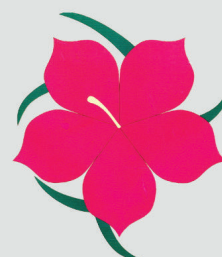


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ORIGINAL RESEARCH PAPER

MORTALITY OF BATS (CHIROPTERA) FROM WIND TURBINES IN MONTENEGRO

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Key words:

wind power farm, monitoring, bat fatalities, Montenegro.

Ključne riječi:

vjetropark, monitoring, smrtni slučajevi slijepih miševa, Crna Gora.

SYNOPSIS

The first post-construction monitoring of the impact of the windfarm on bat fauna in Montenegro started in 2019 and was completed in 2022 in the area of the “Možura” windfarm. This research paper presents the results of that monitoring, i.e. the data of bat fatalities at the windfarm in Montenegro. During four years of research and monitoring in the area of the “Možura” windfarm, where there are 23 wind turbines, a total of ten carcasses of bats were noted; one carcass of *Myotis myotis/M. blythii* was recorded in 2019, three carcasses of bats *Pipistrellus pipistrellus*, *Pipistrellus kuhlii* and *Hypsugo savii* were recorded in 2021, and six carcasses of bats *Pipistrellus pipistrellus*, *Pipistrellus kuhlii* and *Eptesicus serotinus* were recorded in 2022.

SINOPSIS

SMRTNOST SLIJEPIH MIŠEVA (CHIROPTERA) OD VJETROTURBINA U CRNOJ GORI

Prvi postkonstrukcioni monitoring uticaja vjetroelektrana na faunu slijepih miševa u Crnoj Gori započet je 2019. godine, a završen 2022 godine na području vjetroparka „Možura“. U ovom radu su dati rezultati tog monitoringa tj. zabilježeni slučajevi stradalih slijepih miševa od vjetroelektrana u Crnoj Gori. Tokom četiri godine istraživanja/monitoringa na području vjetroparka „Možura“ koji ima ukupno 23 vjetroelektrane, registrovano je ukupno deset stradalih jedinki slijepih miševa: u 2019. godini je nađeno jedno truplo vrste *Myotis myotis/M. blythii*, 2021. godine tri stradala slijepa miša vrsta: *Pipistrellus pipistrellus*, *P. kuhlii* i *Hypsugo savii*, a 2022. godine stradalo je šest jedinki slijepih miševa vrsta: *Pipistrellus pipistrellus*, *P. kuhlii* i *Eptesicus serotinus*.

INTRODUCTION

For the last twenty years, a large number of windfarms have been built to use wind energy in Europe (WindEurope, 2024).

In each phase of building, windpower plants might have a greater or lesser impact on bats. One of the most negative impacts of windpower plants is the mortality of bats.

The mortality of bats in windfarms occurs due to direct collision with, or as a result of “barotrauma” (Arnett et al., 2008; Baerwald & Barclay, 2009; Cryan & Barclay, 2009; Grodsky et al., 2011).

The post-construction monitoring of bat fauna has

shown numerous fatalities of bats in many countries (Ahlen, 2003; Johnson *et al.*, 2003; Kerns & Kerlinger, 2004; Arnett, 2005; Georgiakakis *et al.*, 2012).

For this reason, the impact assessments of the construction and operation of wind power stations are mandatory, in order to avoid or minimise negative impacts on bats.

Montenegro, currently, has three windfarms: one on the Krnovo and the second on the Gvozd, northeast of Nikšić city and the third on Možura Hill, located north of Ulcinj city. This research paper presents the results of the four-year post-construction monitoring

of the bat fauna in the “Možura” windfarm, i.e. the recorded cases of bat deaths in that locality in

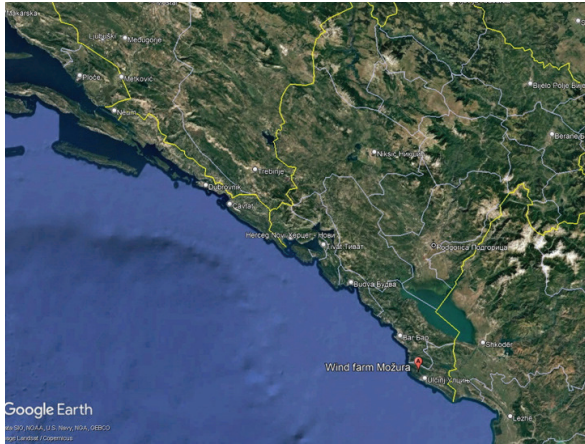


Figure 1: Location of the windfarm “Možura”.

SUBJECT AND RESEARCH METHODS

The “Možura” windfarm is located on the Možura hill (Figure 1), starting from the wind turbine number 1 (coordinates 41°59'16.8”N, 19°09'51.0”E, 420 m a.s.l.) to the wind turbine number 23 (coordinates 41°57'53.9”N, 19°14'35.2”E, 620 m a.s.l.). The individual power of the wind turbine is 2 MW, or 46 MW in total. The rotor diameter of the wind turbine is 121 m, and the pillar is 100 m high (Cigre, 2016) (Figure 2).

The relief of the Možura area is characterized by numerous sinkholes, karren fields and karstified depressions on limestone ridges extending in a northwest-southeast direction: Volujica (256 m a.s.l.) – Šasko brdo (106 m a.s.l.), Možura (589 m a.s.l.) – Briska gora (188 m a.s.l.), Marjan (398 m a.s.l.) – Bijela gora (327 m a.s.l.), and Mendre (162 m a.s.l.) – Pinješ (110 m a.s.l.), with intervening depressions and valleys: Kunje – Pelinkovići – Donja Klezna – Šasko Lake, Kručë – Bratica – Pistula and Valdanos – Ulcinj.

On the eastern side of Možura Hill, there are forests of the Hungarian oak (*Quercus frainetto*) and the Turkey oak (*Quercus cerris*), as well as pastures and areas of agricultural land. The northeastern slopes are covered by the Macedonian oak forests, sub-Mediterranean dry grasslands, and shrub vegetation, while the central part is dominated by the Macedonian oak forest. The southwestern side includes areas of pseudomaquis, true maquis, dense and impenetrable shrub vegetation, agricultural arable land, and meadows.

The methodology used to monitor bat mortality in the “Možura” windfarm was carried out according to

Montenegro.



Figure 2: The windfarm “Možura”.
Photo: Ćeda Ivanović

EUROBATS (Rodrigues et al., 2015). Research was conducted during the various periods each year from 2019 to 2022, respectively.

According to the methodology, the search process for dead bats started a half hour after sunrise to minimise removal of carcasses from scavengers. An area with a radius of 50 meters from each wind turbine was searched. Researchers were taking notes on the species of bats found in the field; position of carcasses (GPS coordinates, distance to the windturbine); state of carcasses; type of wounds; and evaluation of the date of death.

In accordance with the methodology, the shortest possible time interval between visits to windfarms was observed in about eight visits per month.

The methodology used to monitor bat mortality in the “Možura” windfarm was carried out according to EUROBATS (Rodrigues et al., 2015). Research was conducted during the various periods each year from 2019 to 2022, respectively.

According to the methodology, the search process for dead bats started a half hour after sunrise to minimise removal of carcasses from scavengers. An area with a radius of 50 meters from each wind turbine was searched. Researchers were taking notes on the species of bats found in the field; position of carcasses (GPS coordinates, distance to the windturbine); state of carcasses; type of wounds; and evaluation of the date of death.

In accordance with the methodology, the shortest possible time interval between visits to windfarms was observed in about eight visits per month.

RESULTS AND DISCUSSION

During a four-year period of this research, in the area of the windfarm “Možura”, a total of ten dead bats were found, namely:

- In 2019, one individual of the species: *Myotis myotis* (Borkhausen, 1779/*Myotis blythii* (Tomes, 1857);
- In 2021, three individuals of three species: *Pipistrellus pipistrellus* (Schreber, 1774) *Pipistrellus kuhlii* (Kuhl, 1817) and *Hypsugo savii* (Bonaparte, 1837);
- In 2022, six individuals of the species: *P. pipistrellus*, *P. kuhlii* and *Eptesicus serotinus* (Schreber, 1774).

Detailed findings are summarised below in Table 1.

Monitoring in 2019 was carried out from August, 22nd to October 30th, lasting 21 days. During that period, the wind power station was in trial mode, which means they were put into operation occasionally. In that period, no dead bats were found.

The second year field research was conducted from May 20th to October 21st 2020, lasting 40 fieldwork days. During this monitoring period, carcasses of bats were not found (Ivanović & Mulaomerović, 2020).

The third year of monitoring started on March 25th and ended on October 18th 2021, lasting 46 fieldwork days. In this period, three dead bats were found: *Pipistrellus pipistrellus*, *P. kuhlii* and *Hypsugo savii* (Ivanović, 2021; Ivanović & Mulaomerović, 2021).

The fourth year of field research, was conducted from April 15th to August 27th 2022. Before starting the research, we received a photo of a dead bat from the worker of the windfarm “Možura”, which was taken in July 2019. Based on it, it was concluded that it is most probably the species *Myotis myotis*/*M. blythii* (Figure 3) (Ivanović & Mulaomerović, 2019).

A bat carcass was found under WT 3 (41°59'12.53"N, 19°10'18.38"E, 406 m a.s.l.), according to the worker. Based on the photo, we concluded that the carcass is a few days old, partially eaten, and its left forearm was broken, which indicates a collision with wind turbine's rotor blades.

In the research period in 2019 (ultrasound detection with bat detector), the presence of *Myotis myotis* was not recorded in the windfarm, while the *Myotis blythii* was registered only a few times (Ivanović, 2019).

Table 1: Findings of dead bats on the windfarm “Možura”.

Species	Date	Location	Details
<i>Myotis myotis</i> / <i>Myotis blythii</i>	July 2019.	in the circle of the WT 3 41°59'12.53"N 19°10'18.38"E	An approximately 3-day-old carcass, partly mummified, open wounds were visible on the back side of the head and neck, partially eaten, the forearm was broken.
<i>Pipistrellus pipistrellus</i>	26.06.2021.	15 m west of WT 5 41°59'7.30"N 19°10'45.40"E	♂, ad, FA = 29,4mm, approximately 3 days old carcass, partly mummified.
<i>Pipistrellus kuhlii</i>	05.09.2021.	20 m northwest of WT 1 41°59'16.65"N 19° 9'51.67"E	♂, ad, FA = 34,2 mm, approximately 3 days old carcass, partly mummified.
<i>Hypsugo savii</i>	05.09.2021.	25 m west of WT 1 41°59'16.67"N, 19° 9'51.31"E	♀, ad, FA = 35,8 mm, fresh, bloody carcass, injury visible.
<i>Eptesicus serotinus</i>	05.06.2022.	35 m northwest of WT 2 41°59'15.30"N 19°10'2.82"E	♂, ad, FA = 48,3 mm, partly mummified, ruptured abdominal cavity (possible "barotrauma").
<i>Pipistrellus kuhlii</i>	05.06.2022.	Under WT 21 41°58'1.68"N 19°14'12.03"E	♂, ad, FA = 33,6 mm, approximately 2-day-old carcass, partly mummified.
<i>Eptesicus serotinus</i>	05.06.2022.	Under WT 21 41°58'1.94"N 19°14'11.55"E	♀, ad, FA = 48,7 mm, fresh carcass.
<i>Pipistrellus kuhlii</i>	05.06.2022.	Under WT 22 41°57'57.02"N 19°14'22.77"E	♂, ad, FA = 33,8 mm, fresh carcass.
<i>Pipistrellus pipistrellus</i>	06.06.2022.	Under WT 18 41°58'15.07"N 19°13'37.59"E	♀, ad, FA = 30,2 mm, fresh carcass.
<i>Eptesicus serotinus</i>	06.06.2022.	Under WT 18 41°58'14.73"N 19°13'37.50"E	♂, ad, FA = 49,2 mm, fresh carcass.

Abbreviations: WT- wind turbine, ♀ - female, ♂ - male, ad - adult, FA - forearm length

During the research in the years 2020, 2021 and 2022 (ultrasound detection with a bat detector), species from the genus *Myotis* had extremely low/negligible activity in the windfarm (Ivanović & Mulaomerović, 2020; 2021; 2022).

Species *Myotis myotis* and *Myotis blythii* were registered in a wider area of the windfarm, in the cave on Velika/Velja Gorana (41°59'33.77"N, 19°13'53.55"E), the Sumporna pećina Cave (41°55'11.76"N, 19°12'47.94"E), and the Jošova pećina Cave (41°55'7.02"N, 19°12'53.97"E) (Presetnik et al., 2014; 2017).

It can be assumed that the death of *Myotis myotis*/*Myotis blythii* in the windfarm has happened during an overflight the windfarm from the shelter/cave on Velja Gorana to the grassy areas on the southern side of the Možura hill and Ulcinj/Solana.

Mortality of these species in European windfarms is not significant due to their low flying, i.e. flight near and around vegetation (Dietz et al., 2009; Rodrigues et al., 2015).

Pipistrellus pipistrellus (Figure 4) is a very rare species in the area around Bar and Ulcinj (Presetnik et al., 2014; Théou & Đurović, 2015; Théou et al., 2020). During the four years of monitoring (ultrasound detection with a bat detector) on the windfarm "Možura", extremely low activity of this species was recorded (Ivanović, 2019; Ivanović & Mulaomerović, 2020; 2021; 2022).

Pipistrellus pipistrellus has the highest mortality rate from wind turbines (Rodrigues et al., 2015). Mortality of these species is very high where windfarms are located near forests, while in open areas, mortality is significantly lower (Niermann et al., 2009).

Pipistrellus kuhlii (Figure 5 and 7) is the most common species that has been recorded around Bar and Ulcinj (Presetnik et al. 2014, 2017; Théou & Đurović, 2015; Théou et al., 2020). Among all identified species (ultrasound detection) in the wind farm "Možura", *Pipistrellus kuhlii* had the highest activity (Ivanović, 2019; Ivanović & Mulaomerović, 2020; 2021; 2022).

Pipistrellus kuhlii has a high risk of collision with the wind turbines (Rodrigues et al., 2015). This species is also included in the high-risk category of mortality in windfarms (Rodrigues et al., 2015).

Hypsugo savii (Figure 6) is the third most numerous species (with the phonetic group *Pipistrellus kuhlii/nathusii* and *Tadarida teniotis*) that was recorded in the "Možura" windfarm during monitoring (Ivanović, 2019; Ivanović & Mulaomerović, 2020; 2021; 2022). This species also belongs to high-risk category of

mortality in windfarms (Rodrigues et al., 2015).

The activity of *Eptesicus serotinus* (Figure 7, in the middle) in the "Možura" windfarm, during four years of monitoring, was of low intensity. (Ivanović, 2019; Ivanović & Mulaomerović, 2020; 2021; 2022). Fatalities of this species from wind turbines have been recorded, but not in such significant numbers (Rodrigues et al., 2015).



Figure 3: Carcass of *Myotis myotis*/*M. blythii*.
Photo: Robin Lee



Figure 4: Carcass of *Pipistrellus pipistrellus*.
Photo: Vera Lasica



Figure 5: Carcass of *Pipistrellus kuhlii*.
Photo: Čeda Ivanović

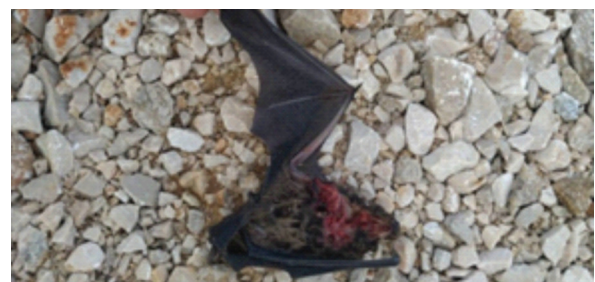


Figure 6: Carcass of *Hypsugo savii*.
Photo: Čeda Ivanović



Figure 7: Carcasses of *Pipistrellus kublii*, *Eptesicus serotinus*, *Pipistrellus pipistrellus*.
Photo: Marko Lasica

CONCLUSION

During the monitoring period of four years (2019-2022), ten dead bats were found on the “Možura” windfarm.

All fatalities of species of bats are in the category of high risk of collision with wind turbines, except the species of the genus *Myotis*.

