EDUCATIONAL AND SCIENTIFIC COUNCIL OF THE UNIVERSITY OF BELGRADE
FACULTY OF BIOLOGY

At the VII regular session of the Teaching and Scientific Council of the University of Belgrade, Faculty of Biology, held on May 13, 2024, based on the request of mentor Dr. Duško Ćirović, associate professor at University of Belgrade, Faculty of Biology and Dr. Anne Hertel, research fellow, Ludwig Maximilian University of Munich, the Commission for the review and evaluation of the doctoral dissertation of Neda Z. Bogdanović, research associate at University of Belgrade, Faculty of Biology, titled: **„Spatio-temporal movement patterns of brown bears (*Ursus arctos*) in the Central Balkans**" has been appointed consisting of:

1. Dr. Andreas Zerosser, Professor, University of South-Eastern Norway – Faculty of Technology, Natural Sciences and Maritime Sciences, campus Bø;
2. Dr. Milan Plećaš, Assistant Professor, University of Belgrade, Faculty of Biology;
3. Dr. Aleksandra Penezić, Assistant Professor at University of Belgrade, Faculty of Biology.

The Commission has reviewed completed doctoral dissertation of the candidate and submits to the Teaching and Scientific Council of the University of Belgrade, Faculty of Biology the following:

R E P O R T

General information about the doctoral dissertation

The doctoral dissertation of **Neda Z. Bogdanović**, titled **„Spatio-temporal movement patterns of brown bears (*Ursus arctos*) in the Central Balkans**" presents an original scientific research prepared as a set of three published scientific articles, representing a single topic unit with a synthetic presentation of introduction, discussion and conclusion sections. The dissertation is written in English on 82 pages and divided into 6 parts: **Introduction** (19 pages), **Research objectives** (1 page), **Scientific papers resulting from the doctoral dissertation** (43 pages), **Discussion** (7 pages), **Conclusion** (1 page), and **Literature** (11 pages). The doctoral dissertation also contains the following unpaginated pages: Title page on English and Serbian language, Information on mentors and the Commission members, Statement of gratitude, Abstract of the doctoral dissertation with key words on English and Serbian language and Content. At the end of the doctoral dissertation, the following documents are attached: Author's biography, Statement of authorship, Statement of the identity of the printed and electronic versions of the doctoral dissertation and Statement of use.

Analysis of the doctoral dissertation

The main objective of the doctoral dissertation of Neda Bogdanović was to analyze the spatio-temporal movement patterns of brown bears (*Ursus arctos*) in the Central Balkans. The study is based on GPS telemetry data collected in the period from 2007 to 2022. Telemetry research is at forefront of modern technology in the field of idioecological research and allows collection of large amount of high-quality data with minimal disturbance to the animals. Therefore, GPS

telemetry data can significantly contribute to a better understanding of the ecology of species and serve as a basis for appropriate management and conservation decisions.

Equipping 20 bears with GPS collars provided insights into various aspects of the species' ecology: the diel and seasonal activity patterns of the different age and reproductive categories of bears, a better understanding of their hibernation behavior, but also of their preferred habitats. In addition, the statistical modelling revealed areas where the bears could potentially expand their range in the future, but also areas where a functional connectivity between the three present bear populations in Serbia could be established. Considering the fact that brown bear distribution in Europe is highly fragmented, as shown by the existence of 10 different populations, connecting the three populations in Serbia would significantly contribute to the long-term conservation of the brown bear in Europe.

The first part of the doctoral dissertation, **Introduction**, is divided into three chapters with several subchapters. At the beginning of the first chapter, entitled „Living in a changing world – effects of human disturbance and climate change on wildlife behavior", the candidate gives a brief overview of the main factors threatening biodiversity today, emphasizing the vulnerability of mammals, especially large carnivores. In the second chapter „Brown bear as model species for assessing anthropogenic pressure on the large carnivore behavior", the candidate concisely outlines the basic biological and ecological characteristics of the model species – the brown bear. She also gives an overview of the former and current distribution of the species in Europe and the world, as well as the latest data on the species' status and population trends in Serbia. The third chapter entitled „Human disturbance, management practices and climate change alter brown bear behavior and life history", provides a detailed overview of the current knowledge on the factors that threaten brown bears on a global scale, but also how the factors discussed affect the behavior and ecology of the species.

