

University of Sopron
Roth Gyula Doctoral School of Forestry and Wildlife Management Sciences

Ph.D. thesis

**Herpetofaunistic diversity of the Cres-Lošinj Archipelago
(Croatian Adriatic)**

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Introduction

In recent years the Croatian islands, especially those of the Cres-Lošinj Archipelago became the focus of research of herpetologists. However, in spite of a long interest encompassing more than a hundred years, numerous gaps remain in our herpetological knowledge. For this reason, the author wished to contribute to a better understanding by performing studies outlined below.

Aims

The first task was to map the distribution of amphibians and reptiles inhabiting the archipelago as data were lacking for several of the smaller islands and also the fauna of the bigger islands was insufficiently known.

Subsequently, the faunistic information derived from the scientific literature and field surveys conducted by the author as well as available geological and paleogeological data were compared and analysed from a zoogeographic point of view.

The author wished to identify regions of the islands boasting the greatest herpetofaunal diversity by creating dot maps based on collecting localities. To answer the question which snake species and which individuals are going to be a victim of the traffic snake roadkill and literature survey were used. The author also identified where are the areas where the most snakes are hit by a vehicle on Cres. By gathering road-killed snakes and comparing their locality data with published occurrences the author sought to identify species most vulnerable to vehicular traffic and road sections posing the greatest threat to snakes on Cres Island.

Material and methods

Between 2002 and 2014, the author visited the area ten times and spent 52 days in the field. During this period, he surveyed the islands of Cres and Lošinj by car and foot while for reaching another 23 islands of the archipelago he used a motorboat.

In a follow-up study, the author performed a biogeographic analysis of herpetofaunistic data collected in the Adriatic Basin and the Kvarner Islands. The occurrences of amphibian and reptiles species recorded at least from four islands of the archipelago were displayed individually on distribution maps. The author of the present thesis generated topographic models of the sea bed in order to reveal former land bridges and their order of inundation, and to provide insight about the possible ways of their colonisation. By using the Arrhenius model the author displays the relationship between the size of the islands in the region and the number of amphibian and reptile species inhabiting them.

In the next part of the dissertation, eight geographic region are defined and their herptile diversity – the number of species occurring in each of them – compared based on dot map data. Studying snakes run over by cars was another part of the author's investigations, made possible by a permit issued by the Ministry of Culture of the Republic of Croatia (permit nr.: 532-08-01-01/1-11-02). As part of this project, the sizes (body masses and total lengths) of all snakes found dead-on-road were recorded and every specimen was documented by photography. The data collected were statistically analysed to reveal which species and which size classes of snakes were the most affected. The road sections posing the greatest threat to these animals were subsequently highlighted on a map.

Results

Faunistics

The author's field surveys documented the following species (listed by island):

- Batelić: Italian Wall Lizard (*Podarcis sicula*).
- Cres: European Green Toad (*Pseudepidalea viridis*), European Tree Frog (*Hyla arborea*), Marsh Frog (*Pelophylax ridibundus*), Hermann's Tortoise (*Testudo hermanni*), European Glass Lizard (*Pseudopus apodus*), Blue-throated Keeled Lizard (*Algyroides nigropunctatus*), Western Green Lizard (*Lacerta bilineata*), Sharp-snouted Rock Lizard (*Dalmatolacerta oxycephala*), Dalmatian Wall Lizard (*Podarcis melisellensis*), Common Wall Lizard (*Podarcis muralis*), Balkan Whip Snake (*Hierophis gemonensis*), Aesculapian Snake (*Zamenis longissimus*), Four-lined Snake (*Elaphe*

quatuorlineata), Leopard Snake (*Zamenis situla*), Eastern Montpellier Snake (*Malpolon insignitus*), European Cat Snake (*Telescopus fallax*).

- Ilovik: European Green Toad (*Pseudepidalea viridis*), Italian Wall Lizard (*Podarcis sicula*), Balkan Whip Snake (*Hierophis gemonensis*).

- Koludarc: Dalmatian Wall Lizard (*Podarcis melisellensis*).

- Kormati: Italian Wall Lizard (*Podarcis sicula*).

- Kozjak: Italian Wall Lizard (*Podarcis sicula*).