The number of days spent in the research field, the method of searching for carcasses, the number of searchers, etc., certainly has an effect on the final number of dead bats found. The number of days spent in the field, the carcass search methodology, the number of searchers and related factors undoubtedly influence the final number of recorded bat fatalities.

During surveys of bat mortality in this area, no searcher efficiency trials were conducted to assess carcass detection rates, nor were trials carried out to determine the proportion of placed carcasses removed by predators before searchers entered the field.

Considering a lack of data on the mortality of bats in windfarms from neighbouring countries (Bašić et al., 2017; Kapeš, 2018; Zgajmajster et al., 2007; Jančar, 2006), we can conclude that these data represent a significant contribution to the knowledge in research about the ecology of bats in relation to wind power plants in Montenegro and thus in the entire European bat fauna.

REFERENCES:

- AHLEN, I. 2003: Wind turbines and bats - a pilot study. Final report 11. December 2003. - *Sveriges Lantbruksuniversitet, Department of Conservation Biology*, 5 pp. Available from: <http://docs.wind-watch.org/Ahlen-windturbines-bats-2003.pdf> (22. 1. 2023.).
- ARNETT, E. B. 2005: Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat fatality search protocols, patterns of fatality, and behavioural interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative. - *Bat Conservation International*. Austin, Texas, USA, 187 pp.
- ARNETT E. B., BROWN W. K., ERICKSON W. P., FIEDLER J. K., HAMILTON B. L., HENRY T. H., JAIN A., JOHNSON G. D., KERNS J, KOFORD R. R., NICHOLSON C. P., O'CONNELL T. J., PIORKOWSKI M. D., TANKERSLEY JR. R. D. 2008: Patterns of bat fatalities at wind energy facilities in North America. - *Journal of Wildlife Management*, 72: 61–78.
- BAERWALD, E. F. & BARCLAY, R. 2009: Geographic Variation in Activity and Fatality of Migratory Bats at Wind Energy Facilities. - *Journal of Mammalogy*, Lawrence, Kansas, 90, 6: 1341–1349.
- BAŠIĆ, I., ČURKOVIĆ, I., LUKAČ, D. 2017: Utjecaj vjetroelektrana na populacije šišmiša. 20. smotra i natjecanje hrvatskih Globe škola – Zadar, 2017., 6 pp. Available from: https://globe.pomsk.hr/smotra2017/projekti/Matonickin/Opis%20projekta%20Kastel%20staflic_final.pdf (19. 12. 2022.).
- CIGRE, 2016: Elaborat o priključenju VE Možura na prenosni sistem Crne Gore. *Elektroenergetski koordinacioni centar*, d.o.o, Podgorica, 11 pp.
- CRYAN, P. M. & BARCLAY, R. M. R. 2009: Causes of bat fatalities at wind turbines: hypotheses and predictions. - *Journal of Mammalogy*, Lawrence, Kansas, 90, 6: 1330–1340.
- DIETZ, C., VON HELVERSEN, O., NILL, D. 2009: Bats of Britain, Europe & Northwest Africa. - *A & C Black*, London, 400 pp.
- GEORGIAKAKIS, P., KRET, E., CARCAMO, B., DOUTAU, B., KAFKALETOU- DIEZ, A., VASILAKI, D., PAPADATOU, E. 2012: Bat fatalities at wind farms in north-eastern Greece. - *Acta Chiropterologica*, Warsaw, 14, 2: 459–468.

- GRODSKY, S. M., BEHR, M. J., GENDLER, A., DRAKE, D., DIE TERLE, B. D., RUDD, R. J., WALRATH, N. L. 2011: Investigating the causes of death for wind turbine-associated bat fatalities. - *Journal of Mammalogy*, Lawrence, Kansas, 92, 5: 917–925.
- IVANOVIĆ, Č. 2019: Stanje faune slijepih miševa na području vjetroparka “Možura”. - *E3 Consulting*, Podgorica, 44 pp.
- IVANOVIĆ, Č., 2021: Prvi zabilježeni slučajevi stradalih slijepih miševa na vjetroelektrani u Crnoj Gori. - *Nas krš*, Sarajevo, XLI, 54.
- IVANOVIĆ, Č. & MULAOMEROVIĆ, J., 2019: Prvi slučaj stradanja šišmiša na farmi vjetroturbina u Crnoj Gori. - *Nas krš*, Sarajevo, XXXIX, 52: 45–48.
- IVANOVIĆ, Č. & MULAOMEROVIĆ, J. 2020: Prva godina postkonstrukcionog monitoringa slijepih miševa u vjetroparku “Možura”. - *E3 Consulting*, Podgorica, 27 pp.
- IVANOVIĆ, Č. & MULAOMEROVIĆ, J. 2021: Druga godina postkonstrukcionog monitoringa slijepih miševa u vjetroparku “Možura”. - *E3 Consulting*, Podgorica, 47 pp.
- IVANOVIĆ, Č. & MULAOMEROVIĆ, J. 2021: *Pipistrellus pipistrellus*, 26. 6. 2021, Možura windfarm (Montenegro) / *Pipistrellus pipistrellus*, 26. 6. 2021, vjetropark Možura (Crna Gora). - *Hypsugo*, Sarajevo, VI, 1: 60-62.
- IVANOVIĆ, Č. & MULAOMEROVIĆ, J. 2022: Treća godina postkonstrukcionog monitoringa slijepih miševa u vjetroparku “Možura”. - *E3 Consulting*, Podgorica, 26 pp.
- KAPEŠ, M. 2018: Utjecaj vjetroelektrana na okoliš. Završni rad. - *Međumursko veleučilište u Čakovcu*, 54 pp. Available from: <https://urn.nsk.hr/urn:nbn:hr:110:148540> (19. 12. 2022.).
- KERNS, J., KERLINGER, P. 2004: A study of bird and bat collision fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual report for 2003. - *FPL Energy and Mountaineer Wind Energy Center Technical Review Committee*, 39 pp., Available from: <https://tethys.pnnl.gov/sites/default/files/publications/Curry-2004.pdf> (19. 12. 2022.).
- JANČAR, T. 2006: Vetrna elektrana Trtar Krtolin (Hrvaska) ubila Savijevega netopirja. - *Glej, netopir!*, Ljubljana, 3, 1, 34.
- JOHNSON, G. G., ERICSON, W. R., STRICKLAND, M. D., SHEPERD, M. F., SHEPERD, D. A., SARAPPO, S. A. 2003: Mortality of bats at a large-scale wind power development at Buffalo Ridge, Minnesota. - *The American Midland Naturalist*, Notre Dame, Indiana, 150: 332-342.
- NIERMANN, I., BEHR, O., BRINKMAN, R. 2009: Bat fatalities at wind energy facilities in Germany. In: 1st International Symposium on Bat Migration: Berlin, 16th - 18th of January 2009. - *Leibniz Institute for ZOO and wildlife research*, Berlin, 23 pp.
- PRESETNIK, P., PAUNOVIĆ, M., KARAPANDŽA, B., ĐUROVIĆ, M., IVANOVIĆ, Č., ŽDRALEVIĆ, M., BENDA, P., BUDINSKI, I. 2014: Distribution of bats (Chiroptera) in Montenegro. *Vespertilio*, Praha, 17: 129–156.
- PRESETNIK P., RADONJIĆ, M., PAVLOVIĆ, E., GOJZNIKAR, J., JOVANOVIĆ, M. 2017: Rezultati istraživanja faune slijepih miševa tokom istraživačkog kampa studenata biologije „Ekosistemi Balkana – Skadarsko jezero 2017” (Crna Gora). - *Hypsugo*, Sarajevo, II, 2: 41-52.
- RODRIGUES, L., BACH, L., DUBOURG-SAVAGE, M.-J., KARAPANDŽA, B., KOVAČ, D., KERVYN, T., DEKKER, J., KEPEL, A., BACH, P., COLLINS, J., HARBUSCH, C., PARK, K., MICEVSKI, B., MINDERMAN, J. 2015: Guidelines for consideration of bats in wind farm projects. Revision 2014. EUROBATs Publication Series No. 6 (English version). - *UNEP/EUROBATs Secretariat*, Bonn, Germany, 133 pp.
- THÉOU, P. & ĐUROVIĆ, M. 2015: Conservation action plan for bat population in Shkodër/Skadar area. - *Montenegrin Ecological Society*, Podgorica, 72 pp.
- THÉOU P., RADONJIĆ, M., LOCE, E., STOJANOV, A., RALEVIĆ, S. 2020: New data on bats from the Shkodër/Skadar lake – Buna/Bojana river transboundary area (Albania and Montenegro). - *Hypsugo*, Sarajevo, 5, 1: 14–28.
- WINDEUROPE, 2024: Wind energy facts and figures. 32 pp. Available from: <https://proceedings.windeurope.org/.../20250317-Policy-booklet-Value-of-wind.pdf>
- ZAGMAJSTER, M., JANČAR, T., MĻAKAR, J. 2007: First record of dead bats (Chiroptera) from wind farms in Croatia. - *Nyctalus*, Berlin, 12, 2-3: 234-237.

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ORIGINAL RESEARCH PAPER

HABITAT SUCCESSION AND POPULATION DENSITY OF BREEDING *Lanius collurio* IN PAŠIĆA POLJE, BOSNIA AND HERZEGOVINA

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Ključne riječi:

Rusi svračak,
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gustina populacije,
pokrivenost žbunjem,
Bosna i Hercegovina.

SYNOPSIS

This study provides the first comprehensive information on the habitat preferences of the Red-backed Shrike (*Lanius collurio*) in Pašića polje, Bosnia and Herzegovina. The research was conducted in an area of approximately 100 ha in the municipality of Bosansko Grahovo. Population density varied depending on the ratio of trees to shrubs. The results show that the most suitable habitats for this species are mosaic landscapes with 10% to 50% shrub cover. Significantly higher abundance was observed in habitats with 10% to 30% shrub cover compared to forests or pastures. These findings highlight the influence of habitat type on Red-backed Shrike abundance in Pašića polje. The study also presents population estimates and habitat associations across eight habitat types, demonstrating that shrub cover and habitat heterogeneity are key factors for conservation planning.

SINOPSIS

SUKCESIJA STANIŠTA I UTICAJ NA GUSTINU POPULACIJE SVRAČKA (*Lanius collurio*) U PAŠIĆA POLJU, BOSNA I HERCEGOVINA

Ova studija pruža prve sveobuhvatne podatke o stanišnim preferencijama crvenoleđeg svračka (*Lanius collurio*) u Pašića polju, Bosna i Hercegovina. Istraživanje je sprovedeno na području od približno 100 ha u opštini Bosansko Grahovo. Gustina populacije varirala je u zavisnosti od odnosa drveća i žbunja. Rezultati pokazuju da su najpogodnija staništa za ovu vrstu mozaični pejzaži sa 10% do 50% pokrivenosti žbunjem. Znatno veća brojnost zabeležena je u staništima sa 10% do 30% pokrivenosti žbunjem u poređenju sa šumama ili pašnjacima. Ovi nalazi ističu uticaj tipa staništa na brojnost crvenoleđeg svračka u Pašića polju. Studija takođe prikazuje procene brojnosti i povezanost vrste sa osam različitih tipova staništa, ukazujući na to da su pokrivenost žbunjem i stanišna heterogenost ključni faktori za planiranje očuvanja.

INTRODUCTION

The Red-backed Shrike (*Lanius collurio*) breeds across most parts of Europe and western Asia and winters in tropical Africa. According to the IUCN Red List (2024), it is classified as Least Concern (LC), with a stable population trend. However, some parts of its range have experienced significant population declines, making its status less secure in certain areas. According to Lefranc & Worfolk (1997), the Red-backed Shrike breeds in temperate and Mediterranean climates. It requires sunny, warm, usually dry, and

level or gently sloping terrain, with scattered bushes, shrubs, or low trees that provide hunting perches overlooking areas of short grass, heath, or bare soil. The species generally breeds between 500 and 1,500 meters above sea level but can occasionally be found up to 1,700 meters. Locally, it may also occur at sea level and in low hills.

High-quality habitats typically feature a mosaic of grassy vegetation, alternating between tall and short growth, with bare patches and available perches. In agricultural landscapes, the species occupies neglected overgrown patches, heaths, open downs, abandoned

orchards and gardens, hedgerows, and scrub along railways or roadsides. It is also found in temporary steppe-like habitats, such as military training grounds, burned forests, forest clearings, and spruce (*Picea* spp.) plantations (Lefranc & Worfolk, 1997; Brambilla et al., 2007; Yosef et al., 2012; Polak & Filipiuk, 2014). Additionally, it breeds in forest clearcuts, particularly in northern Europe (Hollander et al., 2011; Söderström & Karlsson, 2011; Lislevand, 2012).

Nesting habitat selection depends on breeding requirements, while habitat use outside the breeding season is determined by food availability (Block & Brennan, 1993). The Red-backed Shrike is particularly sensitive to agricultural intensification and land abandonment, both of which can significantly impact its population (Brambilla et al., 2007).

Nesting territory characteristics have been described in numerous studies (Cramp & Perrins, 1993; Olsson, 1995a; Lefranc & Worfolk, 1997; Kuper et al., 2000; Harris & Franklin, 2000a; Guerriere & Castaldi, 2006; Casale & Brambilla, 2009; Polak, 2012; Morelli et al., 2016, among others). The highest densities of breeding pairs in Europe are found in farmland, forest edges, grasslands, dense hedgerows along roadsides, and open areas with bushes or small tree patches, as well as in parks and open gardens (Tryjanowski et al., 2000; Morelli, 2012; Kwieciński & Pawlak, 2015).

Research in the Western Balkans remains limited, with most studies focused on Central or Northern Europe (Kuzniak & Tryjanowski, 2000; Vanhinsbergh & Evans, 2002; Roos & Pärt, 2004; Tryjanowski et al., 2006; Baláž, 2007; Titeux et al., 2007; Goławski & Meissner, 2007; Brambilla et al., 2009; Svendsen et al., 2015). This species is also present in the karst poljes of Bosnia and Herzegovina (Obratil 1984, 1987 & 2006; Kotrošan et al., 2013; Marić 2022a, 2022b, 2023), although data on its biology remain scarce and fragmented. Further research into the reproductive characteristics and ecological requirements of this species in karst poljes under different land management regimes is crucial to understanding the factors affecting its survival.

According to Marić (2022a), nesting of *L. collurio* was recorded in six habitat types: 1) forests along the banks of creeks and rivers, 2) tall deciduous and evergreen shrubs (up to 7–10 m) or degraded forests with large clearings in various stages of degradation, 3) deciduous shrubs: bushes, low trees, and shrubs (mostly up to 3 m high) with large clearings (20–70%), 4) dry calcareous grasslands, from karst poljes to the montane zone (habitats 3 and 4 have undergone

afforestation in the last 20 years), 5) meadows and agricultural lands (arable fields, grasslands, and wet meadows of karst poljes), 6) settlements (villages and towns) with orchards.

My aim was to study the population density of Red-backed Shrikes nesting in different habitats to compare species abundance across nine habitat types and determine habitat suitability in karst poljes. Identifying suitable habitats is essential for the effective conservation of this species.

METHOD

1. Study area

The study was conducted in the municipality of Bosansko Grahovo, in a karst polje (Pašića) in western Bosnia and Herzegovina. A 100-hectare study site was selected, extending approximately 6 km in length. The research area (44°07'N / 16°25'E) is located southeast of the village of Luka. The study area is situated at an elevation of 820–900 m above sea level and is covered by a mosaic of continental habitats that includes grasslands, shrublands, and woodlands. The central parts of karst poljes are generally marshy or cultivated areas, although each field has its own distinct landscape characteristics. Pašića Polje exhibits these features (Fig. 1). The central part of the polje (around 800 m a.s.l.) is classified as a Meadows & Agricultural land habitat type, through which the Korana River flows.

The dry, elevated areas are predominantly grasslands (DCG = Dry calcareous grasslands). Shrublands (SCH = deciduous bushes) typically border the grasslands (shrubs covered much of the study site), transitioning into tall shrublands (HSCH = high deciduous and evergreen shrubs), which at higher elevations develop into deciduous forests (For = forests, deciduous and evergreen) (habitat types according to Marić 2022). Most of the area is covered by human-modified natural vegetation. For more details on the characteristics of the study area, see Marić (2022a).