In the second part of the doctoral dissertation, **Research objectives**, the candidate concisely and clearly presents the main objectives of the dissertation. Considering the conservation status of the brown bear in Serbia and the insufficient knowledge about the ecology of the species in the study area, the main subject of the doctoral dissertation was to analyze the spatio-temporal movement patterns of the brown bear based on GPS telemetry data. In addition to the main objective of the doctoral dissertation, three specific goals were defined:

1. analysis of movement patterns between different age (adult and subadult bears) and reproductive classes (males, solitary females and females with offspring) during two biologically important seasons - the mating and hyperphagia seasons.

2. analysis of winter behavioral patterns of bears grouped into five categories based on their age and reproductive status (adult males, subadult males, solitary females, females with cubs of the year and females with yearlings). In addition, the goal was to identify the effects of climate (temperature and snow depth) and anthropogenic variables (supplementary feeding) on the hibernation behavior of brown bears.

3. Spatial analysis based on all available data on the presence of bears (telemetry, camera traps, traces of activities in the habitat) to predict a possible expansion of the brown bear range in Serbia. The underlying idea was to assess the importance of different environmental variables (land cover, distance to settlements, distance from roads) for the distribution of bears, to identify habitats suitable for bears and to evaluate the connectivity between the three European brown bear populations in Serbia.

In the part **Scientific papers resulting from the doctoral dissertation**, three papers are included.

In the first paper, titled „Seasonal and diel movement patterns of brown bears in a population in south-eastern Europe", it was shown that the movement patterns of brown bears are influenced by the time of day (day/night) and differ significantly between the different reproductive categories of bears during the two analyzed seasons (mating season and hyperphagia season). Bears follow a bimodal activity pattern with the highest movement rates during night and crepuscular hours which can be further modified by intrapopulation relations. The differences in movement and activity patterns were much more pronounced during the mating season compared to the hyperphagia when movements of all reproductive classes were mainly driven by food search. In contrast, during the mating season, adult males and solitary females exhibited very similar movement and activity patterns (result of mate searching behavior), while females with dependent offsprings and subadult males modified their patterns. In particular, females with dependent offsprings moved significantly more during the daylight hours to avoid infanticide. Subadult males travelled significantly longer distances compared to all other bear classes, likely related to natal dispersal and avoidance of inbreeding. In addition, the results of this doctoral dissertation showed that the movement patterns of bears could also be influenced by the supplementary feeding practice and the large number of tourists in the studied area, but more data are needed to further confirm this hypothesis.

In the second paper, titled „Cozy den or winter walk: the effects of climate and supplementary feeding on brown bear winter behavior", the candidate showed that brown bear winter behavior patterns varied across age and reproductive classes, but also in the same individual monitored over several years. In general, among 31 analyzed winter events, hibernation was registered in 25 events, either as a single (6 events) or intermittent event (19 cases), while in 6 cases the bears did not show behavior consistent with hibernation. Analysis of the 25 hibernation events confirmed that the total time spent in hibernation ranged from 42 to 172 days (mean 97 days), with males spending significantly less time in the den compared to females (on average 80 and 130 days, respectively). The results showed significant variations between females of different reproductive status. In particular, females with cubs of the year hibernated the longest (155 days on average), followed by the only monitored female with yearlings (136 days), while solitary females stayed in the dens the least (99 days on average). The analyzes showed that the bears entered the dens within a two-month period from November to January and left between January and May. Among 6 events in which hibernation was not registered, 3 males showed semiactive behavior with short periods of inactivity (range 1-26 days), while the other 3 males remained active throughout the entire winter. However, movement of the winter-active bears was influenced by snow depth and distance to the nearest feeding site. In addition, both semiactive and active bears were found to significantly reduce their movements with increasing snow depth, moving on average 1.1 km per day in 50 cm deep snow, compared to 2.5 km per day when there was no snow. Although the use of supplementary feeding sites varied throughout the year, it was found that bears spent significantly more time at these sites in the winter months than in the summer. In light of this, the candidate emphasizes that the predicted mild winters and prolonged food availability in combination with supplementary feeding could lead to a more frequent absence of hibernation in the future. In addition, the candidate highlights that the absence of hibernation in females could significantly affect their reproductive success and survival of offspring, so further research into how these factors influence bear hibernation is necessary.