- Lošinj: European Green Toad (*Pseudepidalea viridis*), Hermann's Tortoise (*Testudo hermanni*), Mediterranean House Gecko (*Hemidactylus turcicus*), European Glass Lizard (*Pseudopus apodus*), Blue-throated Keeled Lizard (*Algyroides nigropunctatus*), Western Green Lizard (*Lacerta bilineata*), Dalmatian Wall Lizard (*Podarcis melisellensis*), Italian Wall Lizard (*Podarcis sicula*), Four-lined Snake (*Elaphe quatuorlineata*), Eastern Montpellier Snake (*Malpolon insignitus*).

- Male Orjule: Italian Wall Lizard (*Podarcis sicula*).

- Male Srakane: Italian Wall Lizard (*Podarcis sicula*).

- Mali Osir: Dalmatian Wall Lizard (*Podarcis melisellensis*).

- Mali Plavnik: Italian Wall Lizard (*Podarcis sicula*).

- Oruda: Loggerhead Sea Turtle (*Caretta caretta*), Italian Wall Lizard (*Podarcis sicula*).

- Palacol: Italian Wall Lizard (*Podarcis sicula*).

- Plavnik: Dalmatian Wall Lizard (*Podarcis melisellensis*), Italian Wall Lizard (*Podarcis sicula*), Balkan Whip Snake (*Hierophis gemonensis*), European Cat Snake (*Telescopus fallax*).

- Susak: Mediterranean House Gecko (*Hemidactylus turcicus*), Dalmatian Wall Lizard (*Podarcis melisellensis*), Italian Wall Lizard (*Podarcis sicula*), Green Whip Snake (*Hierophis viridiflavus*).

- Sveti Petar: Italian Wall Lizard (*Podarcis sicula*).

- Trasorka: Italian Wall Lizard (*Podarcis sicula*).

- Unije: European Green Toad (*Pseudepidalea viridis*), Loggerhead Sea Turtle (*Caretta caretta*), Dalmatian Wall Lizard (*Podarcis melisellensis*), Italian Wall Lizard (*Podarcis sicula*), Green Whip Snake (*Hierophis viridiflavus*).

- Vele Orjule: Italian Wall Lizard (*Podarcis sicula*).

- Vele Srakane: Italian Wall Lizard (*Podarcis sicula*).

- Veli Osir: Dalmatian Wall Lizard (*Podarcis melisellensis*).

- Visoki: Italian Wall Lizard (*Podarcis sicula*).

- Zabodaski: Italian Wall Lizard (*Podarcis sicula*).

- Zeča: Dalmatian Wall Lizard (*Podarcis melisellensis*), Italian Wall Lizard (*Podarcis sicula*).

In addition dot maps illustrating the distribution of herptiles on Cres were prepared, based on literature data and the author's own observations.

Biogeography

According to the calculations of the author there was a moderate positive correlation between the size of an area and the number of species present.

Of the amphibians, *Pseudepidalea viridis* was found on the islands of Cres, Ilovik, Lošinj, Unije and Krk.

On the Kvarner Islands Hermann's Tortoises (*Testudo hermanni*) occur in small numbers and therefore vulnerable on Krk, Cres, Lošinj and maybe Plavnik.

The presence of the Mediterranean House Gecko (*Hemidactylus turcicus*) was proven only on Krk, Lošinj, Susak and Karbarus. Its alleged occurrence on the islands of Cres and Plavnik needs to be confirmed.

The European Glass Lizard (*Pseudopus apodus*) is certainly present on the islands of Cres, Lošinj and Krk, but may occur, according to unconfirmed sightings, on the islands of Ilovik, Plavnik and Sveti Petar too.

The eastern boundary of the range of the Western Green Lizard (*Lacerta bilineata*) is running across the Cres-Lošinj Archipelago and the Istrian Peninsula. From here towards the East the Eastern

Green Lizard (*Lacerta viridis*) is found. *Lacerta bilineata* is native to the islands of Cres, Lošinj and Trstenik but the taxonomic status of Ilovik Island population of green lizards is uncertain. The species is most probably absent from Krk.

Podarcis sicula could be found on the following islands of the archipelago (including Krk): Batelić, Ilovik, Kormati Kozjak, Lošinj, Male Orjule, Male Srakane, Mali Plavnik, Mišar, Mišnjak, Oruda, Palacol, Plavnik, Samunčel, Školjic, Susak, Sveti Petar, Trasorka, Unije, Vele Orjule, Vele Srakane, Visoki, Zabodaski, Zaglav, Zeča, Krk, and maybe Cres.