The selected sites

In 2019, I defined eight vegetation types based on vegetation structure and the percentage ratio between grassy vegetation vs bushes and forests. The selected sites include: one typical forest habitat, two habitats with predominantly shrub/forest vegetation, two habitats with an equal proportion of open areas and shrub/forest vegetation, and three habitats where pastures dominate. Pastures with scattered shrubs were studied in Marić (2022b).

The eight studied plots consist of: study plot consisted of: **1.** up to 10% open areas, 2% bushes and 88% woods-trees; **2.** about 30% open areas, 10% bushes (around open areas or around glades) and 60% woods; **3.** about 30% open areas, 50% bushes and 20% woods; **4.** about 50% open areas, 25% bushes and 25% woods; **5.** about 50% open areas, 45% bushes and 5% trees; **6.** about 70% open areas, 10% trees and 20% bushes; **7.** about 70% open areas, 30% bushes; **8.** about 90% open areas, 10% bushes. Rocky formations occur in all habitats and sometimes make up more than 5% of the habitat area.

1. For = forest (woods), deciduous and evergreen. The forest in the municipality of B. Grahovo is represented by several phytocoenoses (Marić, 2022a). In this area, one habitat type was defined: 91K0 - *Aremonio-Fagion* (according to the NATURA 2000 classification). Relatively well-preserved forests are rare, while degraded and sprout forests in various developmental stages are more common. Key species: *Fagus sylvatica*, *Acer obtusatum*, *Acer campestre*, *Fraxinus ornus*, *Carpinus betulus*, *Betula pendula*.

2. Degraded deciduous forests (ranging from 7 to 15 meters in height) with tall shrubs (up to 7m) and bushes, covering approximately 70% of the area (50% woods and 20% shrubs), with large forests

clearings. Key species: *F. sylvatica*, *Acer spp.*, *Quercus spp.*, *Sorbus aria*, *F. ornus*, *C. betulus*, *B. pendula*, *Populus tremula*. Shrubs are mainly dominated by *Corylus avellana* and *Crataegus spp.* Two habitat types were identified according to the NATURA 2000 classification: 9140 (*Aceri-Fagetum* – degraded stages) and 91K0 (*Ostrya-Fagetum* – degraded stages)

3. HSCH Forests with large clearings, consisting of deciduous tall shrubs and bushes, covering approximately 70% of the area (50% shrubs and 20% woods). NATURA 2000 habitat type: 9140 (*Aceri-Fagetum* – degraded stages) Key species: Trees: *C. betulus*, *Carpinus orientalis*, *Sorbus aucuparia*, *F. ornus*, *B. pendula*, *P. tremula*, *Pyrus pyraster*, Shrubs: *Rosa spp.*, *Crataegus spp.*, *C. avellana*, *Cornus mas*, *Cornus sanguinea*, *Ostrya carpinifolia*, Grasslands and grassy layers: Primarily classified under 6210, with some areas corresponding to 62A0 (according to NATURA 2000).

4. SCH = Deciduous bushes and shrubs, consisting of low trees and shrubs (mostly up to 5 meters in height), with large clearings (50%). Habitat composition: 50% open areas, 25% bushes, 25% woods. The grasslands and grassy layer correspond to the NATURA 2000 habitat types 6110, 6210, and 62A0. Key species: *Crataegus spp.* and *C. avellana* are dominates (approximately 50% vs others) followed by *Rosa spp.*, *C. mas*, *C. sanguinea*, *C. orientalis*, *O.*

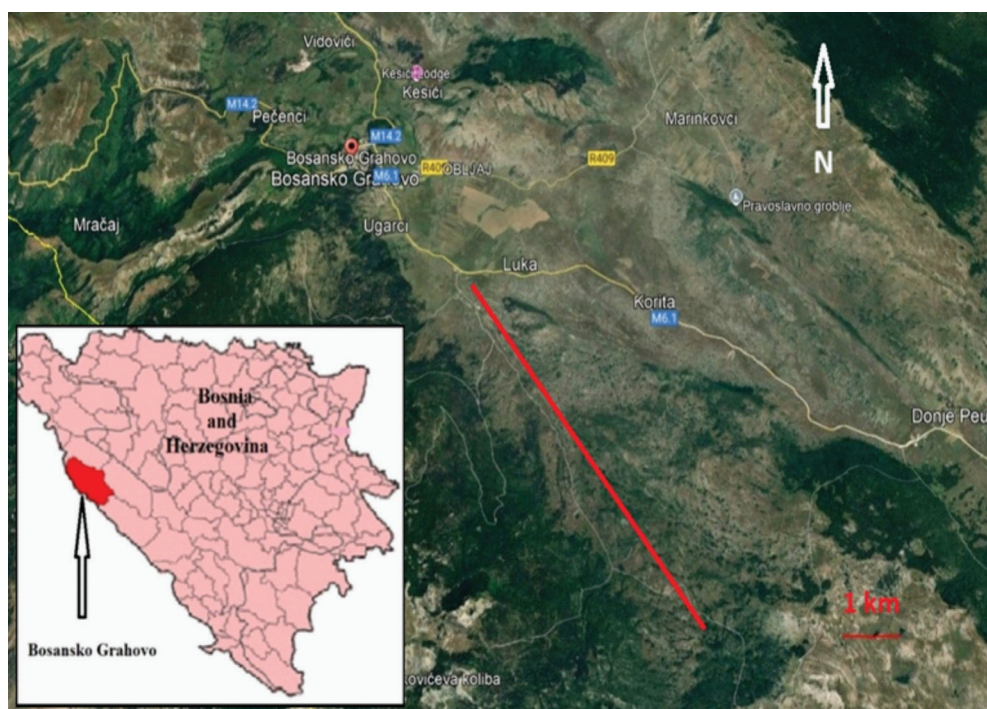


Figure 1: Position of investigated areas in the municipality of Bosansko Grahovo (localities): red line transects position.

carpinifolia, *F. ornus*, *S. aucuparia*, *P. tremula*, *Pyrus spinosa*, etc. These vegetation types represent common forms of succession, occurring in the progradation line as an intermediate developmental stage between pastures and permanent forest formations.

5. SCH = Deciduous Bushlands, Deciduous bushes and shrubs, consisting of low trees and shrubs (mostly up to 5 meters in height), with large clearings. Habitat composition: 50% open areas, 45% bushes, 5% trees. Key species: *C. avellana* (dominated), followed by *Rosa* spp., *Crataegus* spp., *Oreoherzogia* spp., *Amelanchier ovalis*, *C. mas*, *C. sanguinea*, *F. ornus*, *O. carpinifolia*, etc. These vegetation types are common forms of succession, occurring in the progradation line as an intermediate developmental stage between pastures and permanent forest formations. In all the previously described habitats, *Sesleria autumnalis* is the dominant grass.

6. DCG = Dry calcareous grasslands, these habitats are characterized by approximately 70% open areas, 20% bushes, and 10% trees. The tree layer mainly consists of *O. carpinifolia*, *F. ornus*, and *Prunus mahaleb*, while the shrub layer is predominantly composed of *C. avellana*=50%, and then follows *Crataegus* spp., *C. mas*, *C. sanguinea*, *Euonymus* spp., and *Oreoherzogia* spp. In open areas three habitat types have been defined (NATURA 2000 codes): 6110, 6210, and 62A0. The grasslands or the grassy layer are the following species: *Centaurea scabiosa*, *Eryngium campestre* and surrounding shrubs *Sesleria autumnalis* if the terrain is flat.

Habitat type 6110 is typically found around rocky outcrops and is often interspersed within other habitat types, such as 6210. The 6110 grassland vegetation consists mainly of: *Thymus* spp., *Globularia* spp., *Teucrium montanum*, *Sedum acre*, *Lotus corniculatus*, *Dorycnium germanicum*, *Potentilla* spp., and others. Vegetation of Habitat Types 6210 & 62A0 (NATURA 2000 Code) consists: *Festuca pseudovina*, *Brachypodium pinnatum*, *Bromus erectus*, *Koeleria pyramidata*, *Koeleria splendens*, *Leontodon hispidus*, *Orchis* spp. (e.g. *Orchis morio*), *Polygala comosa*, *Primula veris*, *Sanguisorba minor*, *Satureja subspicata*, *Satureja montana*, *Scorzonera villosa*, *Scabiosa leucophylla*, *Stipa bromoides*, *Teucrium montanum*, *Potentilla tomasiniana* (the dominant grassland species), than *Genista* spp., *Eryngium* spp., *Gentiana* spp., *Plantago* spp., *Trifolium* spp., *Salvia* spp., *Danthonia* spp., *Cirsium* spp., and others.

The mentioned grassland vegetation or pasture vegetation is also characteristic of the other three habitat types listed below.

7. DCG = Dry calcareous grasslands, habitats without trees, about 70% open areas and 30% bushes. A habitat with larger or smaller valleys, mostly covered in shrubs. The grassy and shrubby cover is mostly the same as in habitat 6, but tall trees are absent. Shrubs are generally up to 3 meters tall, sometimes slightly taller in the valleys.

8. DCG = Dry calcareous grasslands with small groups of shrubs or individual bushes, consisting of approximately 90% open areas and 10% shrubs. The shrub layer is mainly dominated by *C. avellana*, followed by *Crataegus* spp., *Rosa* spp., *Oreoherzogia* spp., and *C. mas*. In the past, the flat valleys were mown or ploughed, but they are now mostly overgrown with shrubs. The grass cover is generally similar to that in habitats 6 and 7.

In habitats numbered 5–8, *C. avellana* dominates with approximately 50–60%, followed by *Crataegus* spp., *Rosa* spp., and *C. mas* with around 30%, while all other shrub species account for about 10%.

2. Census method

Bird (Red-backed Shrikes) counts were conducted between May 20 and June 30 during the years 2019–2024 by the author. This period coincides with the breeding season of the studied species. Surveys were carried out at five-day intervals using the transect method, under favorable weather conditions—without rain and with wind not exceeding level 4 on the Beaufort scale—as such conditions hinder the detection of birds by sight and sound.

The abundance of Red-backed Shrikes was assessed within a 100-meter-wide strip on both sides of a 500-meter-long transect (10 ha). The selection of transect width was based on years of field experience (see Marić, 2021), indicating that a distance of 100 meters from individuals does not cause them to leave their perches. Eight transects were established in the study area, arranged in a single southeast–northwest sequence, with a minimum distance of 150 meters between them (as the distance between nests was usually less than 100 meters). A total of 142 systematic transect surveys were conducted. Each study site was surveyed at a slow walking pace, two to three times in the morning (06:00–12:00 h), during each study year. The route was approximately linear (totaling 5.7 km) to avoid overlap and minimize the risk of double counting. Each transect was walked in 20–25 minutes.

The survey unit was “the pair”, which meant a singing or otherwise observed male, observed female, a group of fledglings or inhabited nest (Koskimies

& Väisänen, 1988). The majority of the pairs were represented by singing males.

Vegetation structure was measured along all segments of each transect. Within these transects, the coverage of shrub vegetation, tree coverage, and the number of shrub and tree species were visually assessed.

3. Statistical analyses

The red-backed shrike abundance data gathered during the six monitoring years were compared using ANOVA and t- test. The same tests were run to compare data collected in the various breeding sites and years. The measures are presented as mean values, with max and minimum values. All statistical tests were independent and two-tailed. Results are considered significant if $P \leq 0.01$. All tests were carried out using the SPSS v. 13.0 software package.

The scores of all sampling were averaged in each line transect, and the mean scores of all transects were used for comparison because year did not affect the abundance (a short period for changes to occur), allowing us to pool across all 6 years for maximum sample size.

RESULTS

The results of *Lanius collurio* abundance across eight different habitat types, which vary in the proportion of trees and shrubs relative to grassland vegetation, are presented in Table 1. Significant differences in the

abundance of the Red-backed Shrike were found in relation to the percentage cover of woody and pasture vegetation. These differences were not statistically significant in habitats with a 50:50 ratio, nor between the two habitats with 10% and 30% tree cover, as well as between habitats 5 and 6 (i.e., 50% and 70% grassland/herbaceous vegetation), see table 2.

As the amount of open space increased, the abundance of Red-backed Shrikes significantly increased ($R = 0.92$) (Fig. 1), with the highest numbers recorded in the habitat containing only 10% shrub cover. However, no significant increase was found compared to the habitat with 30% shrub cover. The density of breeding pairs (or singing males) per 10 ha was 6.0 vs. 5.6.

The lowest abundance was observed in the forested habitat (90% tree cover), where only a single Red-backed Shrike pair was recorded during one year (with the nest found in a hawthorn bush). Nests in other habitat types were not the subject of systematic investigation.

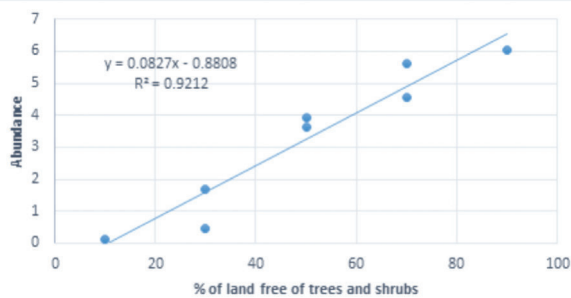
In forest habitats with small clearings, the Red-backed Shrike was not recorded at all, whereas it was observed only in areas with compact open patches of about 1 ha. In habitat type 2, with 30% open space and very few shrubs, the species was recorded at least once during the transect walk each year. In a habitat with denser shrub coverage (habitat type 3), usually one male was recorded per transect, occasionally two.

No habitats	1	2	3	4	5	6	7	8
%	10	30	30	50	50	70	70	90
Average	0.19	0.47	1.67	3.61	3.94	4.55	5.6	6.0
SD	0.403	0.515	0.485	0.70	0.72	0.62	0.698	0.594
Min	0	0	1	3	3	4	5	5
Max	1	1	2	5	5	5	7	7

Table 1: The average breeding density the population in study area (mean 10h¹), % = proportion of land uncovered by trees and shrubs.

	1 (10%)	2 (70%)	3 (70%)	4 (50%)	5 (50%)	6 (70%)	7 (70%)	8 (90%)
1	/	0.935	0,0001	0.00001	0.00001	0.00001	0.00001	0.00001
2	0.935	/	0.004	0.00001	0.00001	0.00001	0.00001	0.00001
3	0.0001	0.004	/	0.00001	0.00001	0.00001	0.00001	0.00001
4	0.00001	0.00001	0.00001	/	0.87	0.02	0.00001	0.00001
5	0.00001	0.00001	0.00001	0.87	/	0.42	0.00001	0.0001
6	0.00001	0.00001	0.00001	0.02	0.42	/	0.007	0.0001
7	0.00001	0.00001	0.00001	0.00001	0.00001	0.007	/	0.75
8	0.00001	0.00001	0.00001	0.00001	0.00001	0.0001	0.75	/

Table 2: Differences between eight groups (1–8). % = proportion of land uncovered by trees and shrubs. Numbers in bold indicate no statistical significance.



Graph 1: Abundance of *L. collurio* in eight habitats with different wood cover percentage class.

The highest number of males was recorded in the seventh and eighth habitat types (with 70% and 90% open space, respectively), most frequently totaling six males (see Table 1).

DISCUSSION

Lanius collurio (Linnaeus, 1758) is the most widespread species of the Laniidae family in Central Europe, and in the karst poljes of Bosnia and Herzegovina (Obratil, 2006; Marić, 2022). However, the habitat preferences of the Red-backed Shrike have not yet been studied in these poljes. According to Marić (2022a), the Red-backed Shrike, compared to other species, inhabits the widest range of habitats in the study area, specifically within the municipality of Bosansko Grahovo. This study provides data on the population size of the Red-backed Shrike across eight habitats differing in vegetation structure and cover. Estimating population size of any bird species is of great importance, particularly for conservation purposes. The research on *L. collurio* was conducted in an area undergoing rapid ecological transformation in the past, 15 to 20 years. These changes are largely attributed to the decline in domestic livestock, especially sheep, which historically outnumbered other types of grazing animals by a significant margin (Marić, 2022a).

