LIFE SAFE - CROSSING

ACTION D1. MONITORING THE IMPACT OF THE CONCRETE CONSERVATION ACTIONS

Report of the Impact of the C-Action – DEADLINE August 2023

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Introduction

The LIFE SAFE-CROSSING (LIFE17NAT/IT/464) project aimed at implementing actions to reduce the impact of roads on some priority species in four European countries: Apennine brown bear (*Ursus arctos marsicanus*) and wolf (*Canis lupus*) in Italy, Iberian lynx (*Lynx pardinus*) in Spain, and Brown bear (*Ursus arctos*) in Greece and Romania. The main actions carried out were:

- Installation of Animal-Vehicle Collision Prevention Systems on most critical road segments;
- Adaptation of crossing structures to enhance connectivity for the target species;
- Development of activities to increase the attention of drivers about the risk of collisions with the target species.

The goal of Action D1 was the evaluation of the effectiveness of the concrete conservation actions carried out in the frame of the project: installation of AVC-PS and virtual fence, adaptation of crossing structures, and installation of road panels developed through the application of the neuromarketing techniques.

The evaluation was made taking into account several parameters in order to obtain an exhaustive overview of the impact of each type of implemented interventions. This deliverable summarizes the main results obtained in each project countries.

1. Parameters used to evaluate the concrete conservation actions

The concrete conservations interventions implemented in all the project countries were the followings:

- Installation of 26 AVC-PS;
- Installation of 36,5 Km of virtual fence;
- Interventions to adapt 98 crossing structures;
- Installation of 148 road panels.

In the frame of the action the road mortality monitoring sessions and traffic volume and speed monitoring sessions were carried out following the same methodology already applied in the frame of Action A5.

The evaluation of the concrete conservation action was carried out on the basis of the following parameters:

AVC-PS

For each AVC-PS installed in the project area we analyzed the activations of the system:

- Number of road kills before and after the installation of the system along the road segment covered by the AVC-PS (i.e. the road stretch between the flashing light panels of the AVC-PS);
- Number of activations of PIR sensors and thermal camera (an indicator of the presence of animals near the road);
- Number of activations of the acoustic deterrence (an indicator of the simultaneous presence of wildlife and vehicles approaching at>= 50 Km/h).

Virtual fence

- Number of road kills before and after the installation of the system along the road segment covered by VF (i.e. the road segment between the first and the last device);
- Reactions of animals through the triggering of the devices (videos collected through camera trapping and observation sessions with thermal camera in Romania).

Adaptation of crossing structures

- Number of wildlife passages before and after the interventions

Road panels

- Replies to questionnaires submitted to drivers

The results are presented in the following paragraphs for each project area, with the exception of the evaluation of the effectiveness of the road panels, for which an overall assessment was made through the analysis of cumulative responses to the questionnaires. In the conclusions, an overall assessment of the impact of concrete conservation actions will be made. All maps and photos of the concrete actions of intervention are included in the annexes of the deliverables of Actions C1, C2, and C3, so they are not included in this document.

2. Results

2.1 Maiella National Park

In the Maiella National Park the following interventions have been implemented:

- Installation of 5 AVC PS
- Installation of ~ 20 Km of Virtual Fence (VF)
- Adaptation of 9 crossing structures (2 cleaned and 7 adapted with fences installation)
- Installation of 60 road panels

The selection of the road segments where to intervene and the choice of interventions to be implemented (Table 1), was based on the results of Actions A3, A4, and A5 thus taking into account data on road mortality, type and distribution of crossing structures, AVC risk and location of the AVC clusters and, last but not least, the ecological evaluation of the area in relation to corridors identified for the Apennine brown bear range expansion from/to PNM to/from other protected areas (Ciucci et al. 2017) and in relation to areas important to ensure ecological connectivity inside the Park. The installation of road panels in the frame of Action C3, beyond following the same criteria above-mentioned, was also implemented in 2 additional road stretches in order to spread the message carried by panels throughout the Park and not only on the roads actually included in the project area (see Table 1).

Table 1. Distribution of the concrete conservation interventions on the monitored road segments in the Maiella National Park.

** Additional road segments interested by C3 Action in order to have road panels spread throughout the Park.*

Transect code	Road Segment	AVC-PS	Virtual fence (km)	Adpted crossing structures	Road panels
1 – SS487	S. Valentino- Caramanico Terme	1	4.4	2 (cleaned)	4
2- SS487/SP54	Caramanico Terme-Campo di Giove				6
3a - SP12	Cansano-Campo di Giove				2
3b – SP12/SS84	Campo di Giove - Pescocostanzo				5
3c – SP55	Pescocostanzo-Cansano				4
4 – SS487	Sulmona-Cansano				4
5 – SS5/SS17	Tocco da Casauria-Corfinio		5.3		7
6 – SS17	Corfinio- Roccaraso	4	9.7	7 (1.5 Km of Fences installed)	16
7 – SP84	Rccaraso-Ateleta				4
	Staz. Palena-Lama dei Peligni*				6
	P.sso S. Leonardo-Pacentro*				2
	Total	**5**	**19.4**	**9**	**60**

2.1.1 Road mortality and traffic measurement sessions

Monitoring of road mortality was continued during Action D1 applying the same methods reported in the action-specific report of Action A5. All the 7 transects identified were monitored except for one stretch of the transect number 3 (3c Pescocostanzo-Cansano) and the transect number 2 (Caramanico Terme-Campo di Giove) as the cost/benefit ratio (i.e. work/actual AVCs found) resulted during Action A5 was too unfavourable probably due to the extreme low traffic levels.