Podarcis melisellensis could be documented from the following islands of the archipelago (including Krk): Cres, Karbarus, Koludarc, Lošinj, Male Srakane, Mali Osír, Plavnik, Susak, Trstenik, Unije, Vele Srakane, Veli Osír, Zabodaski, Zeča, Krk; its presence on Mali Plavnik and the island of Murtar is likely.

The Balkan Whip Snake (*Hierophis gemonensis*) is present on every bigger island of the archipelago (Cres, Lošinj, Plavnik, Unije, Susak, Ilovik, Sveti Petar [unconfirmed] and Zeča [unconfirmed]). The Green Whip Snake (*Hierophis viridiflavus*) occurs on Krk, Susak and Unije.

The European Cat Snake (*Telescopus fallax*) can be found on the islands of Cres, Lošinj, Plavnik and Krk, however due to its secretive habits the species has likely remained undetected on some other islands in the region.

To clarify possible dispersal scenarios the author presents sea bed topography models of the region showing situations at water levels 20, 40 and 70 m lower than present.

Nature conservation

The dissertation also deals with the 42 snakes found dead-on-road on Cres, which represent the following species: *Hierophis gemonensis*, *Elaphe quatuorlineata*, *Zamenis situla*, *Zamenis lonigissimus*, *Malpolon insignitus*, *Telescopus fallax*.

Discussion

Evaluation of the faunistic results

Fields surveys conducted by the author and his collaborators between 2002 and 2017 revealed several new island records, such as:

- Cres: *Dalmatolacerta oxycephala* (TÓTH et al. 2006)
- Ilovik: *Pseudepidalea viridis*, *Hierophis gemonensis* (TÓTH et al. 2009a)
- Lošinj: *Pseudepidalea viridis*, *Eurotestudo hermanni*, *Pseudopus apodus* (TÓTH et al. 2009b)
- Mali Osír: *Podarcis melisellensis* (TÓTH et al. 2017)
- Mali Plavnik: *Podarcis sicula* (TÓTH et al. 2017)
- Plavnik: *Telescopus fallax* (TÓTH et al. 2006)
- Susak: *Hierophis viridiflavus* (TÓTH et al. 2017)
- Unije: *Hierophis viridiflavus* (TÓTH et al. 2006)
- Veli Osír: *Podarcis melisellensis* (TÓTH et al. 2017)
- Zeča: *Podarcis sicula* (TÓTH et al. 2017)

By studying the dot maps based on amphibian and reptile records it was possible to identify regions with the highest diversity and habitats frequented by the individual species.

The author is the first to document partially melanistic specimens of the Aesculapian Snake (*Zamenis longissimus*) from Cres, the same colour morph being known only from Krk within the archipelago.

The habitat typology subdivision of the 25 members of the archipelago is complete, where the most common habitat was the seashore and macchia or garrigue, whereas the least common were loess walls and swardy habitats. This paper is the first to present the habitat use preferences of the archipelago's herpetofauna.

The co-occurrence of *Podarcis sicula* and *Podarcis melisellensis* was confirmed for the first time at two new locations, the islands of Zabodaski and Zeča. Even though some authors claimed Kormati and Mali Plavnik to be inhabited by *Podarcis melisellensis*, both islands proved to harbour, at least

at present, *Podarcis sicula* only. It was not possible to confirm the presence of *Podarcis sicula* from all over Lošinj, as suggested by earlier authors, since this species could be observed only in the settlements of Mali Lošinj and Artatore.

Although some experts claimed Batelić, Kozjak, Trasorka, Male Orjule and Vele Orjule to be inhabited by melanistic individuals of *Podarcis sicula*, the author was able to verify the occurrence of such specimens on Male Orjule and Trasorka only.

Evaluation of the biogeographical results

The number of species of amphibians and reptiles greatly depends on the size of a given island and the herpetofaunal richness of other pieces of land in its vicinity, which showed a moderate positive correlation in the case of the Cres-Lošinj Archipelago. In some cases the islands were simply too small for providing suitable living conditions to more than a single species. Compared with the larger islands of the Mediterranean and the Adriatic Sea, the diversity of amphibians and reptiles is remarkably high on Cres and Krk, in spite of the fact that many are much bigger than the latter two islands.