The highest population densities were recorded in sites where shrub cover ranged between 10% and 30% (Graph 1). These results are consistent with previous studies conducted across various regions of Europe. According to Cramp & Perrins (1993), Farkas et al. (1997), and Gołowski & Gołowska (2007), the highest breeding pair densities in Europe occur in agricultural ecosystems, followed by forest edges, grasslands, dense roadside hedges, open areas with shrubs or small tree clusters, as well as parks and open gardens (Brambilla et al., 2007; Yosef et al., 2012; Morelli, 2012; Kwieciński & Pawlak, 2015; Tryjanowski et al., 2000). However, across different

parts of its range, this species shows significant variation in habitat preferences, particularly regarding vegetation cover and the specific types of shrubs present in the area (Cramp & Perrins, 1993; Olsson, 1995a; Lefranc & Worfolk, 1997; Harris & Franklin, 2000; Väli, 2005; Guerriere & Castaldi, 2006; Casale & Brambilla, 2009; Pawlak & Kwieciński, 2015).

The highest abundance found in habitats with 10% and 30% shrub cover is consistent with the findings of Brambilla et al. (2007). The height of shrubs is an important factor, usually ranging from 1 to 3 meters (Lefranc & Worfolk, 1997), while Morelli (2011) set the minimum suitable height at 0.5 meters. According to Väli (2005), the most frequent nesting sites are in human settlements, and the occurrence of this habitat type has been increasing over time. The same author also notes that nesting is relatively common in cleared forest areas, meadows with trees, other grassy landscapes, as well as in shrubland habitats and young forests. In the studied area, the highest abundance was recorded in human settlements (Marić, 2022b). According to research (Baláž, 2007; Svendsen et al., 2015; Morelli et al., 2016), the Red-backed Shrike is adapted to forest-steppe habitats with suitable perches and open areas, which are crucial for its hunting strategy. The choice of nesting habitat depends on breeding requirements, while habitat use outside the breeding season is determined by food availability (Block & Brennan, 1993).

In habitats with the most favorable conditions, an abundance of about 6 singing males/pairs was recorded (Table 1). A similar density of 5.4 pairs per 10 hectares was reported in southeastern Switzerland (Engadin) (Pasinelli et al., 2007), while Némethová (2002) recorded slightly higher values (up to 6.6 pairs per 10 hectares). The abundance of Red-backed Shrikes in this study was higher than the average values reported from most regions in Poland and several other European countries (Kuźniak, 1991; Winiecki et al., 1997; Guerriere & Castaldi, 2006; Sikora, 2007; Morelli, 2012; Brambilla et al., 2009; Gołowski et al., 2023). However, data from Hungary (Farkas et al., 1997) show higher values than in this work, then Casale and Brambilla (2009) reported a density of up to 10 pairs per hectare (from Italy) and Denac (2003) over 20 pairs per hectare from Slovenia.

The lowest abundance was recorded in forest ecosystems, which is consistent with findings from the literature (Brambilla et al., 2009; Ceresa et al., 2012 and all aforementioned authors). According to earlier research (Marić, 2022b), the abundance of the Red-backed Shrike in pastures with isolated shrubs



Figure 2: A typical habitat in a karst polje for *Lanius collurio* (approximately 10% shrub cover).

is significantly lower than in habitats with a greater number of individual shrubs or shrub groups (10–50% cover). In pastures without any shrubs or bushes, this species was not found in the past (unpublished data). Pasture habitats are often considered optimal for the Red-backed Shrike due to the abundance of food and suitable nesting sites, but only when there is a significant presence of shrubs (Lefranc & Worfolk, 1997; Brambilla et al., 2007).

A typical *L. collurio* territory covers an area from 1–2 ha up to 5–6 ha (Cramp & Perrins, 1993; Lefranc, 1993; Olsson, 1995b; Harris & Franklin, 2000; Svendsen et al., 2015), while this result indicates a territory size ranging from a minimum of 1 ha to 3 ha in areas without shrubs and trees, though these areas must be compact. According to Moes (1993) and Kuźniak & Tryjanowski (2000), a single pair's territory may reach up to 25 ha, which in this area would correspond to the density found in pastures with sparse individual shrubs and meadow/agricultural land (Marić, 2022b). Based on all the above, it can be concluded that the abundance of *Lanius collurio* varies depending on many factors and differs significantly across habitats in different geographical regions.

Changes over the past 30 years have led to the significant transformation of pastures that were once adjacent to forest ecosystems, which are now mostly converted into low woodlands. These pastures with sparse shrub cover now have more tall trees than shrubs, while open or small, mosaic-like areas remain only in shallow and rocky terrain. In the wider area of the study site, 20–30% of pastures—specifically areas where shrub cover was less than 50%—have already disappeared. As shown by the results of this study, such habitats are less suitable for this species, and its population is rapidly declining in these areas.

It has also been established that the gradual

encroachment of shrubs in pastures contributes to an increase in the abundance of *Lanius collurio* (Marić, 2022b). However, the results indicate that when shrub cover in pasturelands reaches approximately 50%, it significantly reduces the abundance of this species. Since the pastures in the karst fields, as well as in the surrounding habitats, have been abandoned for over 30 years, the process of succession toward shrub-dominated vegetation is already well underway. Given that natural succession is a slow process, the decline in the population of this species under such conditions is also expected to be gradual.

At the same time, many areas are being reforested with evergreen species (*Pinus* spp.), accelerating the transformation of pastures into shrubland and, ultimately, forest. Areas that were reforested 25–30 years ago have already developed into forest ecosystems (personal observation).

According to data from *Forest Management Company "Hercegbosanske šume" Ltd. Kupres*, (Šumsko gospodarsko društvo "Hercegbosanske šume" d.o.o. Kupres) approximately 100,000 hectares in Canton 10 have already been reforested, and within 20–25 years, these areas will likely become unsuitable for *L. collurio*, leading to its eventual disappearance from the region. Natural succession and reforestation, together with the disappearance of livestock (following the exodus of the human population), have likely contributed to the local extinction of *Anthus campestris* from pasture habitats (Marić, 2022b).

The Red-backed Shrike has been classified as a declining species in Europe (Tucker & Heath 1994, Brambilla et al. 2007). This trend, common across Europe (Donald et al., 2001), has led to a sharp reduction of open habitats suitable for grassland and farmland species in northern Spain (Regos et al., 2016; Tellería et al., 2008; Tellería, 2018). It is important to note that the species *Emberiza citrinella*

has also disappeared from the study area, due to habitat changes in the broader region (see Marić, 2022b).

Since this species inhabits a variety of habitats (this study and Marić, 2023), the Red-backed Shrike can be considered a good indicator species for assessing landscape change and nature management in this region, as previously suggested by Fuisz & Yosef (1998); Latus et al. (2004); Tryjanowski et al. (2011); Bech et al. (2021). The results have important implications for an effective conservation strategy for areas with large and viable populations of this threatened species. According to MacDonald et al. (2000), implementing effective conservation strategies is crucial to preventing further population decline, which requires a thorough understanding of the species' biology, including its specific ecological needs (Titeux et al., 2007; Tryjanowski et al., 2011).

CONCLUSION

The population of the Red-backed Shrike has declined across its geographical range due to habitat loss, primarily driven by intensive land use. In karst polje areas, a further decline is expected as grasslands undergo natural succession into scrub and forest, particularly in regions with minimal human activity and no domestic livestock. Additionally, intensive afforestation with *Pinus* species contributes to this process.

This study provides valuable new insights into the

ecology of this poorly known species within karst polje habitats. The results highlight the ecological plasticity of the Red-backed Shrike in selecting breeding habitats, demonstrating its ability to utilize a variety of landscapes. Through the first formal assessment of habitat selection by this species during the breeding season, we found that the Red-backed Shrike prefers habitats with lower shrub and tree cover.

The research indicates that the most suitable habitats for this species are mosaic landscapes where shrub cover ranges between 10% and 50%. In other words, preferred habitats have relatively low densities of shrubs and trees.

In conclusion, this study represents the first detailed census of Red-backed Shrikes in karst poljes. Regular monitoring across different areas of karst poljes is essential for assessing the impact of evolving agricultural practices, especially in abandoned fields. This information on habitat requirements of the studied species can be used while planning their protection and conservation.

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Ethical note: This study was observational and non-invasive. Data were collected in public places where no special permit was required. Our data collection caused only brief and minimal disturbance to birds which typically did not differ from standard background disturbance caused by other site visitors.

REFERENCES:

- BALÁŽ, V. 2007: On the breeding biology of the Red-backed Shrike (*Lanius collurio*) in the newbreaks of SW Slovakia. – *Acta Zoologica Universitatis Comenianae*, 47(1):35–39.
- BLOCK, W. M. & BRENNAN, L. A. 1993: The habitat concept in ornithology. Theory and applications. – In: Power, D. M. (ed.) *Current Ornithology* 11: 35–91. – Plenum Press, New York, DOI: 10.1007/987-1-4757-9912-5-2
- BECH, J., GRAUBÆK, P., LARSEN, P. E., STRANGE, K.-E. & VALEUR, B. 2021: Rødrygget Tornskade på Rørvighalvoen 1973–2020. Bestandsudvikling og målrettet naturpleje. – *Dansk Ornitologisk Forenings Tidsskrift* 3, 15 pp. (In Danish)
- BRAMBILLA, M., RUBOLINI, D., & GUIDALI, F. 2007: Between land abandonment and agricultural intensification: Habitat preferences of Red-backed Shrikes *Lanius collurio* in low-intensity farming conditions. – *Bird Study*, 54(2), 160–167.
- BRAMBILLA, M., CASALE, F., BERGERO, V., CROVETTO, G. M., FALCO, R., NEGRI, I., SICCARDI, P. & BOGLIANI, G. 2009: GIS-models work well, but are not enough: habitat preferences of *Lanius collurio* at multiple levels and conservation implications. – *Biological Conservation*, 142(2): 2033–2042. DOI: 10.1016/j.biocon.2009.03.033
- CASALE, F., & BRAMBILLA, M. 2009: Averla piccola. Ecologia e conservazione. – *Fondazione Lombardia per l'Ambiente e Regione Lombardia*, Milano 254 pp.
- CERESA, F., BOGLIANI, G., & BRAMBILLA, M. 2012: The importance of key marginal habitat features for birds in farmland: an assessment of habitat preferences of Red-backed Shrikes *Lanius collurio* in the Italian Alps. – *Bird Study*, 59(3): 327–334. <https://doi.org/10.1080/00063657.2012.676623>
- CRAMP, S. & PERRINS, C. M. (eds). 1993: Red-backed Shrike, *Lanius collurio*. The birds of Europe, the Middle East and North Africa. Vol. VII. Oxford-New York.
- DENAC, D. 2003: Population decline and land-use changes in hunting habitat of the Red-backed Shrike *Lanius collurio* at Šturmovci (NE Slovenia). – *Acrocephalus*, 24 (118): 97–102.
- DONAL, P. F., GREEN, R. E., & HEATH, M. F. 2001: Agricultural intensification and the collapse of Europe's farmland bird populations. — Proceedings of the Royal Society of London. *Series B: Biological Sciences*, 268(1462): 25–29. <https://doi.org/10.1098/rspb.2001.0201>

- org/10.1098/rspb.2000.1325
- MacDONALD, D., CRABTREE, J.R., WIESINGER, G., DAX, T., STAMOU, N., FLEURY, P., GUTIERREZ LAZPITA, J. & GIBON, A. 2000: Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. - *Journal of Environmental Management*, 59: 47-69.
- FARKAS, R., HORVÁTH, R., & PÁSZTOR, L. 1997: Nesting success of red backed shrike (*Lanius collurio*) in a cultivated area. - *Ornis Hungarica*, 7: 27-37.
- FUISZ, T.I. & YOSEF, R., 1998: Habitat choice of post-breeding Red-backed Shrikes (*Lanius collurio*) in northeastern Hungary. (Proc. of the Second Intern. Shrike Symposium) - *IBCE Technical Publications*, 6: 26-29.
- GOŁAWSKI, A. & GOŁAWSKA, S. 2007: Habitat preference in territories of the Red-Backed Shrike *Lanius collurio* and their food richness in an extensive agriculture landscape. - *Acta Zoologica Academiae Scientiarum Hungaricae*, 54: 89-97
- GOŁAWSKI, A. & MEISSNER, W. 2007: The influence of territory characteristics and food supply on the breeding performance of the Red-backed Shrike (*Lanius collurio*) in an extensively farmed region of eastern Poland. - *Ecological Research*, 23(2): 347-353 DOI:10.1007/s11284-007-0383-y
- GOLAWSKI, A MROZ., E., GOLAWSKA., PARAPURA., A. & ZDUNIAK., A: 2023: Brood survival in the Red-backed Shrike *Lanius collurio* in eastern Poland. *Journal of Ornithology*, 164: 921-929. <https://doi.org/10.1007/s10336-023-02084-6>
- GUERRIERE, G. & CASTALDI, A. 2006: Caratteristiche del sito di nidificazione, densità e biologia riproduttiva dell'Averla piccola, *Lanius collurio*, in Italia centrale. - *Avocetta*, 29:5-11
- HARRIS, T. & K. FRANKLIN. 2000: Shrikes and bush shrikes. - Princeton University Press; *Christopher Helm*, London, United Kingdom. 392 pp.
- HOLLANDER, J., VAN DYCK, H., SAN MARTIN, G., & TITEUX, N. 2011: The impact of forest clearing on the distribution of the Red-backed Shrike (*Lanius collurio*) in northern Europe. - *Forest Ecology and Management*, 259(8): 1561-1572.
- IUCN RED LIST. (2024). *The IUCN Red List of Threatened Species*. Version 2024-1. Retrieved from <https://www.iucnredlist.org>
- KOTROŠAN, D., DERVOVIĆ, I., TOPIĆ, G., DROCIĆ, S., GOTOVAC, M., ŠARAC, M. & ŠARČEVIĆ, I. 2013: Rezultati prvog popisa sivog svračka (*Lanius minor*) na kraškim poljima Bosne i Hercegovine. - *Bilten Mreže posmatrača ptica u Bosni i Hercegovini*, 9(9): 40-46.
- KOSKIMIES, P. & VÄISÄNEN, R.A. 1988: Monitoring bird populations. A manual of methods applied in Finland. - *Zoological Museum, Finnish Museum of Natural History, University of Helsinki*, Helsinki, 97 pp.
- KUŹNIAK, S. 1991: Breeding ecology of the Red-backed Shrike *Lanius collurio* in the Wielkopolska region (western Poland). - *Acta Ornithologica*, 26(2), 67-84
- KUZNIAK, S., & TRYJANOWSKI, P. 2000: Distribution and breeding habitat of the Red-backed Shrike (*Lanius collurio*) in an intensively used farmland. - *The Ring*, 22(1): 89-93.
- KUPER, J., VAN DUINEN, G., NIJSSEN, M., GEERTSMAN, M. & ESSELINK, H. 2000: Is the decline of the Red-backed Shrike (*Lanius collurio*) in the Dutch coastal dune area caused by the decrease in insect diversity? *The Ring*, 22: 11-25.
- LATUS, C., SCHULTZ, A. & KUJAWA, K. 2004: Occurrence of the Red-backed Shrike (*Lanius collurio*) depends on natural factors and mode of land use in the Quillow catchment, Germany. — *Biological Letters*, 41(2): 87-93.
- LEFRANC, N. 1993: Les Pies-grieches d'Europa, d'Afrique du nord et du moyen-Orient. 240 pp, *Delachaux et Niestlé S.A., Lausanne, Paris*.
- LEFRANC, N. & WORFOLK, T. 1997: Shrikes. A Guide to the Shrikes of the World, (87-93). *Pica Press, Sussex*. United Kingdom. 192pp.
- LISLEVAND, T. 2012: Habitat and nest placement of Red-backed Shrikes *Lanius collurio* breeding in clear-cuts in southern Norway. - *Ornis Norvegica*, 35: 28-36. DOI: 10.15845/on.v35i0.242
- MARIĆ, D. 2022a: A preliminary assessment of the ornithological importance of karst poljes at Bosansko Grahovo (Western Bosnia and Herzegovina) - results of a large-scale survey in period 1974 to 2020. - *Agriculture and Forestry*, 68 (1): 95-113. DOI:10.17707/AgricultForest.68.1.05
- MARIĆ, D. 2022b: The emigration of the population from the area of Western Bosnia and Herzegovina during the Balkans civil conflict and implications for the Avifauna (Case study Pašića polje at Bosansko Grahovo). - *Ecologica Montenegrina*, 53: 73-91.
- MARIĆ, D. 2023: Changes in the habitat and nest site distribution for two *Lanius* species in karst poljes (Bosnia and Herzegovina). - *Agriculture and Forestry*, 69 (4): 157-172. DOI:10.17707/AgricultForest.69.4.10
- MORELLI, F. 2011: Importance of road proximity for the nest site selection of the Red-backed Shrike *Lanius collurio* in an agricultural environment in central Italy. - *Journal of Mediterranean Ecology*, 11: 21-29.
- MORELLI, F. 2012: Plasticity of habitat selection by Red-backed Shrikes (*Lanius collurio*) breeding in different landscapes. - *The Wilson Journal of Ornithology*, 124(1), 51-56.
- MORELLI, F., MRÓZ, E., PRUSCINI, F., SANTOLINI, R., GOŁAWSKI, A., & TRYJANOWSKI, P. 2016: Habitat structure, breeding stage and sex affect hunting success of breeding Red backed Shrike (*Lanius collurio*). — *Ethology Ecology & Evolution*, 28(2): 136-147. <https://doi.org/10.1080/03949370.2015.1022907>
- MOES, M. 1993: Territory size and habitat selection of the Red-backed Shrike *Lanius collurio* in Luxembourg. *Bulletin de la Société des Naturalistes Luxembourgeois*, 94: 65-72.
- NÉMETHOVÁ, D. 2002: Hniezdné spoločenstvá vtákov vo vetrolamoch juhozápadného Slovenska. - *Príro dovedecká fakulta UK, Bratislava*, Dissertation, 121 pp.
- OBRATIL, S. 1984: Naselja ptica (Aves) u kopnenim biocenozama kraških polja Hercegovine [Communities of birds (Aves) in terrestrial biocenoses of the karst fields of Herzegovina]. - *Glasnik zemaljskog muzeja Bosne i Hercegovine* (PN) NS, 23: 147-184.