In the third paper, titled „Where to go? Habitat preferences and connectivity at a crossroad of European brown bear metapopulations", it was shown that altitude and forest cover are the most important variables in the habitat selection of brown bears in Serbia and that the presence of bears is negatively influenced by human structures (settlements and roads). In addition, there were differences in habitat selection between bears of the studied populations, with bears belonging to Dinaric-Pindos population preferring higher altitudes, while forest cover was the most influential environmental variable for the Carpathian population. The different habitat preferences were discussed in relation to the different orographic and land cover characteristics in western and eastern Serbia, but also to the fact that bear habitat selection is primarily driven by human avoidance, which was also confirmed in other areas. The analysis of habitat suitability revealed 9,400 km^2 of habitat suitable for bears on a coarse scale (5x5 km) and 4,451 km^2 on a fine scale (1x1 km). In addition, the results showed that 35% and 24% of the area at the coarse and fine scales, respectively, are already occupied by bears, indicating that there is still plenty of space for bear populations to increase in size and range in Serbia. It has also been shown that more than half of the occupied suitable habitats are within protected areas, suggesting that the expansion of existing or the establishment of new protected areas could be considered as a conservation measure to protect brown bears. The candidate emphasizes that the results obtained may be of great importance for activities that are currently being carried out as part of the development of the Natura 2000 network. In addition, it has been shown that several areas in the south-east of the country, in particular the Nature Park „Radan Mountain", can function as connectivity zones and promote movement between the three existing bear populations in Serbia if appropriate mitigation measures are implemented. Finally, the candidate emphasizes that future conservation strategies should focus primarily on improving the quality and permeability of human-modified landscapes, but also on adjusting human activities to ensure the long-term coexistence of bears and humans.

In the **Disscusion**, which is organized into four chapters, the candidate has clearly and meaningfully summarized the results presented in the three attached papers and analyzed them in the context of the 196 cited references used in this doctoral dissertation. In this analysis, the candidate showed exceptional talent and ability to interpret the results obtained in the context of existing knowledge and to understand and present their contribution to the long-term conservation and protection of brown bears in Serbia.

At the beginning of the discussion, the candidate discussed the previous research on the brown bear in Serbia and pointed out that until 2015 there was no intensive telemetry research so that the results of this doctoral dissertation are of great importance for the improvement of the current management policy as well as for the long-term conservation of the brown bear in our country.

In the first part of the discussion, the candidate discusses diel and seasonal variations in the movement patterns of bears in Serbia and emphasizes that there are significant differences between the different reproductive categories. The candidate points out that the observed movement and activity patterns of females with cubs and subadult males have probably developed as a response to intrapopulation social dynamics, rather than in response to human disturbance. This is also explained by the "human shield" theory, according to which vulnerable individuals might perceive humans as less threatening than aggressive males, prompting them to approach humans. However, the candidate emphasizes that this behavior may lead to an increase in human-bear conflicts, suggesting that maintaining spatio-temporal separation of human and bear activities should be of the greatest importance for future conservation strategies.

In the second part of the discussion, the candidate discusses the major impact of humans on the movement patterns of many animals, including bears, by modifying habitats and making food sources more reliable and accessible. She also highlights the significant influence of supplementary feeding of wildlife, where food is provided to animals throughout the year at feeding stations, resulting in a significant reduction in their movement rates as well as their home ranges. It is also emphasized that the main purpose of supplementary feeding in Serbia is to prevent bears from approaching human settlements, but also to promote the recovery of the population. Furthermore, the candidate indicates that it is necessary to develop systematic data collection at all feeding sites to better understand the impact of this practice on bear movements.

In the third part, the candidate discusses the effects of climate change and supplementary feeding on brown bear behavior patterns during the winter period and indicates the great variability observed between 31 analyzed winter events. She also points out that in 6 cases hibernation behavior was not registered, suggesting that the availability of food at the feeding stations during winter is one of the reasons for the observed changes in winter behavior of bears, as has been shown in other areas with this practice. Finally, the candidate states that with the increase in winter temperatures and the prolonged food availability, it should be expected that bears, especially males, will skip hibernation more frequently in the coming years.