There are some discrepancies in the reports about the time of the flooding of the Adriatic Basin. However, all authors agree that it started after the last glacial maximum, the process was gradual and by no means constant during different periods. According to several authors, sea levels rose to the biggest extent between 8,500–12,000 years ago. To explore the location and connectivity of the land bridges formed by the flooding, the author prepared sea bed topography models of the Kvarner region especially for this dissertation. Based on these it can be concluded that at water levels 70 m lower than present the islands of Trstenik, Pag and Rab became disconnected from the mainland. However, at sea levels just 30 m lower than present, the islands of Silba, Ist, Molat, Dugi Otok, Sestrunj and Ugljan were still in direct contact with the mainland and the southern Adriatic islands. At water levels 40 m lower than present there was no connection between the northern part of Cres and the Istrian Peninsula, whereas Plavnik and Krk were still connected to the mainland at water levels 20 m lower than today.

Since *Pseudepidalea viridis* needs freshwater for reproduction, this toad is generally found on larger islands only, because smaller islands often harbour no permanent freshwater. As this species has a strong preference for man-made habitats, it has been recorded exclusively from islands permanently populated by humans.

The presence of Hermann's tortoises (*Testudo hermanni*) in the region is not necessarily natural. This species is kept as a pet for example on the island of Lošinj and occurs mostly on inhabited islands of the archipelago.

The Mediterranean House Gecko (*Hemidactylus turcicus*) probably conquered the Cres-Lošinj island group in a passive way, since its occurrence is verified mainly in ports.

Pseudopus apodus could have reached the archipelago either via the Istrian Peninsula or as a waif from the islands of Krk, Pag and Rab, where it is also present.

Lacerta bilineata naturally occurs on the islands of Cres, Lošinj és Trstenik, whilst its presence is on Krk needs confirmation. Some experts think that *Lacerta bilineata* accessed the first two islands over Trstenik, which at some point in history might have been part of a landbridge. This theory is in contradiction with actual faunistic data, since this lizard does not occur on the other islands of the Adriatic, but from the East and South it could have reached the archipelago only over these pieces of lands. On the mainland *Lacerta bilineata* does not farther East than the Istrian Peninsula and is replaced by the closely related Eastern Green Lizard (*Lacerta viridis*) on the continent Southeast of this boundary. Therefore, assuming that its spreading was natural, *Lacerta bilineata* must have reached the island of Cres from the Istrian Peninsula, and then from there extended its range to Lošinj and Trstenik, because it is not known to occur on Plavnik, an island located between Cres and Krk. According to the seabed topography models this reptile species was able to reach Trstenik over Cres by land to sea levels 70 m lower than present, while the overland migratory route between Cres and the Istrian Peninsula possibly became interrupted at water levels approximately 40 m lower than today.

In case of the spreading of *Podarcis melisellensis* it is conspicuous, that this species is absent from the islands located South and Southeast of Lošinj, while on the smaller islands around the two main islands it occurs either alternately or together with *Podarcis sicula*.

Hierophis gemonensis occurs on the islands of Cres, Lošinj, Plavnik, Unije, Susak, Ilovik, and maybe Sveti Petar and Zeča. Since this species is present on the islands of Krk, Pag, Rab, the neighbouring mainland and the Istrian Peninsula, too, it could have arrived from the North and the East as well. It seems that Susak (3,76 km²) is the smallest island in the region inhabited by this species, leaving its alleged occurrence on the island of Zeča (2,55 km²) out of consideration, which has never been verified.

The Green Whip Snake (*Hierophis viridiflavus*) can be found on the island of Krk and on the nearby mainland but is missing from Rab, Pag and Plavnik, therefore its dispersal from this direction is unlikely. Still, it occurs throughout the Istrian Peninsula as well as on Susak and Unije. Therefore, it seems likely that this snake species reached the island of Krk from the mainland, whereas it migrated to Susak and Unije from the Istrian Peninsula but was unable to conquer Plavnik, Cres and Lošinj because these became disconnected from each other by the rising sea levels. The seabed topography models show clearly that there was no connection between the Istrian Peninsula and Susak, Unije or Cres at sea levels 40 m lower than present, while Krk was still connected by a landbridge at sea levels just 10 m lower today.

Evaluation of nature conservational results

In this dissertation Cres was divided to eight zones by the author, and based on the distribution dot maps the number of species per zone was determined. The data highlight areas with the highest herpetofaunistic diversity, and thus worthy of extra protection.

