

Legend: ∑S – total number of species, ∑N – total number of individuals (imagos), D (%) – dominance of species and classification into categories (Eu – eudominant, Do – dominant, Su – subdominant, Re – recedent, Sr – subrecedent), sites: 1 – Amphibian hatchery, 2 – Zelienka, 3 – Vanišovec, 4 – Dolné Valy 1, 5 – Jasenácke, 6 – Horné Valy, * – species of national interest (in accordance with national legislation), ** – species of community interest (in accordance with Habitats Directive), RL SR – threat categories according to Slovak Red list of dragonflies (David, 2001) (EN – Endangered, VU – Vulnerable, LR:nt – Lower risk: near threatened, LR:lc – Lower risk: least concern, DD – Data deficient)

Table 2.

Systematic overview of the determined material of dragonflies in sites inside the MTA

Species / Sites inside the MTA	7	8	9	10	11	12	N∑	D (%)	RL SR
Calopteryx splendens	1			1	2	5	9	0,43 (Sr)	-
Calopteryx virgo						3	3	0,14 (Sr)	-
Lestes barbarus	2	29					31	1,48 (Re)	-
Lestes dryas	7	85			43		135	6,43 (Do)	-
Lestes sponsa	141	96		2			239	11,39 (Eu)	-
Lestes virens	3	21					24	1,14 (Re)	LR: nt
Lestes viridis	28	6		1			35	1,67 (Re)	LR: nt
*Sympecma fusca**	6	8			6		20	0,95 (Sr)	LR: nt
Ischnura elegans	276	14	3		1	1	295	14,05 (Eu)	-
Ischnura pumilio				1			1	0,05 (Sr)	LR: nt
Erythromma viridulum	3	2	3				8	0,38 (Sr)	LR: lc
Coenagrion puella	71	115	7	41	1	72	307	14,63 (Eu)	-
Coenagrion pulchellum	15	4					19	0,91 (Sr)	-
Pyrrhosoma nymphula				14			14	0,67 (Sr)	-
Platycnemis pennipes						2	2	0,10 (Sr)	-
Aeshna mixta	4						4	0,19 (Sr)	DD
Aeshna affinis	9	64	2		6		81	3,86 (Su)	LR: nt
Aeshna cyanea	1					1	2	0,10 (Sr)	-

*Aeshna isosceles**	4	16					20	0,95 (Sr)	VU
*Anax imperator**	4	12	1			2	19	0,91 (Sr)	-
*Brachytron pratense**	4	6					10	0,48 (Sr)	VU
*Cordulegaster heros***				1			1	0,05 (Sr)	-
Cordulia aenea	7	7					14	0,67 (Sr)	-
*Somatochlora flavomaculata**	6	13		37			56	2,67 (Su)	VU
Libellula depressa	3	3		2		7	15	0,71 (Sr)	-
Libellula quadrimaculata	106	79		28			213	10,15 (Eu)	-
*Libellula fulva**		1					1	0,05 (Sr)	EN
Orthetrum cancellatum	3						3	0,14 (Sr)	-
Orthetrum brunneum			2	6			8	0,38 (Sr)	LR: lc
*Orthetrum coerulescens**		20		122			142	6,77 (Do)	EN
Crocothemis erythraea	6	2					8	0,38 (Sr)	LR: lc
Sympetrum danae	13	10					23	1,10 (Re)	LR: lc
Sympetrum flaveolum				3			3	0,14 (Sr)	-
Sympetrum meridionale	1			1		1	3	0,14 (Sr)	LR: nt
Sympetrum sanguineum	163	96	1		19	2	281	13,39 (Eu)	-
Sympetrum striolatum	13						13	0,62 (Sr)	-
Sympetrum vulgatum	1	5		1		2	9	0,43 (Sr)	-
*Leucorrhinia pectoralis***	12	16					28	1,33 (Re)	EN
∑N	913	730	19	261	78	98	**2099**		
∑S	29	25	7	15	7	11	**38**		