Finally, the candidate discusses the habitat preference of bears in Serbia and emphasizes that more than half of the country's surface has undergone a certain degree of anthropogenic modification and that these changes have affected behavior of bears. The candidate highlights the great importance of protected areas for brown bear distribution in Serbia, but also that appropriate conservation measures must be taken outside these areas. Furthermore, the great importance of establishing connectivity between the three present brown bear populations in Serbia is discussed. However, it is emphasized that the highway, the railway, the Morava Valley and the relatively high population density in this area may represent significant movement barriers for bears, and that the establishment of the above-mentioned connectivity requires an assessment of these barriers and the proposal of adequate mitigation measures that will reduce their impact on animal movements while increasing habitat permeability.

In the **Conclusion** part, the results of the doctoral dissertation were summarized in 10 individual conclusions, highlighting the most important factors affecting the observed spatio-temporal movement patterns of brown bears in the Central Balkans:

1. The nocturnal activity of brown bears is primarily a response to increasing human disturbance, although significant within-population and seasonal variations were observed.

2. Females with dependent offspring and subadult males modify their movement patterns (i.e. become more diurnal or disperse) in response to male conspecifics, ultimately to avoid infanticide or inbreeding.

3. All bear classes, with the exception of females with dependent offspring, reduce their movements during hyperphagia compared to the mating season, and intentional food provisioning (i.e. supplementary feeding) probably plays a very important role in shaping the brown bear movement ecology in this study area.

4. The hibernation chronology varies between bears of different sexes and reproductive categories, with males spending significantly less time hibernating compared to females. Among females of different reproductive status, females with cubs of the year are the first

to enter the den and last to leave, followed by females with yearlings and then solitary females.

5. Climate change and increasing availability and predictability of both natural and anthropogenic food resources alter brown bear hibernation behavior.

6. Year-round supplemental feeding facilitates the existence of four different overwintering strategies: obligate hibernation in females with dependent offspring of any age, single facultative hibernation, facultative intermittent hibernation with one or more short stationary periods, and complete activity.

7. Due to the different orography and land cover in western and eastern Serbia, bears belonging to different populations showed distinctive habitat preferences, with altitude being the most important factor in the habitat selection of Dinaric-Pindos bears, while forest cover better explained the occurrence of bears in the Carpathian population.

8. More than 60% of the predicted suitable habitats in Serbia is still available for bear populations to increase in size and range.

9. Protected areas play an important role in brown bear habitat selection, as more than half of bear occurrences are located within these areas.

10. The south-eastern part of Serbia, in particular the "Radan Mountain" Nature Park, represents a possible area where a functional connectivity between three populations could be established in the future, but appropriate mitigation measures need to be implemented.

Based on the results obtained and the above-mentioned conclusions, the candidate formulated a general conclusion: that the research presented here, which represents a first comprehensive study on the ecology of the brown bear in Serbia, confirms the significant impact that humans and their activities have on the behavior of the species. Furthermore, the candidate points out that the results presented are of crucial importance for the evaluation of existing management policies, but also underline their importance for the direction of future conservation efforts to ensure the long-term survival of brown bears in Serbia, but also in Europe.

The last part, **Literature**, contains 196 bibliographic units. The literary sources are cited appropriately and in the right places in the text of the doctoral dissertation.

Published papers and international conferences reports from doctoral dissertation

B1. Papers in international journals (M20)

1. **Bogdanović N**, Hertel A, Zedrosser A, Paunović M, Plećaš M & Ćirović D. Seasonal and diel movement patterns of brown bears in a population in southeastern Europe. Ecol. Evo. 2021; 11(22): 15972-15983 https://doi.org/10.1002/ece3.8267
   (**M22,** IF2021 3.167, Oblast: 75/174 Ecology)
2. **Bogdanović N**, Zedrosser A, Hertel A, Zarzo-Arias A, & Ćirović D. Where to go? Habitat preferences and connectivity at a crossroad of European brown bear metapopulations. Glob. Ecol. Conserv. 2023; 43.
   https://doi.org/10.1016/j.gecco.2023.e02460
   (**M21,** IF2022 4, Oblast: 12/65 Biodiversity Conservation)
3. **Bogdanović N**, Zedrosser A, Hertel A, & Ćirović D. Cozy den or winter walk: the effects of climate and supplementary feeding on brown bear winter behavior. J. Zool. 2024.
   http://doi.org/10.1111/jzo.13174
   (**M21,** IF2022 2, Oblast: 41/177 Zoology)