According to the conducted studies the relationship between *Podarcis melisellensis* and the *Podarcis sicula* is not that obvious as usually assumed, because their co-occurrence was proven for two additional islands, too. Therefore, the claim that the latter species always supersedes the former when the two come in contact becomes increasingly unlikely and there is now some proof that in certain circumstances (at appropriate island size, suitable terrain, etc.) these lizards readily share their (micro)habitats with each other.

On Cres and Lošinj vehicular traffic poses a threat to the herpetofauna, especially snakes, so the author investigated this matter more closely on the island of Cres. The high proportion of the two opisthoglyphous species in the sample of road-killed snake is conspicuous. Based on literature data and the author's own experience, live individuals of *Malpolon insignitus* are rarely seen on Cres, while specimens of this species are represented in the highest percentage (38%, viz. 16 individuals) among roadkills, for which phenomenon there is no plausible explanation. In the case of *Telescopus fallax*, the reason for its apparent rarity might be its secretive lifestyle and nocturnal habits: whereas there is just a single record of this species in the scientific literature, we have counted no less than six specimens (14%) in our sample of road-killed snakes. The author statistically defined the size class at which most of the snakes are killed by vehicular traffic on the island. One needs to take into consideration that individuals living under similar conditions and representing the same species and same age group might differ considerably in size according to their sex, whereas individuals of the same taxa might occasionally show a great deviation from the standard according to population. This is especially true for mainland vs island populations, as the food resources available to the latter are necessarily limited.

Based on data from the literature it seems that the proportion of road-killed snakes has increased over the last decades compared to individuals of the same species observed live on the island of Cres. Therefore, using data from the literature the author identified locations where snakes were found dead on road and on a map highlighted road sections most dangerous to snakes. The majority of these locations and sections are situated along the Merag – Cres – Belej – Osor road, since most tourists access the resorts of Lošinj Island over this route.

It should be noted that all but one DOR snakes reported in the literature were found in May or June. The probable reason behind this being that researchers conduct their field studies mostly in this

period of the year. These months fall within the breeding season and the active period of local snakes prior to aestivation, at the same time the peak of the holiday season is yet to be reached. Although during the summer season traffic gets heavier compared to May and June, snakes also become less active.

New scientific results (thesis)

Faunistics

T1: The author's studies contributed several new locality data to the herpetofaunistic literature, as follows:

- Cres: *Dalmatolacerta oxycephala* (TÓTH et al. 2006)
- Ilovik: *Pseudepidalea viridis*, *Hierophis gemonensis* (TÓTH et al. 2009a)
- Lošinj: *Pseudepidalea viridis*, *Testudo hermanni*, *Pseudopus apodus* (TÓTH et al. 2009b)
- Mali Osir: *Podarcis melisellensis* (TÓTH et al. 2017)
- Mali Plavnik: *Podarcis sicula* (TÓTH et al. 2017)
- Plavnik: *Telescopus fallax* (TÓTH et al. 2006)
- Susak: *Hierophis viridiflavus* (TÓTH et al. 2017)
- Unije: *Hierophis viridiflavus* (TÓTH et al. 2006)
- Veli Osir: *Podarcis melisellensis* (TÓTH et al. 2017)
- Zeča: *Podarcis sicula* (TÓTH et al. 2017)

T2: Field surveys conducted in the archipelago revealed the co-occurrence of *Podarcis sicula* and *Podarcis melisellensis* on Zabodaski and Zeča (TÓTH et al. 2017a).

T3: Distribution dot maps of amphibian and reptile species occurring on Cres were created based on the literature survey and first-hand data collected by the author (TÓTH et al. 2006).

T4: The partially melanistic colour morph of the Aesculapian Snake (*Zamenis longissimus*) known exclusively from Krk in the Croatian Archipelago was shown to be present on Cres (TÓTH et al. 2017c), too.

Biogeography

T5: A moderate strong, positive correlation was proven between area size and total number of amphibian and reptile species in the Cres-Lošinj Archipelago.

T6: With the aid of seabed topography models it was possible to show that at which sea level the islands of the archipelago became disconnected from the mainland and the neighbouring islands.

T7: In the cases of *Lacerta bilineata* and *Hierophis viridiflavus* it became possible to identify the possible routes of overland migration to the Cres-Lošinj Archipelago.

Nature conservation

T8: The distribution dot maps of Cres and the tables based on a literature survey and the author's own data have shown that the Beli region has the highest number of amphibian and reptile taxa (21 species), followed by the Merag Peninsula (18 species), the Vrana-Martinišćica region (18 species) and the area around Osor (17 species), respectively.