- (in Serbo-Croatian, with English Summary)
- OBRATIL, S. 1987: Naselje ptica u ekosistemima Gatačkog polja i okoline prije izgradnje TE Gacko [Communities of birds in the ecosystems of Gatački polje and its surroundings before the construction of the Gacko TPP]. – *Glasnik zemaljskog muzeja Bosne i Hercegovine*, (PN) NS 25–26: 211–237. (in Serbo-Croatian, with English Summary)
- OBRATIL, S. 2006: Ekološka diferencijacija faune ptica Livanjskog polja (Bosna) [Ecological differentiation of the bird fauna of Livanja polje (Bosnia)]. – *Glasnik zemaljskog muzeja Bosne i Hercegovine* (PN) NS, 32: 45–81. (in Croatian, with English Summary)
- OLSSON, V. 1995a: The Red-backed Shrike *Lanius collurio* in southeastern Sweden: breeding biology. - *Ornis Svecica*, 5:101–110.
- OLSSON, V. 1995b: The Red-backed Shrike *Lanius collurio* in southeastern Sweden: habitat and territory. – *Ornis Svecica*, 5(1): 31–41. DOI: 10.34080/os.v5.23012
- PAWLAK, P. & KWIECIŃSKI, Z. 2015: Successful nesting of Red-backed Shrike *Lanius collurio* near a military airport. - *Ornis Svecica*, 25(1–2): 65–66. <https://doi.org/10.34080/os.v.25.22549>
- PASINELLI, G., MÜLLER, M., SCHAUB, M. & JENNI, L. 2007: Possible causes and consequences of philopatry and breeding dispersal in red backed shrikes. *Lanius collurio*. - *Behavioral Ecology and So ciobiology*, 61: 1061-1074.
- POLAK, M. 2012: Habitat preferences of the sympatric Barred Warbler (*Sylvia nisoria*) and the Red-backed Shrike (*Lanius collurio*) breeding in central Poland. – *Annales Zoologici Fennici*, 49(5–6): 355–363. DOI: 10.5735/086.049.0509
- POLAK, M. & FILIPIUK, M. 2014: Preferencje siedliskowe jarzębatki *Sylvia nisoria* i gąsiora *Lanius collurio* na Środkowym Roztoczu. - *Ornis Polonica*, 55: 22–33 (in Polish).
- REGOS, A., DOMÍNGUEZ, J., GIL-TENA, A., BROTONS, L., NINYEROLA, M. & PONS, X. 2016: Rural abandoned landscapes and bird assemblages: winners and losers in the rewilding of a marginal mountain area (nw Spain). - *Regional Environmental change*, 16: 199-211.
- ROOS, S. & PÄRT, T. 2004: Nest predators affect spatial dynamics of breeding Red-backed Shrikes (*Lanius collurio*). - *Journal of Animal Ecology*, 73: 117–127 DOI: 10.1111/j.1365-2656.2004.00786.x
- SIKORA, A. 2007: Gniazdowanie cennych gatunków Ptaków na Wysoczyźnie Elbląskiej. - *Notatki Ornitologiczne* (Breeding of valuable bird species in the Wysoczyzna Elbląska upland) 48: 246–258 (in Polish).
- SÖDERSTRÖM, B., & KARLSSON, H. 2011: Increased reproductive performance of Red-backed Shrikes *Lanius collurio* in forest clear-cuts. — *Journal of Ornithology*, 152(2): 313–318. <https://doi.org/10.1007/s10336-010-0587-8>
- SVENDSEN, J. K., SELL, H., BØCHER, P., & SVENNING, J.-C. 2015: Habitat and nest site preferences of Red-backed Shrike (*Lanius collurio*) in western Denmark. - *Ornis Fennica*, 92(2): 63–75. <https://doi.org/10.51812/of.133869>
- TELLERÍA, J.L., RAMÍREZ, A., GALARZA, A., CARBONELL, R., PÉREZ-TRIS, J. & SANTOS, T. 2008: Geographical, landscape and habitat effects on birds in northern Spanish farmlands: implications for conservation. *Ardeola*, 55: 203-219.
- TELLERÍA, J.L. 2018: Old Counts Suggest the Collapse of Two Red-Backed Shrike *Lanius collurio* Populations. - *Ardeola*, 65(2): 283-290. <https://doi.org/10.13157/arla.65.2.2018.sc1>
- TUCKER, G. M. & HEATH, M. F. 1994: Birds in Europe: their conservation status. - *Birdlife Conservation Series No. 3. BirdLife International Cambridge*, United Kingdom 600 pp. ISBN 1-56098-527-5.
- TITEUX, N., DUFRENE, M., RADOUX, J., HIRZEL, A. H., & DEFOURNY, P. 2007: Fitness-related parameters improve presence-only distribution modelling for conservation practice: the case of the Red-backed Shrike. — *Biological Conservation*, 138(1–2): 207–223. <https://doi.org/10.1016/j.biocon.2007.04.019>
- TRYJANOWSKI, P., KUŻNIAK, S. & DIEHL, B. 2000: Does breeding performance of red-backed shrike *Lanius collurio* depend on nest site selection? - *Ornis Fennica*, 77: 137-141.
- TRYJANOWSKI, P., SPARKS, T. H. & CRICK, H. Q. P. 2006: Red-backed Shrike *Lanius collurio* nest performance in a declining British population: a comparison with a stable population in Poland. - *Ornis Fennica*, 83(4), 181–186. https://ornisfennica.journal.fi/article/view/133670Ornis_Fennica+1Ornis_Fennica+1
- TRYJANOWSKI, P., HARTEL, T., BÁLDI, A., SZYMAŃSKI, P., TOBOLKA, M., HERZON, I., GOLAWSKI, A., KONVIČKA, M., HROMADA, M., JERZAK, L., KUJAWA, K., LENDA, M., ORLOWSKI, G., PANEK, M., SKÓRKA, P., SPARKS, T., TWOREK, S., WUCZYŃSKI, A. & ŻMIHORSKI, M. 2011: Conservation of farmland birds faces different challenges in Western and Central-Eastern Europe. — *Acta Ornithologica*, 46(1): 1–12. <https://doi.org/10.3161/000164511X589857>
- VANHINSBERGH, D. & EVANS, A. 2002: Habitat associations of the Red-backed Shrike (*Lanius collurio*) in Carinthia, Austria. - *Journal of Ornithology*, 143: 405–415.
- VÄLI Ü 2005: Punaselg-õgija elupaigakasutus Eestis pesakaardiandmestiku põhjal (Habitat use of the red-backed shrike in Estonia). - *Hirundo*, 18: 10-17. (in Estonian)
- WINIECKI, A., GRZYBEK, J., KRUPA, A. & MIELCZAREK, S. 1997: Awifauna łęgowa doliny środkowej Warty – stan aktualny i kierunki zmian. - *Notatki Ornitologiczne*, 38: 87–120 (in Polish).
- YOSEF, R., SHMUELI, G., ARAD, Y., & CHRISTIE, D. 2012: The distribution and habitat preferences of the Red-backed Shrike (*Lanius collurio*) in the Mediterranean region. - *Journal of Ornithology*, 153(2), 303–312.

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THE REPTILE COLLECTION OF THE NATURAL HISTORY MUSEUM OF MONTENEGRO: TAXONOMIC COMPOSITION AND COVERAGE OF THE NATIONAL HERPETOFAUNA

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Gore.

SYNOPSIS

The Reptile Collection of the Natural History Museum of Montenegro represents an important scientific and documentary resource for the study of the national herpetofauna. It comprises 548 inventory units (specimens) and six study specimens, representing 32 native species and two non-native species. In addition, the collection includes three specimens of native species collected outside the territory of Montenegro. In terms of the native fauna of Montenegro, the collection includes 32 species. The collection includes four turtle species (four families), 13 lizard species (three families), and 15 snake species (five families). Compared with the 38 reptile species recorded in Montenegro, the collection covers 32 species (84.2%), with complete representation of snakes and partial coverage of turtles and lizards. Of the seven endemic species recorded in Montenegro, six lizard species and one snake species are included in the collection.

SINOPSIS

Zbirka gmizavaca Prirodnjačkog muzeja Crne Gore predstavlja važan naučni i dokumentacioni resurs za proučavanje nacionalne herpetofaune. Obuhvata 548 inventarnih jedinica (primjeraka) i šest primjeraka studijskog materijala, koji predstavljaju 32 autohtone i dvije alohtone vrste. Pored toga, zbirka obuhvata tri primjerka autohtonih vrsta koji su sakupljeni van teritorije Crne Gore. U pogledu autohtone faune gmizavaca, u zbirci su zastupljene 32 vrste. Zastupljene su četiri vrste kornjača (četiri familije), 13 vrsta guštera (tri familije) i 15 vrsta zmija (pet familija). U poređenju sa 38 vrsta gmizavaca registrovanih u Crnoj Gori, zbirka pokriva 32 vrste (84,2%), pri čemu su zmije u potpunosti zastupljene, a kornjače i gušteri djelimično. Od sedam endemskih vrsta registrovanih u Crnoj Gori, u zbirci je zastupljeno šest vrsta guštera i jedna vrsta zmija.

INTRODUCTION

The first Natural History Collection in Montenegro was established in 1961 within the Republic Institute for Nature Protection by a governmental decree. The collection included several hundred preserved animal specimens, with birds from the Skadar Lake region being the most numerous, as well as fish, mammals, and a smaller number of reptiles. It also contained a valuable herbarium representing the flora of Balkan countries.

The collection was open to the public through a permanent exhibition in the building of the Republic

Institute for Nature Protection in Podgorica. It was additionally presented at Hunting and Fishing Fairs and through scientific publications, particularly in the Journal Bulletin of the Republic Institute for Nature Protection. As the collection specimens were primarily intended for exhibition purposes, limited attention was given to systematic documentation and detailed specimen data. As a result, documentation was often incomplete, and many specimens were not fully processed or scientifically identified.

The building housing the collection was severely damaged during the 1979 earthquake. Although the specimens did not suffer major direct damage at

that time, subsequent relocations to facilities with inadequate microclimatic conditions caused gradual deterioration of the collection. In 1985, the collection was returned to the renovated building of the Institute and placed in a new exhibition space, where it remained until the establishment of the Natural History Museum of Montenegro in 1995. After the Museum was founded, the former exhibition rooms were repurposed as offices, and the natural history material was transferred to a small storage room of approximately 50 m² with inadequate conditions for long-term preservation. The collections continue to be maintained in this storage room. In 2017–2018, the museum storage room was renovated and equipped in accordance with professional conservation standards, and a microclimate control system was finally installed.

At the time the collection was assigned its first curator in June 2000, the museum had no inventory records of preserved reptile specimens inherited from the Institute's collection. Some specimens contained data on the date and locality of collection, as well as the collector, while others lacked any associated information. The curator recorded eight well-preserved reptile specimens from the Institute's collection and 15 specimens donated to the museum from its establishment until 2000.

This study aims to provide a comprehensive overview of the reptile collection of the Natural History Museum of Montenegro. Specifically, it focuses on documenting the historical development of the collection, analyzing its taxonomic composition and specimen diversity, assessing how well it represents the national reptile fauna, and evaluating its conservation and scientific significance.



Figure 1: Fluid-preserved specimens stored in glass jars or cylinders with 75% ethanol.

MATERIALS AND METHODS

The reptile collection of the Natural History Museum of Montenegro comprises specimens preserved primarily in 75% ethanol. Some of the fluid-preserved specimens were previously stored in a freezer or in 4% formalin and were later transferred to 75% ethanol. In total, the collection includes 401 fluid-preserved specimens stored in glass jars or cylinders with 75% ethanol (Figure 1), 117 specimens of lizard skeletons preserved in glycerin and 36 specimens prepared as dermoplastic or skeleton models (Figure 2).

In museum documentation, specimens are recorded as inventory units, each of which may consist of a single or multiple specimens or eggs of the same species. In some cases, multiple specimens of the same species collected at the same locality and on the same date are registered under a single inventory number as an inventory unit. Females with associated clutches, or multiple eggs from a single clutch, are also typically treated as a single inventory unit. Therefore, the total number of inventory units does not necessarily correspond to the total number of individual specimens.

Most species were identified based on relevant herpetological literature. The identification of *Dinarolacerta montenegrina* Ljubisavljević, Arribas, Džukić & Carranza, 2007 was based on published diagnostic characteristics and the geographic origin of the samples (Ljubisavljević et al., 2007).

Conservation statuses are provided according to the IUCN (International Union for Conservation of Nature) Red List of Threatened Species at the regional level (Europe) (IUCN, 2024), the Bern Convention on the Conservation of European Wildlife and Natural Habitats (Council of Europe, 1979), the Habitats Directive (Council of the European Communities, 1992), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (UNEP-WCMC, 2017), the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (UNEP/CMS, 2017), Riješenje o stavljanju pod zaštitu pojedinih biljnih i životinjskih vrsta. Službeni list RCG 76/06, Podgorica: 836 (Republički Zavod za zaštitu prirode Crne Gore), and the Red List of Amphibians and Reptiles of Montenegro (Jelić et al., 2023).

Results

The foundation of the reptile collection was formed by its oldest items, eight well-preserved reptile specimens



Figure 2: Specimens prepared as dermoplastic or skeleton models.

inherited from the natural history collection of the Republic Institute for Nature Protection. Of these, five specimens lacked accompanying data: two dermoplastic specimens of the Hermann's tortoise and the European pond turtle, one fluid-preserved specimen of the Balkan whip snake, and two fluid-preserved specimens of the Leopard snake. The remaining three specimens contained data on locality and date of collection. The oldest specimen in the collection is a fluid-preserved individual of the Common wall lizard *Podarcis muralis* (Laurenti, 1768) from 1969, collected on the left bank of the Lim River near Skakavac (most likely a village in the municipality of Berane) (Figure 3). This is followed by a fluid-preserved specimen of the grass snake *Natrix natrix* (Linnaeus, 1758) from Nikšić, dating from 1983, and a fluid-preserved specimen of the Sand lizard *Lacerta agilis* Linnaeus, 1758 from 1986, collected at Ponikvica, Studeno (Mt. Prekornica).

In the period from the establishment of the Museum until the appointment of the curator responsible for the collection, a total of 15 specimens were donated: three in 1996, one in 1997, four in 1999, and four in

2000, while the year of donation for three specimens could not be determined.

Of the total 15 donated specimens, seven had been stored frozen, including three without any accompanying data, except that they were known to originate from the territory of Montenegro. Despite the lack of any accompanying data, these specimens were incorporated into the collection as the first fluid-preserved specimens prepared by the curator during their traineeship. A total of six fluid-preserved specimens dating from the period 1996–2000 were donated to the Museum in 2022 by the Environmental Protection Agency of Montenegro.