Legend: ∑S – total number of species, ∑N – total number of individuals (imagos), D (%) – dominance of species and classification into categories (Eu – eudominant, Do – dominant, Su – subdominant, Re – recedent, Sr – subrecedent), sites: 7 – Orlovské vŕšky, 8 – Mešterova lúka, 9 – Bežnisko, 10 – Kotlina 1, 11 – Kramárka,12 – Kotlina 3, * – species of national interest (in accordance with national legislation), ** – species of community interest (in accordance with Habitats Directive), RL SR – threat categories according to Slovak Red list of dragonflies (David, 2001) (EN – Endangered, VU – Vulnerable, LR:nt – Lower risk: near threatened, LR:lc – Lower risk: least concern, DD – Data deficient)

CONCLUSION

The aim of our research was to prove that areas in MTAs can be a source of valuable habitats and high species diversity. We found out if and what effect military training activity can have on the occurrence of dragonflies. We evaluated it based on the occurrence of ecologically important species and diversity indices. We compared 6 sites located in the vicinity of MTA Záhorie and 6 sites located directly on the territory of MTA. Both compared areas were formed by sites of similar character and size. Based on the odonatological survey, we found that the results of diversity indices and the total number of species are more favorable for the MTA. Also, the presence of identified species with high ecological value was higher on sites inside MTA, where we can find heterogeneous types of habitats suitable for their occurrence. Important habitats for dragonflies are peatlands, which in the past were particularly endangered by peat extraction and drainage in order to obtain land for agriculture. According to a study from Estonia (Karofeld, 1998), not only in Slovakia was it possible to indirectly preserve these rare ecosystems due to the fact that they were located in the territory of the MTA. MTA, directly and indirectly, helps to maintain such habitats in favorable conditions. The overall area of the military district has a positive effect, which is also relatively well isolated from other negative human influences (excessive tourism, various sources of pollution, urbanization) due to strict security measures. Thanks to regular interventions of military hardware, new habitats suitable for dragonfly reproduction are created. This type of disturbance also prevents their significant transformation or extinction due to advancing succession. Sites located outside the MTA, where revitalization measures have been successfully implemented in the past (sites 2 and 3) and can be left to self-development, offer as suitable habitat for dragonflies as sites located in the Záhorie MTA (sites 7 and 8).

The sites Amphibian hatchery and Horné Valy (sites 1 and 6), where we recorded a relatively high number of species during our research, will gradually disappear without further management measures under the influence of the advancing succession, and with this, we also assume a decrease in the number of species. A similar site in the MTA is Bežnisko (site 9), which is regularly exposed to the passage of tanks and other military hardware, thanks to which overgrowth by vegetation and grounding is prevented.

Data analysis confirmed the hypothesis that sites located inside the MTA will have a higher diversity and number of species than those outside it. In the case of dragonfly habitats, the military training activities help to prevent their gradual overgrowth and grounding, while maintaining the various successive stages that are preferred by the different species of dragonflies. This leads to an increase in species diversity in such an area.

Based on the research, we can conclude that MTA Záhorie is an extremely valuable area from the point of view of odonatology and has great potential in terms of nature protection.

ACKNOWLEDGEMENT

We would like to thank RNDr. Jaromír Šíbl, PhD. for assistance in field research and material determination.

AUTHORS CONTRIBUTIONS

Conceptualization: Z.Š., B.L. and M.M.; Methodology: Z.Š. and B.L.; Data collection: Z.Š.; Data validation and processing: Z.Š. and B.L.; Writing – original draft preparation: Z.Š.; Writing – review and

editing: Z.Š., B.L. and M.M.

FUNDING

This research received no external funding. The research is a part of the master's degree project performed in the Department of Environmental Ecology, Faculty of Natural Sciences, Comenius University in Bratislava, Slovakia. Finalization of the study was conducted with the support of the Slovak National Grant Agency, VEGA project No. 2/0011/21 Landscape ecological aspects of green and blue infrastructure in creating the optimal spatial basis of ecologically stable areas in urbanized landscape.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Cizek O, Vrba P, Benes J, Hrazsky Z, Koptik J, Kucera T, Marhoul P, Zamecnik P, Konvicka M, Conservation Potential of Abandoned Military Areas Matches That of Established Reserves: Plants and Butterflies in the Czech Republic. PLoS ONE, 8(1): e53124, 2013.

David S, Red (Ekosozological) List of Dragonfly (Odonata) of Slovakia. In Baláž D, Marhold K, Urban P (Eds.): Red List of Plants and Animals of Slovakia. Ochr. Prír., 20 (Suppl.), 96–99, 2001.