T9: The habitat typology subdivision of the 25 members of the archipelago is complete, where the most common habitat was the seashore and macchia or garrigue, whereas the least common were loess walls and swardy habitats. This paper is the first to present the habitat use preferences of the archipelago's herpetofauna.

T10: The authors studies have revealed that on the island of Cres the Merag–Cres–Belej–Osor road poses the greatest threat to snakes, with the highest proportion of road-killed individuals being *Malpolon insignitus* (38%). Based on the carcasses collected it was possible to identify the size range at which snakes become victims to vehicular traffic in the highest numbers.

List of publications

Scientific publications related to the subject of the PhD thesis:

- TÓTH, T., GRILLITSCH, H., FARKAS, B., GÁL, J., SUŠIĆ, G. (2006): Herpetofaunal data from Cres Island, Croatia. – *Herpetozoa*, 19 (1/2): 27-58.
- TÓTH, T., FARKAS, B., GÉCZY, Cs., SÓS, E., HALPERN, B., MOLNÁR, Z. (2009a): Herpetofaunal data from Ilovik and neighboring islets (Cres-Lošinj Archipelago, Croatia). – *Herpetozoa*, 22 (1/2): 82-87.
- TÓTH, T., GÉCZY, Cs., SÓS, E., MOLNÁR, Z., HALPERN, B. (2009b): Further data on the herpetofauna of Lošinj Island, Croatia. – *Herpetozoa*, 21 (3/4): 192.
- TÓTH, T., HELTAI, M., KESZI, A., SUŠIĆ, G., MOHAROS, L., FARKAS, B., GÉCZY, Cs., TORDA, O., GÁL, J. (2017a): Herpetofauna inventory of the small islands of the Cres-Lošinj Archipelago (North Adriatic Sea, Croatia). – *Herpetozoa*, 30 (1/2): 21-28.
- TÓTH T., BOKSAI D., GÉCZY C., MIHÁLYI Á., TAKÁCS R., SUŠIĆ G., VINCZEK J., GÁL J., MAROSÁN M., FARKAS B., BOKIS A., HELTAI M. (2017b): Road-killed snakes on the island of Cres (Croatia). – *Biharean Biologist*, 11 (2): 88-93.
- TÓTH, T., MAROSÁN, M., GÁL, J. (2017c): Über eine partiell melanistische Äskulapnatter (*Zamenis longissimus*) auf der Insel Cres. – *ÖGH-Aktuell*, 45: 13-16.

Popular accounts related to the subject of the PhD thesis:

- TÓTH, T. (2005): Herpetofaunistikai túrák a horvátországi Cres szigetén. 1. rész. – *Terrárium*, 7 (5): 24-27.
- TÓTH, T. (2005): Herpetofaunistikai túrák a horvátországi Cres szigetén. 2. rész. – *Terrárium*, 7 (6): 27-31.
- TÓTH, T. (2016): Kígyó kutatás Cres szigetén. – *Állatvilág*, 3 (4): 33.

Conference talk related to the subject of the PhD thesis:

- TÓTH, T. (2015): A Fővárosi Állat- és Növénykert természetvédelmi tevékenysége és kutatásai a horvátországi Cres szigeten. – *Állatkertek közösen és kölcsönösen a természet és a természeti kincsek megőrzéséért. Magyarország-Szlovákia Határon Átnyúló Együttműködési Program 2007-2013 HUSK 1101/2.2.1./0183. Konferencia 2015/04/16.*

Total number of publications by the author:

- Number of articles with an impact factor related to the subject of the PhD thesis: 1.
- Number of original scientific publications related to the subject of the PhD thesis: 5.
- Popular articles related to the subject of the PhD thesis: 3.
- Number of conference talks related to the subject of the PhD thesis: 1.

- Number of articles with an impact factor not related to the subject of the PhD thesis: 10.
- Number of scientific publications in a foreign language not related to the subject of the PhD thesis: 19.
- Number of scientific publications in Hungarian not related to the subject of the PhD thesis: 15.
- Number of conference abstracts not related to the subject of the PhD thesis: 10.
- Number of popular articles not related to the subject of the PhD thesis: 46.
- Number of conference posters not related to the subject of the PhD thesis: 4.
- Number of books, book chapters, university textbooks not related to the subject of the PhD thesis: 6.
- Number of conference talks not related to the subject of the PhD thesis: 8.

- Total number of publications: 119.
- Citation index: 136.