The Reptile Collection comprises 548 inventory units and six specimens of study material that were entered into the museum accession book but not formally inventoried due to their poor condition at the time of collection. The Collection includes representatives of 32 native reptile species, covering multiple developmental stages (adults, subadults, juveniles, and egg clutches), as well as two non-native species: one donated crocodylian specimen without associated data and a clutch (two eggs) of the African

PMCG Evidencije Muzejski predmeti Knjige

Podaravanja Pomoć Ilija Polovic

Muzejski predmeti > *Podarcis muralis* (Laurenti, 1768)

Izmenj

Fotografije Dokumenta Konzervacije Revizije Knjiga izlaza Akcije ... 95/95 <

U knjizi ulaza Inventarisan

Identifikacija

Zbirka: 600 POD GMI: Gmizavci

Broj knjige ulaza: 11-1 Kolektorski broj: L9

Inventarski broj: 784 Raniji inventarski broj:

Redni broj u zbirci: 9

Vrsta predmeta: Mokri preparat

Opis vrsta predmeta: Mokri preparat

Klasifikaciona oznaka: *Podarcis muralis* (Laurenti, 1768)

Naziv predmeta: zidni gušter

Lokalni naziv predmeta: zidni gušter

Broj komada: 1

Vrijednost (EUR):

Procjenu izvio:

UDK (UDC):

Muzejska kategorizacija:

Opis predmeta:

Analiza predmeta:

Nastanak

Lokaliitet: Lijeva obala Lima, kod Skakavca Zemlja: Crna Gora

Lat Long koordinate: UTM koordinate:

Kolektor / Autor: Datum sakupljenja: 26.03.1969.

Kokolektor / Koaautor 1: Kokolektor / Koaautor 2:

Kokolektor / Koaautor 3: Kokolektor / Koaautor 4:

Figure 3: The oldest specimen in the collection: a fluid-preserved specimen of the Common wall lizard.

Table 1: Overview of native species present in the NHMM Reptile collection, with the number of inventory units, endemism, and conservation status. Colour coding is used to distinguish conservation status: threatened categories (NT, VU, EN) are highlighted in red, whereas Least Concern (LC) is indicated in black.

Species (native)	Number of inventory units	Endemism	Conservation status	
			National protection	Threat status (international/national)
Chelonia				
<i>Emys orbicularis</i>	14	-	+	NT / VU
<i>Mauremys rivulata</i>	1	-	+	LC / EN
<i>Testudo hermanni</i>	5	-	+	VU / NT
<i>Caretta caretta</i>	1	-	+	VU / VU
Sauria				
<i>Hemidactylus turcicus</i>	11	-	-	LC / LC
<i>Algyroides nigropunctatus</i>	102	+	+	LC / LC
<i>Dalmatolacerta oxycephala</i>	23	+	+	LC / LC
<i>Dinarolacerta montenegrina</i>	5	+	-	NT / EN
<i>Dinarolacerta mosorensis</i>	144	+	+	NT / VU
<i>Lacerta agilis</i>	8	-	+	LC / LC
<i>Lacerta trilineata</i>	13	+	+	LC / LC
<i>Lacerta viridis</i> complex	16	-	+	LC / LC
<i>Podarcis melisellensis</i>	19	+	+	LC / LC
<i>Podarcis muralis</i>	78	-	+	LC / LC
<i>Zootoca vivipara</i>	1	-	+	LC / LC
<i>Anguis fragilis</i> complex	8	-	+	LC / LC
<i>Pseudopus apodus</i>	5	-	+	LC / LC
Serpentes				
<i>Xerotyphlops vermicularis</i>	1	-	-	LC / DD
<i>Hierophis gemonensis</i>	4	+	+	LC / LC
<i>Dolichophis caspius</i>	7	-	-	LC / LC
<i>Platycephalus najadum</i>	2	-	+	LC / LC
<i>Elaphe quatuorlineata</i>	10	-	+	LC / NT
<i>Zamenis longissimus</i>	5	-	+	LC / LC
<i>Zamenis situla</i>	5	-	+	LC / NT
<i>Coronella austriaca</i>	3	-	+	LC / LC
<i>Telescopus fallax</i>	3	-	-	LC / LC
<i>Natrix natrix</i>	23	-	+	LC / LC
<i>Natrix tessellata</i>	11	-	+	LC / LC
<i>Malpolon insignitus</i>	4	-	+	LC / LC
<i>Vipera berus</i>	2	-	-	LC / LC
<i>Vipera ursinii</i>	1	-	-	VU / VU
<i>Vipera ammodytes</i>	11	-	-	LC / LC

Spur-thighed tortoise *Centrochelys sulcata* (Miller, 1779), laid during its temporary housing in the museum. The eggs did not develop due to inadequate incubation conditions and were subsequently retained in the collection. In addition, the collection includes three specimens of native species collected outside Montenegro: two specimens of *Natrix tessellata* (Laurenti, 1768) from North Macedonia and one specimen of *Hemidactylus turcicus* (Linnaeus, 1758) from Croatia.

The curator of the collection has assembled 449 specimens, while 89 specimens were donated by known contributors and 16 specimens lack information on their donors.

Regarding the native reptile fauna, the collection comprises four turtle species representing four families, 13 lizard species from three families, and 15 snake species representing five families (Table 1).

DISCUSSION WITH CONCLUSIONS

A total of 38 reptile species have been confirmed for the territory of Montenegro. The national reptile fauna comprises seven turtle species from five families, 16 lizard species from five families, and 15 snake species from five families (Leković & Ljubisavljević, in press). Of these, seven species are endemics, including six lizard species and one snake species. Overall, the collection contains 32 of the 38 reptile

species recorded for Montenegro, corresponding to a coverage of 84.2%. Six species are not represented in the collection, all belonging to the group of lizards (three species) and turtles (three species). All snake species recorded for Montenegro are represented in the collection, resulting in 100% coverage for this group. The results highlight the scientific value of the collection and identify taxonomic gaps for future enrichment.

Missing species in the reptile collection:

Three species of turtles: *Trachemys scripta* (Thunberg, 1758), an introduced species first recorded in 2022 (Ljubisavljević, 2022). So far, it has been documented in the coastal region and the eastern subregion of the mountain-basin region of Montenegro (Ljubisavljević, 2022; Iković et al., 2023). It is considered invasive, and its import has been banned in the European Union since 1997 (Bringsøe, 2006; van Dijk et al., 2011); *Chelonia mydas* (Linnaeus, 1758), occasionally occurs in the coastal region of Montenegro, in the Adriatic Sea. The only records so far are from Kotor: Orahovac and Bigova (Gvozdenović et al., 2016); *Dermochelys coriacea* (Vandelli, 1761), occasionally occurs in the Adriatic Sea along the Montenegrin coast. Recorded in Ulcinj (Gvozdenović et al., 2016) and Budva (Kosić, 1896, 1899; Gvozdenović et al., 2016). Three species of lizards: *Tarentola mauritanica* (Linnaeus, 1758), two records exist from the coastal region of Montenegro: Ulcinj (Bruno, 1988) and Bar (Čađenović et al., 2022). The autochthonous origin of populations in the eastern Mediterranean, and consequently in our coastal area, remains questionable; *Podarcis siculus* (Rafinesque, 1810), occurs in the Mediterranean subregion of the coastal region of Montenegro. So far, an isolated population has been confirmed in Kotor and its surroundings, as well as on Mamula Island in

the Bay of Kotor (Džukić et al., 2017). It has been introduced in several Mediterranean countries of Europe, including Montenegro; *Ablepharus kitaibelii* Bibron & Bory de Saint-Vincent, 1833, only one confirmed record of this Short-legged lizard exists in Montenegro, near Berane between the villages of Mašte and Babino (Vergilov et al., 2016).

The absence of several reptile species from the collection of the Natural History Museum of Montenegro can be explained by their ecological and biogeographical characteristics. Introduced species (*Trachemys scripta*, *Tarentola mauritanica*) have only recently been recorded in Montenegro and were not included in earlier collecting efforts. *Podarcis siculus* is also an introduced species, with a limited distribution restricted to isolated populations in Kotor and Mamula Island. Sporadically occurring marine turtles (*Chelonia mydas*, *Dermochelys coriacea*) are rare visitors to the Adriatic coast of Montenegro, usually recorded as isolated individuals. Their unpredictable occurrence makes systematic collection difficult. Finally, *Ablepharus kitaibelii* is an extremely rare species in Montenegro, with only a single confirmed record, and organized field surveys of its potential habitats in the country have not yet been conducted, which naturally limits its representation in museum collection.

Despite these absences, the collection remains a cornerstone for documenting the reptile diversity of Montenegro. It represents a valuable scientific resource and an important component of the country's natural heritage. Future research and collection development may further expand its scope by incorporating newly recorded, introduced, sporadic, or rare species, thereby enhancing its taxonomic completeness and long-term scientific relevance.

REFERENCES:

- BRINGSØE, H. 2006: NOBANIS – Invasive Alien Species Fact Sheet – *Trachemys scripta*. In: Online Database of the North European and Baltic Network on Invasive Alien Species – NOBANIS, www.nobanis.org.
- BRUNO, S. 1988: The herpetofauna from the islands of Cres, Krk and Ada. - Bulletin d'écologie, 19: 265–281.
- COUNCIL OF EUROPE 1979: Convention on the conservation of European wildlife and natural habitats. CETS 104. Bern, Switzerland.
- COUNCIL OF EUROPEAN COMMUNITIES 1992: Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wildlife and flora Habitats Directive - 92/43/EEC.
- ČAĐENOVIĆ, N., RADONJIĆ, T., VUKADINOVIĆ, S. & STAMENKOVIĆ, S. 2022: The Moorish gecko, *Tarentola mauritanica* (Linnaeus, 1758) (Reptilia, Squamata, Phyllodactylidae) a new species for the herpetofauna of Montenegro. In: Živić, M & Petković, B. (eds.), The Book of Abstracts. Third Congress of Biologists of Serbia, p. 189. Serbian Biological Society, Belgrade.
- DŽUKIĆ, G., TOMOVIĆ, LJ., ANĐELKOVIĆ, M., UROŠEVIĆ, A., NIKOLIĆ, S. & KALEZIĆ, M. L. 2017: The herpetological collection of the Institute for biological research "Siniša Stanković", University of Belgrade. - Bulletin of the Natural History Museum, 10: 57–104.
- GVOZDENOVIĆ, S., ĐUROVIĆ, M. & IKOVIĆ, V. 2016: Distribution records of sea turtles in the Montenegrin waters. - Studia Marina, 29 (1): 31–46.

- IKOVIĆ, V., POPOVIĆ, J. & GVOZDENOVIĆ-NIKOLIĆ, S. 2023: Overview of the Pond Slider *Trachemys scripta* (Thunberg in Schoepff, 1792) (Testudines: Emydidae) records in Montenegro. - *Natura Sloveniae*, 25 (2): 61–68.
- IUCN 2024: The IUCN Red List of Threatened Species. Version 2024-1. <<http://www.iucnredlist.org>>.
- JELIĆ, D., IKOVIĆ, V., ČAĐENOVIĆ, N., GVOZDENOVIĆ-NIKOLIĆ, S., VUJOVIĆ, A., LJUBISAVLJEVIĆ, K., TOMOVIĆ, LJ., POLOVIĆ, L., MIĆANOVIĆ, A., KRAJNOVIĆ, M. & BLAŽEVIĆ, M. 2023: Crvena lista vodozemaca i gmizavaca Crne Gore (Red list of Amphibians and Reptiles of Montenegro). Agencija za zaštitu životne sredine Crne Gore, Podgorica, 43 pp.
- KOSIĆ, B. 1896: *Sphargis coriacea* Gray u Jadranskome moru. - *Glasnik Hrvatskog Naravoslovnoga Društva*, 8: 117–144.
- KOSIĆ, B. 1899: *Sphargis coriacea* Gray u Jadranskome moru. Dodatak. - *Glasnik Hrvatskog Naravoslovnoga Društva*, 10: 15–24.
- LEKOVIĆ, L. & LJUBISAVLJEVIĆ, K. (in press): Katalog faune gmizavaca (Reptilia) Crne Gore/ Catalogue of The Reptiles (Reptilia) of Montenegro, Catalogues, The Section of Natural Sciences, Montenegrin Academy of Sciences and Arts, Podgorica.
- LJUBISAVLJEVIĆ, K., ARRIBAS, O., DŽUKIĆ, G. & CARRANZA, S. 2007: Genetic and morphological differentiation of Mosor Rock Lizards, *Dinarolacerta mosorensis* (Kolombatović, 1886), with the description of a new species from the Prokletije Mountain Massif (Montenegro) (Squamata: Lacertidae). - *Zootaxa*, 1613: 1–22.
- LJUBISAVLJEVIĆ, K. 2022: First record of the Yellow-bellied Slider, *Trachemys scripta scripta* (Testudines: Emydidae) in Montenegro. - *Herpetology Notes*, 15: 493–497.
- REPUBLIČKI ZAVOD ZA ZAŠTITU PRIRODE CRNE GORE, 2006: Riješenje o stavljanju pod zaštitu pojedinih biljnih i životinjskih vrsta. - Službeni list RCG 76/06, Podgorica: 836, Republički Zavod za zaštitu prirode Crne Gore, 2006.
- UNEP-WCMC 2017: UNEP-WCMC Species Database: CITES Listed Species on the World Wide Web. <https://cites.org/eng/disc/species.php>.
- UNEP/CMS 2017: Convention on Migratory Species Homepage. Available online: <http://www.cms.int/species>.
- VAN DIJK, P. P., HARDING, J. & HAMMERSON, G. A. 2011: *Trachemys scripta* (errata version published in 2016). The IUCN Red List of Threatened Species 2011: e.T22028A97429935.
- VERGILOV, V., HRISTOV, G., LUKANOV, S., LAMBEVSKA, A. & TZANKOV, N. 2016: First record of *Ablepharus kitaibelii* (Bibron & Bory de Saint-Vincent, 1833) in Montenegro. *Biharean Biologist*, 10: 65–66.

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“THE GOOD OLD” WORKING MODEL vs IT/VR/AI/etc.

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SYNOPSIS

Key words:

Working model,
IT,
new technologies,
interactivity.

The rapid development of information technologies, characteristic of the 21st century, and the broad range of possibilities and methods of application that this progress brings have certainly influenced contemporary museology, particularly museum presentation. Various digital tools and technological innovations are now widely used in communication between museums and their audiences, and the number of scholarly papers dealing with this topic is growing daily. There is no doubt that the use of information technologies in museum presentation offers certain benefits: it improves the way museums communicate with visitors and even, one might say, redefines the methodology of presentation, exhibition design, and the very purpose of the museum object.

Nevertheless, in the case of a technical museum such as the Nikola Tesla Museum, whose presentation is fundamentally based on working models, one may ask whether too much emphasis and attention have perhaps been given to the use of information technologies in museum display. Drawing on decades of experience with both approaches within the Museum's highly developed exhibition activities, it is possible to open a discussion (if not reach a conclusion) about the advantages and/or disadvantages of various digital technologies when compared with, so to speak, classic working models and exhibits.

SINOPSIS

„Stari, dobri“ radni model protiv IT/VR/AI/ITD

Ključne riječi:

Radni model,
IT,
nove tehnologije,
interaktivnost.

Ubrzani razvoj informacionih tehnologija, karakterističan za 21. vek, i čitava paleta različitih mogućnosti i metoda upotrebe koje razvoj te oblasti donosi, svakako su uticali i na savremenu muzeologiju, a posebno na muzejsku prezentaciju. Različiti digitalni alati i tehnološke inovacije uveliko su u upotrebi kada je u pitanju komunikacija na relaciji muzej-publika, a broj naučnih radova koji se bavi ovom tematikom raste svakodnevno. Nema sumnje da upotreba informacionih tehnologija u muzejskoj prezentaciji donosi određene benefite, unapređujući način komunikacije muzeja sa publikom pa čak, može se reći, i redefinišući metodologiju prezentacije, dizajna izložbenih postavki i osnovne svrhe muzejskog predmeta.

Ipak, na primeru i praksi jednog tehničkog muzeja kakav je Muzej Nikole Tesle, koji osnovu prezentacije bazira na radnim modelima, može se postaviti pitanje da li je možda ipak preveliki akcenat i pažnja data upotrebi informacionih tehnologija u muzejskoj prezentaciji. Na decenijskom iskustvu upotrebe i jednih i drugih alata u okviru izrazito razvijene izložbene delatnosti Muzeja Nikole Tesle, može se otvoriti tema (ako ne i zaključak) o prednostima i/ili manama različitih digitalnih tehnologija u kontekstu poređenja sa, uslovno rečeno, klasičnim radnim modelima/eksponatima.