Dolný A, Bárta D, Waldhauser M, Holuša O, Hanel L et al., The dragonflies of the Czech Republic: ecology, conservation and distribution. Czech Union for Nature Conservation, Vlašim, 672 pp, 2008.

Gajdoš P, Majzlan O, Spiders (Araneae) of the sandy and loess dunes in the south-western Slovakia. Folia faunistica Slovaca, 6, 19–32, 2001.

Hammer Ø, Harper DAT, Ryan PD, PAST: Paleontological Statistics software packagefor education and data analysis – Paleontologia electronica, 4(1), 9 pp, 2001.

Harabiš F, Dolný A, Military training areas as refuges for threatened dragonfly species: Effect of spatial isolation and military activity. Biol. Conserv., 217, 28–35, 2018.

Jentsch A, Friedrich S, Steinlein T, Beyschlag W, Nezadal W, Assessing Conservation Action for Substitution of Missing Dynamics on Former Military Training Areas in Central Europe. Restoration Ecology, 17(1), 107–116, 2009.

Kalivodová M, Kanka R, Miklós P, Sládkovičová V, Žiak D, Importance of Wetland Refugia in Agricultural Landscape Provided Based on the Community Characteristics of Small Terrestrial Mammals. Ekológia (Bratislava), 37(4), 358–368, 2018.

Karofeld E, Effects of bombing and regeneration of plant cover in Kõnnu-Suursoo raised bog, North Estonia. Wetlands Ecology and Management, 6, 253–260, 1998.

Krawczyk R, Zubel R, Komsta Ł, Military Training Areas and Vegetation – the Effect of Explosion Craters on Species Diversity along a Moisture Gradient. Polish Journal of Ecology, 67(3), 194–205, 2019.

Lindenmayer DB, MacGregor Ch, Wood J, Westgate MJ, Ikin K, Foster C, Ford F, Zentelis R, Bombs, fire and biodiversity: Vertebrate fauna occurrence in areas subject to military training. Biol. Conserv., 204, 276–283, 2016.

Mazzacano C, Paulson D, Abbott J, Backyard ponds: Guidelines for creating and managing habitat for dragonflies and damselflies. Migratory dragonfly partnership, Portland, 22 pp., 2014.

Mišíková K, Dobiášová K, Checklist of bryophytes of the Borská nížina lowland (Slovakia). Acta Botanica Universitatis Comenianae, 49, 19–29, 2014.

Quist MC, Fay PA, Guy ChS, Alan K, Knapp AK, Rubenstein BN, Military training effects on terrestrial and aquatic communities on a grassland military installation. Ecological Applications, 13(2), 432–442, 2003.

Reinhardt I, Kluth G, Nowak C, Szentiks CA, Krone O, Ansorge H, Mueller T, Military training areas facilitate the recolonization of wolves in Germany. Conservation Letters, e12635, 2019.

Simaika JP, Samways MJ, Frenzel PP, Artificial ponds increase local dragonfly diversity in a global biodiversity hotspot. Biodivers. Conserv., 25, 1921–1935, 2016.

Šíbl J, Klimová K, Restoration and management of sand dune habitats in Záhorie military training area. VTSÚ Záhorie, ŠOP SR and BROZ, Senica – Bratislava, p. 28, 2011.

Šíblová Z, Moyzeová M, Dragonflies and damselflies (Odonata) research of wetlands in the area of Borská nížina lowland. Ekologické štúdie, 10(1), 119–126, 2019.

Waldhauser M, Černý M, Dragonflies of the Czech Republic – A guide for determining our species and their larvae. Czech Union for Nature Conservation, Vlašim, 184 pp, 2014.

Warren SD, Holbrook SW, Dale DA, Whelan NL, Elyn M, Gimm W, Jentsch A, Biodiversity and the heterogeneous disturbance regime on military training lands. Restoration Ecology, 15(4), 606–612, 2007.

Whittaker RH, Evolution and measurement of species diversity. Taxon, 21(2–3), 213–251, 1972.

Zentelis R, Banks S, Roberts JD, Dovers S, Lindenmayer D, Managing military training-related environmental disturbance. J. Environ. Manage., 204, 486–493, 2017.