B2. Presentations from the international conference printed in excerpt (M34)

1. **Bogdanović N**, Hertel A, Zedrosser A, Paunović M, Plećaš M, Ćirović D. Reproductive class and season affect diel activity patterns of brown bears in Serbia. 27th Internation Conference on Bear Research and Management, 14-16 and 21-23 September. 2021; p. 141 (**M34**)

2. Ćirović D, **Bogdanović N**, Spasojević S, Paunović M. Haematology and serum biochemistry parameters of the brown bear from Serbia. 27th Internation Conference on Bear Research and Management, 14-16 and 21-23 September. 2021; p. 118 (**M34**)

Plagiarism check of the doctoral dissertation

The doctoral dissertation of **Neda Z. Bogdanović**, index number E3001/2018 was sent to the „Svetozar Marković" University Library on **May 13, 2024** for a software check of originality using the iThenticate program. The mentor received the report containing the results of the check on the **same day**.

The results of the software check of this doctoral dissertation show that the similarity index is 3%. Further examination of the Report revealed similarity with 17 summarizing sources. A detailed analysis of the received Report and matching segments revealed that the similarity with four sources was 2%, while all other similarities were 1%. The matches resulted from English terms, the mentor's affiliation, publications resulting from the doctoral dissertation, common appendices attached to the dissertation, and common terms and phrases typical for this doctoral dissertation topic.

Taking all of the above into account, the report proves the originality of the doctoral dissertation of candidate **Neda Z. Bogdanović**, titled **„Spatio-temporal movement patterns of brown bears (*Ursus arctos*) in the Central Balkans"**, so that the procedure for its defence can be continued.

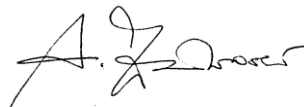**Opinion and proposal of the Commission**

The doctoral dissertation of **Neda Z. Bogdanović**, research asociate at University of Belgrade, Faculty of Biology, titiled **„Spatio-temporal movement patterns of brown bears (*Ursus arctos*) in the Central Balkans"** represents the first comprehensive research in the field of brown bear ecology in Serbia and makes a significant contribution to the overall knowledge of spatio-temporal movement patterns of bears, as well as the most important factors that affect observed patterns. According to the research approach and the interpretation of the results obtained, this dissertation represents an original scientific contribution to the knowledge of the brown bear (*Ursus arctos*) ecology and enables the evaluation and improvement of existing conservation measures by using modern research methods.

In writing this doctoral dissertation, the candidate has demonstrated the ability to precisely define scientific problems and research objectives, to apply appropriate methods of data collection and analysis, to discuss them in a high-quality manner and to draw adequate conclusions based on the results obtained.

Based on the above-mentioned regarding the doctoral dissertation of Neda Z. Bogdanović, which indicate the quality and original scientific contribution of the results obtained, and the fact that the very extensive tasks set for the purpose of this research have been fulfilled and verified by papers published in international journals, as well as the fact that the dissertation contains all relevant and necessary elements, the Commission proposes with great pleasure to the Educational and Scientific Council of the University of Belgrade, Faculty of Biology, to accept this report and enable **Neda Z. Bogdanović** the public defence of her doctoral dissertation titled **„Spatio-temporal movement patterns of brown bears (*Ursus arctos*) in the Central Balkans"**.

In Belgrade, 14.05.2024.

COMMISSION:

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Dr. Andreas Zedrosser, Professor,
University of South-Eastern Norway –
Faculty of Technology, Natural Sciences and Maritime Sciences, campus Bø

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Dr. Milan Plećaš, Assistant Professor
University of Belgrade, Faculty of Biology

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Dr. Aleksandra Penezić, Assistant Professor
University of Belgrade, Faculty of Biology