Introduction

The history and development of technical museums are linked to the 19th and early 20th centuries and are directly connected, on the one hand, to the rapid growth of industry and technology and, on the other, to the great world exhibitions, which influenced not only the expansion of museum objects within

collections but also the increasing popularity of such museums among the public. At the same time, it can be said that the history and evolution of working models in museology paralleled the history of technical museums precisely because of the very nature of these objects, which demonstrated specific technological processes to visitors—perhaps making

the first step toward removing the barrier between the museum object and the visitor and, indeed, marking the beginnings of interactivity (Maroević 1993, p. 38).

The great world exhibitions of the late 19th and early 20th centuries accompanied the industrial revolution and technological progress. The role of working models as demonstrators of industrial processes and technological advancement was both educational and promotional. It was precisely during this period that major technical museums were established, such as the Deutsches Museum in Munich, founded in 1903, whose exhibitions were based on working and educational models (Hudson 1987, p. 31). At the same time, this was also the period in which Nikola Tesla (1856–1943) lived and worked. Tesla both visited and participated in world exhibitions, presenting his inventions and using demonstration models and analogies in his expositions and lectures (Jovanović 2014).

The Founding of the Nikola Tesla Museum

After the death of Nikola Tesla on January 7, 1943, the legal custodian of his estate became Sava Kosanović, the son of Tesla's sister Marica. Through Kosanović's efforts, Tesla's entire legacy was transferred from New York to Belgrade in 1951. By the decision of the Council for Science and Culture of the Government of the Federal People's Republic of Yugoslavia (FPRY), a Commission for Opening the Legacy of Nikola Tesla was established on July 9, 1952. On October 29 of the same year, a resolution was passed to arrange and classify Tesla's legacy according to the nature of the materials. Acting on the proposal of the Council for Science and Culture, the Government of the FPRY issued a resolution on December 5, 1952, founding the Nikola Tesla Museum. The document was signed by the President of the FPRY Government, Josip Broz Tito. Professor Veljko Korać of the Faculty of Philosophy in Belgrade was appointed as the Museum's first director. Between 1952 and 1955, an extensive process of classifying the materials and preparing and realizing the first permanent exhibition was carried out with the expertise and dedication of specialists from various fields and institutions. The concept for the inaugural permanent display, dedicated to Tesla's discoveries, was developed by a team of professors from the Faculty of Electrical Engineering together with Professor Korać. The Nikola Tesla Museum officially opened to the public on October 20, 1955 (Smiljanić 2003, p. 17).

From its very inception, the Nikola Tesla Museum

focused on presenting Tesla's inventions through working models. The task of designing the permanent exhibition dedicated to Tesla's discoveries was entrusted to engineer Jovan Surutka, who prepared the technical documentation for the production of the working exhibits. The first permanent exhibition featured 15 (or 16) working exhibits, most of which were created by a team of experts at the Institute of the Serbian Academy of Sciences for the study of electrical phenomena, as well as by the "Nikola Tesla" Radio Industry, the Military Technical Institute of the Yugoslav Army, and the Faculty of Electrical Engineering. Most of these exhibits are still part of the Museum's permanent display today (Radić-Kalderon & Civrić 2003, p. 135).

Over the next three decades, the condition and number of working models and scale replicas remained almost unchanged, with the exception of a panel dedicated to the Tesla unit—whose exact date of creation is unknown but is presumed to have been made when the unit was defined within the SI system (1960)—and a panel from the Niagara hydroelectric power plant generator, which was donated to the Museum in 1976.

Through the efforts of Professor Ilija Volčkov, several new working exhibits were produced in 1986 (or 1982, according to some sources). These were intended both to expand the traveling exhibition *The Life and Work* of Nikola Tesla, originally prepared in 1963, and to create a number of models that were donated to other institutions, including the Polytechnic Museum in Moscow, the Technical Museum in Vienna, the Science Museum in London, the National Museum of American History within the Smithsonian Institution in Washington, D.C., and the Technical Museum in Budapest. Between 1963 and 1996, this exhibition was presented in around one hundred locations and cities across the former Yugoslavia and in about fifteen foreign countries (Civrić 2003, p. 189). During the 1990s, despite the poor economic and political situation caused by the wars in the former Yugoslavia, the number of exhibition items nevertheless increased. Additions included scale models of Tesla's laboratories in Colorado and Long Island, a model of the Adams hydroelectric power plant at Niagara, as well as several new working models. After 2000, both the number of exhibits and the Museum's exhibition activities grew rapidly; from 2000 to the present, the collection has nearly doubled in size, creating conditions for the establishment of a dedicated museum collection.



Photo 1: Tesla Oscillating Transformer 500 kV.



Photo 2: Induction motor with Egg shaped rotor.

Collection T:21

The collection of working models and scale replicas of the Nikola Tesla Museum today numbers around 100 inventory items. To provide a clearer overview of the collection and its objects, as well as to better understand the collection’s function—primarily in relation to exhibition activities, which represent the main purpose of these items—I will attempt to define its structure through several classifications.

The structural division of objects within Collection T:21 can be determined according to several parameters:

1) Division by time of creation,

The exhibits can be categorized into two groups according to the period in which they were created: those produced at the time of the Museum’s founding and before its opening to the public, and those created afterward, from 1955 to the present day. As previously mentioned, for the Museum’s first permanent exhibition, from its establishment up to its public opening, 15 working models were produced—16 exhibits in total, since the Model of the Spiral Secondary of a High-Frequency Transformer, which was part of the permanent display’s scenography, was included in the collection when it was formally established in 2014. The second category comprises exhibits that were produced (or acquired) from the Museum’s opening to the present. These items are closely tied to the needs of exhibition activities beyond the Nikola Tesla Museum itself and reflect the development of such activities over the years. It can also be said that the growth in the number of these exhibits has been proportional to the expansion

of these activities as well as to the increasing global popularity of Nikola Tesla.

2) Division by location,

The division of exhibits according to their location also separates the objects into two categories: those displayed in the Museum’s permanent exhibition and those kept in the storage facilities of the Nikola Tesla Museum, including items that are loaned for the Museum’s traveling exhibitions. This classification is important in practical terms because it reflects the operational logic of the Museum’s exhibition activities. The current permanent exhibition, designed in 2016 by Dr. Branimir Jovanović and still in place today with only minor modifications, retains a large portion of the working models from the original permanent display.¹ In this sense, the location-based division partially overlaps with the time-based division. However, this overlap is only approximate, as the permanent exhibition also includes exhibits produced after 1955. It is also worth noting that for working models displayed outside the Museum, namely at traveling exhibitions, a system of control switches has been introduced to operate the devices. These switches are connected to time relays that regulate the operating periods and pauses of each exhibit, allowing visitors to directly activate the working models themselves. By contrast, in the Museum’s permanent exhibition the devices are operated by a demonstrator, who simultaneously

¹ The only exceptions are the exhibits Mechanical Analogy of the Rotating Magnetic Field, Four Circuits in Resonance, Radio-Controlled Boat, and Oil-Filled Transformer, which have been removed from the permanent exhibition (the first two are used for the Museum’s traveling exhibitions).

explains their function. While this provides a higher-quality mode of presentation, such a guided-tour concept—and even the presence of a demonstrator—cannot always be ensured at traveling exhibitions.

3) Thematic division

The thematic division of exhibits refers to the aspect of Tesla's life and scientific work to which they are related. Nikola Tesla's scientific work can broadly be grouped into three main areas: The System of Production, Transmission, and Use of Alternating Current, High-Voltage, High-Frequency Currents, and Mechanical Engineering. To these three scientific categories a fourth, more informal group can be added—“Other”—which includes replicas of Tesla's personal belongings, items related to his social life, copies of documents, and similar materials. This thematic division is significant because it defines the actual number of exhibits available for use, given that many objects have duplicates. The growing demand for traveling exhibitions after 2000, and especially after 2015, created a need for the production of new exhibits. The increasingly frequent requirement to organize more than one exhibition at the same time led to the replication of certain working models. As a result, the collection contains multiple copies of models such as the Egg-Shaped Rotor Induction Motor, Tesla Oscillating Transformer, and various scale models and replicas. Consequently, the total number of inventory units does not correspond to the number of items that can be displayed in a single exhibition. Rather, this division indicates the availability of objects for simultaneous displays. This approach has proven highly practical given the growing popularity and demand for traveling exhibitions. At present, the Nikola Tesla Museum is able to organize three different exhibitions simultaneously, in addition to maintaining its permanent display

Analyzing the history of the Nikola Tesla Museum's exhibition activities and taking into account the thematic division of the exhibits, it can be concluded that certain Tesla inventions—and the working models corresponding to them—can serve as representatives of each thematic area. Accordingly, the induction motor represents the first theme (the system of production, transmission, and use of alternating current), the Tesla oscillating transformer represents the theme of high-voltage, high-frequency currents, and the Tesla pump represents the field of mechanical engineering. It follows that these three working models form the conceptual foundation for a large number of the Museum's exhibitions and for the broader presentation of Tesla's work, which

has indeed been the case. The further development of new working models can thus be defined as the supplementation of each of these thematic areas, modeled on the original permanent exhibition. For this reason, all three types of induction motors presented in the permanent display have been produced (induction motor with a disc-shaped rotor, “Egg of Columbus”, and induction motor with a squirrel-cage rotor), along with various models of Tesla transformers, Tesla pumps, and other models corresponding to these thematic areas, as well as scale models and replicas that also follow the same themes.

Requirements of working exhibits

Unlike scale models or static objects, working exhibits are by their very nature prone to malfunctions and require regular maintenance. This need was formally recognized in 2011, when an agreement was signed with engineer Radomir Putnik for regular (and emergency) maintenance of the Nikola Tesla Museum's working exhibits. The Museum also collaborates with engineers Velimir Mrđen and Velibor Zlatanović, who have created some of the working models, as well as with other specialists. There remains an ongoing need for inter-institutional cooperation in this field.

Working models also impose visitor safety requirements. Over years of practice, the Museum has continuously improved this aspect, introducing various measures to protect both visitors and the exhibits themselves. This includes collaboration with the Laboratory for the Study of the Effects of Ionizing and Non-Ionizing Radiation at the Department of Physics, Faculty of Sciences, University of Novi Sad.

Information Technologies in the Nikola Tesla Museum

The growing global popularity and interest in Tesla—especially after the commemoration of the 150th anniversary of his birth—and the proportional increase in demand for more traveling exhibitions at the beginning of the new millennium have brought new challenges for museum presentation and the need to design new themes and exhibits. At the same time, museum presentation methods worldwide have been undergoing modernization and exploring different forms and modes of communication with audiences. Between 2016 and the present, the Nikola Tesla Museum has organized more than 30 traveling exhibitions both in Serbia and abroad. Some of the most visited were held in Shanghai (over 300,000 visitors), Milan (over 70,000), Barcelona (over 150,000 visitors), and Madrid (over 100,000 visitors). This period was also marked by the rapid development

of information technologies and the diverse tools they provide. As early as 2003, the Nikola Tesla Museum began using the possibilities of information technology and animation to create animated content that demonstrates the operation of various Tesla inventions—both those already represented by working models and those for which the Museum does not possess an appropriate working model.

Another milestone, the 160th anniversary of Nikola Tesla’s birth, brought a further surge of popularity and public interest in Tesla, and consequently new demands for presentation. The Museum’s permanent exhibition was updated, and the concept of traveling exhibitions was raised to a higher level through the inclusion of professional designers and the adoption of various IT technologies, such as mapped projections, animated content on touch screens, and similar innovations. In addition, the permanent exhibition was enriched with new content developed in collaboration with the Digital Mind studio, employing the latest technologies of the time. One notable feature was the VR application “Doživi Teslu” (“Experience Tesla”), which allowed visitors

to attend a lecture by an animated Tesla in a digital virtual space on various topics. A similar project was created in cooperation with the Faculty of Electronic Engineering in Niš: a VR application of Tesla’s famous Long Island laboratory enabled visitors, using VR equipment, to explore a digitized version of this laboratory. This application was used as supplementary content for some traveling exhibitions and other organized programs of the Nikola Tesla Museum². More recently, the growing popularity of social media has created a need for the continuous production of content tailored to these platforms. In response, the Museum has increasingly turned to animated content and embraced the advantages of the rapidly developing AI technologies—a development that can justifiably be described as a “revolution.” AI technology will undoubtedly continue to reveal both its potential and its shortcomings, the latter being particularly evident during the developmental stage we are currently witnessing.

² This technology was discontinued during the COVID-19 pandemic and has never been reintroduced into the program, as it was deemed impractical under the prevailing conditions.



Photo 3: VR application “Doživi Teslu”.

The “match” result?

Summarizing all of the above—the Museum’s extensive experience with presentation methods and traveling exhibitions, together with the availability of various new technologies—one can conclude that working models ultimately hold a significant advantage over IT technologies, which is also my personal impression. Field experience has shown that audiences are far more interested in

and fascinated by the “live” working model than by animations, VR, or similar digital features. Within the permanent exhibition of the Nikola Tesla Museum, Tesla’s oscillating transformer with an output voltage of 500 kW, built in 1954, remains the most popular exhibit. This suggests that, no matter how advanced new technologies may be, they are accessible in everyday life, whereas working models are something visitors rarely have the opportunity to

encounter. Another reason may lie in the fact that, regardless of technological progress, a boundary between the real and the virtual world persists—and visitors consistently seem to prefer reality. When considerations of cost-effectiveness are added—namely, that all new technologies require significant

financial resources and quickly become obsolete—the outcome of this “match” clearly favors the working models, while information technologies assume only a supporting role that is not indispensable.

REFERENCES:

- Civrić, Z. 2003: *Izložbena, izdavačka, javna i obrazovna delatnost Muzeja Nikole Tesle u Muzej Nikole Tesle: 1952-2003*. Beograd: Muzej Nikole Tesle
- Hudson, K. 1987: *Museum of Influence*. Cambridge University Press, 228pp.
- Jovanović, B. 2014: *Teslin čudesni svet*. Beograd: Vulkan, 320pp.
- Maroević, I. 1993: *Uvod u muzeologiju*. Zagreb: Zavod za informacijske studije Odsjeka za informacijske znanosti Filozofski fakultet Sveučilišta u Zagrebu, 286pp.
- Radić-Kalderon, J. Civrić, Z. 2003: *Stalna postavka Muzeja Nikole Tesle u Muzej Nikole Tesle: 1952-2003*. Beograd: Muzej Nikole Tesle.
- Smiljanić, D. 2003: *Muzej Nikole Tesle u Muzej Nikole Tesle: 1952-2003*. Beograd: Muzej Nikole Tesle.

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INTERACTIVITY, INTERPRETATION, INSPIRATION: EDUCATION IN THE NEW MUSEUM PERMANENT EXHIBITION

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SYNOPSIS

The newly renovated Croatian Natural History Museum is a dynamic, inclusive space for knowledge and experience. The modern exhibits support multi-layered education based on interactivity, interpretation, and inspiration. By observing the displays and engaging with digital tools, multimedia, and tactile elements, visitors become participants in a story where knowledge is conveyed not only through information but also through personal experience. The focus is on accessibility, interactivity, and inclusivity, attracting new audiences – middle-aged and older individuals, previously marginalized communities, the growing number of foreign nationals living in Croatia, and tourists. Through innovative exhibition concepts and new technologies, education within this framework also fosters social change – the museum becomes a gathering place for the local community and a center for lifelong learning. This approach creates opportunities for new knowledge – not only about the natural specimens on display, but also about identities, ecology, and the contemporary challenges of climate change.

SINOPSIS

INTERAKTIVNOST, INTERPRETACIJA, INSPIRACIJA: EDUKACIJA U NOVOM MUZEJSKOM POSTAVU

Novi, obnovljeni Hrvatski prirodoslovni muzej dinamičan je i inkluzivan prostor znanja i doživljaja. Moderno koncipirani novi postavi omogućuju višeslojnu edukaciju koja se temelji na interaktivnosti, interpretaciji i inspiraciji. Promatranjem izloženih sadržaja te integracijom digitalnih alata, multimedije i taktilnih elemenata, posjetitelji su dionici priče gdje se znanje ne prenosi samo informacijom, već i osobnim doživljajem. Naglasak je na pristupačnosti, interaktivnosti i uključenosti, čime se privlači nova publika – ona srednje i starije dobi, zajednice koje su prije bile marginalizirane, te sve brojniji strani držljavani koji žive u Zagrebu i Hrvatskoj kao i turisti. Kroz inovativne koncepte izlaganja i korištenje novih tehnologija, edukacija u novom okviru donosi i društvene promjene – muzej postaje mjesto boravka i druženja lokalne zajednice, mjesto cjeloživotnog obrazovanja. Takav pristup stvara prostor za nova znanja – ne samo o izloženim prirodninama, već i o identitetima, ekologiji i suvremenim izazovima koje donose klimatske promjene.

INTRODUCTION

Following a comprehensive renovation, the Croatian Natural History Museum has become a contemporary, inclusive space for knowledge and experience. The new permanent exhibition marks a paradigm shift – the museum is no longer a place of silence and static exhibits, but a dynamic educational centre where knowledge is built through interactivity,

interpretation, and inspiration. The museum follows modern practice, which increasingly emphasises active participation and visitor interaction, rather than passive viewing of exhibits. In the new exhibition, the visitor is not just a spectator but also a participant in the process of learning and discovery.

This article demonstrates how the new exhibition at the Croatian Natural History Museum enables

multi-layered education and lifelong learning, with an emphasis on inclusivity for diverse visitor groups through the use of digital and tactile tools, as well as the cultural and social significance of the museum as a place for meeting and exchanging knowledge. The use of new interactive and interpretive methods in the exhibition aims to contribute to more effective education and to show how such approaches inspire audiences to gain a deeper understanding of natural, cultural, and historical heritage. The new exhibition is the result of a project to implement a new museum, renovate and extend the historic building that houses it, and create a new display with new content, entitled “The Keeper of Heritage as a Catalyst for Development, Research and Learning – the New Croatian Natural History Museum”. The project for the building’s renovation and the new permanent exhibition was led and coordinated by the Museum’s Director, Professor Dr Tatjana Vlahović, with her team headed by Dr Iva Mihoci, a museum curator.

DISCUSSION

A thorough reconstruction of the museum’s building has made this 18th-century historic nobleman’s palace in Zagreb’s Upper Town functional for the modern activities of the Croatian Natural History Museum, adapting its facilities for the exhibition of the museum’s rich collections while also presenting the value and uniqueness of the building itself, both for the museum and the city as part of its tourist offering. The Croatian Natural History Museum now has both an impressive building and a contemporary organisation. This primarily refers to the exhibitions, which present part of the vast natural heritage that the Museum preserves and displays.

The reconstruction helped the museum solve problems that had significantly hindered its development, primarily the inadequate spaces for displaying natural history exhibits, a lack of space for ancillary facilities (such as a children’s workshop or a souvenir shop), and outdated infrastructure, which did not allow for the use of modern audio-visual technologies. The adaptation has given the building a completely new lease of life, and the museum has become a thoroughly engaging 21st-century institution, full of creative, interactive content for all visitors.

It is now recognised that a museum is not, and should not be, just a scientific institution (collection, study, and identification of exhibits) but also a space of interest to a wider audience, which should be attracted with additional content (Majanović (1994), Bauer (1975, 1985)). A museum must function openly,

as a place where everyone is welcome and where new insights are gained about one’s own cultural and natural heritage and identity. This is achieved through specific actions devised by professional museum staff, through which the museum becomes involved in the life of the local community. Events that attract media attention will ultimately result in a greater number of visitors. The aim is for the museum to be visited more by individual visitors and families, in addition to organised school groups. These are the fundamental starting points in considering how to design and implement a new exhibition. A larger space designated for the exhibition and presentation of the museum’s collection certainly contributes to this. Modern exhibitions are designed with many interactive features that offer numerous opportunities for preparing a variety of educational programmes in which visitors can participate actively, reflect on what they have experienced, and be creative at the same time (according to Toma (2010)). The thorough renovation of the old historic nobleman’s house not only enabled the expansion of the exhibition space, and thus the creation of a modern, interactive exhibition, but also made the museum accessible to people with various disabilities, which had not been possible in the previous museum due to numerous obstacles such as stairs and narrow corridors. All of this was taken into account during the design of the building’s internal reconstruction, to enable people with various forms of disability not only to visit the museum but also to enjoy a more pleasant, barrier-free experience, thereby ensuring equality with other members of the community. However, the concept of the ability to “move freely and without hindrance” refers not only to physical barriers such as stairs or entrances and exits that are too narrow, but also to the provision of information and orientation in visual and tactile forms for people with special needs (Bosnar-Salihagić, 1999). For each group of people with disabilities (those with motor impairments, the deaf, the blind, etc.), specific requirements must be met. For example, a lift is provided for people with reduced mobility where stairs are present, and entrance doors and corridors are widened in accordance with the standards required to facilitate their movement. For visually impaired and blind visitors, tactile objects are provided in each thematic section, along with descriptions in Braille (**Photo 1**). For deaf and hard-of-hearing visitors, subtitles are provided in all video and film presentations (**Photo 2**). The accessibility of the museum buildings to people with disabilities is an important part of their integration into society, and “accessibility” here means much more than just



Figure 1: A tactile museum object for blind and partially sighted people (dinosaur hall).

physical access; it also denotes the availability of information, which is of great importance. In the new museum, the primary focus is on accessibility for visitors with disabilities, making the Croatian Natural History Museum a museum for all, with a spacious, representative, modern new permanent exhibition that ensures excellent visitor flow and communication.

The museum's new permanent exhibition is accessible, tailored to the general public, and presents natural history through the items it houses. The guiding principle behind the entire exhibition concept is to answer the questions: what is life, how was it created, how has it evolved through geological time, and what is life like today? Our new exhibition can be described in one word: change – a change in matter, form and size, a change in time and space. Through exhibits from the museum's collections, the permanent exhibition presents the diversity of organisms that have evolved over geological history, their diversity today, their interrelationships, and the threats to which species are currently exposed (Mihoci, Brezinščak, 2024). The permanent exhibition spans three floors over an area of almost 3,000 m², and consists of the Mineralogical and Petrographic Exhibition, the Geological and Palaeontological Exhibition, and the Botanical

and Zoological Exhibition. Through 43 thematic units, visitors can discover topics and objects by looking, listening and touching. In every exhibition room, there is a central item that can be explored by touch, surrounded by collection exhibits, mainly originals, as well as by many multimedia screens with additional information such as maps, charts, games, scientific contests, and more (Photo 3). Alongside the exhibition rooms are memorial rooms, which are like time capsules, dedicated to the distinguished naturalist museum founders and creators of the museum's collections, Spiridion Brusina and Dragutin Gorjanović Kramberger, offering visitors a glimpse into the beginnings of natural science in Croatia.

The new museum exhibition is interactive, its interpretation offers numerous possibilities, and it is also an inspiration. The new exhibition has also brought new challenges, opportunities and ideas in the education of museum visitors. The popular-educational programmes of the Croatian Natural History Museum are an umbrella term for programmes organised and run at the museum, ranging from guided, classical and interpretative tours, through specialist and creative workshops, to exhibitions of pupils' works produced in the workshops, meetings with naturalists, lectures, cooperation with other museums and educational and cultural institutions, as well as participation in interdisciplinary and EU-funded projects. All educational programmes are aimed at museum visitors – from pre-school children and pupils to older visitors and senior citizens. Also, brochures with basic information about the exhibition and the museum itself have been prepared for visitors in several languages. For younger visitors, there is a kind of tour-guide that leads them around the museum by having them solve certain tasks. Education programmes are tailored for first-time visitors, regular visitors, hobbyists and amateur naturalists, as well as professionals in the field of natural sciences. It is well known that a museum is not a school, and that



Figure 2: Adaptation for the deaf and hard of hearing, film subtitling.



Figure 3: One of the thematic units in the museum features a tactile object in the centre, original natural history exhibits, and interactive and multimedia content.

knowledge is acquired here informally, through visual, interactive and enjoyable content, because learning is not subject to the same evaluation as it is at school. This benefits both pupils and teachers, as everyone is more relaxed and therefore more open to new knowledge. Through its educational department, the museum makes a great effort to provide visitors – who are mostly pupils, though there are more and more adults – with a comprehensive and inclusive exhibition, accompanied by a suitable educational programme. The beauty of minerals, the mystery of fossil remains, and the diversity of taxidermied animals – which can only be seen in the museum, from butterflies and shells, bats and birds to tiny creatures from the depths of the earth – show visitors just how fascinating and worth exploring the world around us is. Each segment of the exhibition, each thematic unit, presents its theme through large-scale dioramas, primarily featuring original exhibits, but also models and replicas, as well as interactive elements for exploration, play, or getting additional information. In the newly renovated museum, there is also an educational workshop space where students can gain additional knowledge about topics from the exhibition, which is important because it further expands and strengthens their understanding (**Photo 4**).



Figure 5: Museum atrium – space for performances, concerts, panel discussions ...



Figure 4: Museum workshop.

Alongside the exhibitions, an important museum space is the covered atrium, which conceptually connects all the museum's sections. Furthermore, it adds to the museum's value as it is used for various cultural and professional events throughout the year, regardless of the weather (**Photo 5**). Visitors are also given a glimpse of the museum's work "behind the scenes", for example, by visiting a new laboratory that is open for viewing, where interested visitors can see what is done in museum laboratories and how museum exhibits are prepared and mounted for display. This also provides an excellent opportunity to organise various natural science courses for students, scientists, and amateur hobbyists (**Photo 6**). Visitors are particularly interested in the multimedia hall, where 3D animations are projected onto a huge wall surface as an integrated part of the exhibition. At the same time, this multifunctional space also serves as an open platform for showcasing purpose-developed interactive content in the natural, technical and social sciences, in the arts and in medicine (Mihoci, Vlahović, 2025) (**Photo 7**). Last but not least, no less important is the opening of the gift shop, as this is also a form of popularisation and education for visitors. The tour of the museum ends in the museum shop. A souvenir has long since ceased to be merely an item bought



Figure 6: Museum science lab.



as a memento of a place visited; it is now an object that carries its own educational message, and as such becomes interesting to most visitors. The souvenirs on offer are related to the museum's core content, so in addition to museum publications accompanying the exhibitions, there are also publications aimed at the very youngest visitors (picture books, colouring books), as well as for scientists. The educational publications on offer explain natural sciences in line with school curricula and are therefore recognised as supplementary teaching aids. In addition to

publications, various original minerals, fossils, as well as educational posters, games, fashion accessories (T-shirts, hats, ties, bags) and many useful items are also on offer, all of which promote knowledge of the natural sciences. Every museum shop or souvenir shop contributes to bringing the museum to life, but more importantly, to attracting visitors. The products sold are, in a way, ambassadors for the museum, spreading its reputation, especially if a visitor buys them and gives them as gifts to others (Gob, Drouguet, 2007) (Photo 8).



Figure 7: Multimedia Hall for lectures, presentations, meetings ...



Figure 8: Souvenir shop - selection from the museum souvenir offer based on museum collections.

In brief, here is what the newly renovated Museum offers:

1. Atrium

This contemporary covered space unites history, science and culture, and is the first area visitors encounter. Its main attractions are models of a colossal shark, a dolphin and an extinct giant marine mammal. The multipurpose space is suitable for museum openings, events, concerts and performances. Equipped with a PA system, theatrical lighting, a projector and a projection screen, the atrium is a highly attractive venue for receptions, performances, concerts and conferences. The atrium also features two bridges on the first and second floors, providing excellent vantage points for the exhibits and enabling circular circulation. The bridges incorporate modern technical solutions required for year-round cultural and scientific events.

2. Mineralogical and Petrological Display

The exhibition begins in the multimedia hall with the thematic section "Space", featuring items from the meteorite collection. As visitors progress through the permanent display, they encounter the petrological collections, exploring the diversity of rocks, followed by the evolution and variety of minerals through mineral systematics. The exhibition continues with a display of the physical properties of minerals and an introduction to the specialised mineral collections unique to our Museum.

3. Evolution

This section explores the origin of life on Earth and the theory of evolution through the work of Darwin and Wallace. It marks the transition from non-living to living matter.

4. Geological-Palaeontological Display

This presentation of the geological past, using material from the geological and palaeontological collections, guides visitors through our planet's history from around 4.6 billion years ago, through the age of the supercontinent Pangaea, the dominance of reptiles in the Jurassic and Cretaceous periods, and the emergence of the world as we know it today, including the frequent climatic reversals of the Quaternary. This exhibition concludes with the evolution of hominins and presents the theme of the Krapina Diluvian.

5. Botanical and Zoological Exhibition

On the second floor, the living world that surrounds us today is presented, along with the threats to

biodiversity. The display features three-dimensional habitat reconstructions, the Tree of Life, the plant kingdom, the museum's largest collections – its entomological collections – and the diversity of invertebrates and vertebrates. The final part of the exhibition is dedicated to the importance of natural history museums, tracing their history back to 1846. This section vividly illustrates the museum's role in preserving natural heritage as a witness to time and space.

6. Multimedia Space

The latest multimedia installation is unique in Croatia, allowing you to travel through space and time with interactive 3D flights across the entire known universe. The new Natural History Museum features cutting-edge technology – an impressive system that provides visitors with a unique virtual reality experience through wall and floor projections. Using an advanced laser projection tracking system, Deep Space offers a fascinating view of the universe and exemplifies interactive media art. This innovative addition opens the door to a new dimension of learning and entertainment, making the Natural History Museum an unmissable destination for all science and technology enthusiasts.

7. Annexe

The 350 m² space, equipped with the latest technology, is used for the museum's temporary and guest exhibitions.

8. Museum Education Workshop

This space for educational activities and work with children and adults is also a place for visitors to stay and socialise, as well as hosting specialist and creative workshops. Alongside a reference library of museum publications, a variety of interactive exhibits are available for visitors to use independently.

9. Scientific Laboratory

The new laboratory, equipped with modern technology and apparatus, enables the exploration of natural phenomena, plant and animal species, and geological samples, and is particularly useful for research projects.

10. Museum Shop – Souvenir Shop

A wide range of educational museum publications and souvenirs, based on exhibits from the permanent display and the museum's collection, are offered to popularise and educate about the natural sciences.

11. Photo Point

The museum entrance features a life-size reconstruction of a multi-metre-tall Istrian dinosaur, and as a photo point for visitors, it has become a favourite spot for creating memories of their visit to the museum (**Photo 9**).

Photo documentation: Croatian Natural History Museum, Zagreb, Croatia



Figure 9: Photo point – a large model of a dinosaur whose footprints were found in Croatia.

REFERENCES:

- MAJANOVIĆ, N. 1994: Dr. Bauer i muzejska pedagogija. *Muzeologija*, br. 31, Muzejski dokumentacijski centar, Zagreb, 29-33.
- BAUER, A. 1975: Muzejska pedagogija. *Referat sa VIII. kongresa Saveza muzejskih društava Jugoslavije*, 26.-28. V. Bilješke. - Literatura. Pula. 101-111.
- BAUER, A. 1985: *Savjetovanje o pedagoškoj djelatnosti u muzejima u Sloveniji*. ARGO, br. 25., Ljubljana, 83.
- TOME, S. 2010: Zašto se ne bismo rasonodili u muzeju i istovremeno naučili nešto novo?, *Zbornik radova muzejskih pedagoga Hrvatske s međunarodnim sudjelovanjem*, Hrvatsko muzejsko društvo, Zagreb. 71 – 77.
- BOSNAR SALIHAGIĆ, Ž. 1999: Muzeji i osobe s posebni potrebama, *Vijesti muzealaca*, br. 1-4. Hrvatsko muzejsko društvo, Zagreb. 11-113.
- GOB, A. & DROUGUET, N. 2007: *Muzeologija - Povijest, razvitak, izazovi današnjice*. Antibarbarus, Zagreb.
- MIHOCI, I. & BREZINŠČAK, R. 2024: *Hrvatski prirodoslovni muzej*, deplijan, Hrvatski prirodoslovni muzej, Zagreb.
- MIHOCI, I. & VLAHOVIĆ T. 2024: Novi stalni postav Hrvatskog prirodoslovnog muzeja, *Vijesti Hrvatskog geološkog društva* 61/2, Hrvatsko geološko društvo, Zagreb.

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