From October 2020 to August 2023, in PNM, 322 systematic road mortality monitoring sessions were implemented during which 12[1] dead animals were found (Table 2).

[1] The actual number of animals found dead is 15 but 3 of them were not relevant for the analysis implemented in the frame of the LIFE SAFE-CROSSING (meaning they were not target species, other wild carnivores nor ungulates). See paragraphs below for better explanation.

Table 2. Road mortality monitoring sessions and Traffic volume monitoring sessions implemented during Action D1 in PNM.

Transect code – -Road segment	Lenght (Km)	N. of road mortality monitoring sessions (from10/2020-08 2023)	Total number of animals found dead (from10/2020-08 2023)	N. of traffic volume monitorig sessions (from10/2020-08 2023)
1- S. Valentino- Caramanico Terme	11.5	48	0	11
2- Caramanico Terme- Campo di Giove	26.2	0	0	0
3a - Cansano-Campo di Giove	5.1	54	0	0
3b - Campo di Giove -Pescocostanzo	19.1	52	0	0
3c - Pescocostanzo-Cansano	21.2	0	0	0
4 - Sulmona-Cansano	11.3	54	1	0
5 - Tocco da Casauria-Corfinio	16.3	56	6	11
6 - Corfinio- Roccaraso	47.3	56	5	9
7 - Rccaraso-Ateleta	12.3	2	0	0
	Total	**322**	**12**	**31**

Specifically, 3 wild boars, 4 Stone martens, 2 badgers, 1 red deer, 1 fox and 1 wild cat were found dead. Beyond the systematic monitoring, data on AVCs were also collected opportunistically whenever a dead animal was reported or found dead by PNM staff outside from the systematic monitoring sessions. The systematic/opportunistic road mortality monitoring allowed the collection of the data on AVCs to be used to assess effectiveness of both AVC PSs and VF. Beyond the road mortality monitoring, also the installation of the Traffic Measurement Device (TMD) continued during Action D1. Specifically, during action D1, 31 sessions were implemented from Winter 2020-2021 to summer 2023 along the 3 roads interested by C1-C2 interventions: SS5 (5-Tocco da Casauria-Corfinio), SS487 (1 – S. Valentino-Caramanico Terme) and SS17 (6 – Corfinio-Roccaraso) (Table 2). Monitoring activity was planned on a seasonal basis like in Action A5 but a spring monitoring session was added in action D1 while in Action A5 only summer-autumn-winter sessions were implemented because in spring 2020 SARS CoV2 restrictions affected the field activities.

2.1.2 Monitoring of AVC PSs effectiveness

Five AVC PSs have been installed in 4 locations in the Maiella NP in the period winter-spring 2020-2021. Their effectiveness has been assessed through the analysis of two data: the number of AVCs happened before and after their installation and the comparison between the risk of AVC and the actual number of AVCs happened after their installation.
Methods to quantify the AVCs before and after their installation refer to: the selection of target animals, the assessment of the periods to be considered “before” and “after” and the assessment of the road stretch actually covered by the AVC PS (Table 3).

Table 3. Methods used to quantify the effectiveness of the 5 AVC PSs installed in PNM through the comparison of AVCs happened before and after their installation.

VARIABLE	CRITERIA	EXPLANATION	ACTIONS INVOLVED IN DATA COLLECTION
Selection of target animals	Bear, wolf, other wild carnivores, ungulates	Consistent with the choices made for Action A3	A3-A5-D1
Assessment of "before" and "after"	01/04/2021 considered the date when all AVC PSs achieved full functionality 2009-31/03/2021 as "before (1)" period 2019-31/03/2021 as "before (2)" period	All the AVC PSs passed through an adjusting phase so that the "after" period doesn't start from the date of installation but from the date of achievement of 100% functionality. Before the LIFE SAFE-CROSSING starting no systematic collection of AVCs was carried out so that we decided to quantify the "before" period using both the whole data set and only the dataset collected with the systematic monitoring.	Opportunistic activity before the starting of the project A3-A5-D1
Assessment of the road stretch covered by the AVC PS	Road stretch encompassed between the first and last flashing panels	This road stretch represents the one where AVCs can be avoided through both the working of the acoustic deterrence for animals and the alarm for drivers.	C1-D1

To compare the risk of AVCs with the actual number of AVCs happened after the installation of this prevention measure, we analysed the data stored by each AVC PSs (and accessible through the specific App) and the road mortality data collected through Action D1. Methods to quantify the risk of AVCs and the actual number of AVCs happened refer to the choice of the parameters stored by the AVC PSs to be used and the selection of actual AVCs data to be used (i.e. assessment of the target species and the target road stretch). This last choice was consistent with the one of the before-after comparison while two parameters among all the ones stored by the AVC PSs have been chosen (Table 4).

Table 4. Methods used to quantify the effectiveness of the 5 AVC PSs installed in PNM through the comparison of the AVC risk with the actual number of AVCs happened.

PARAMETER	CRITERIA	EXPLANATION	ACTIONS INVOLVED IN DATA COLLECTION
Activation of sensors and/or thermal cameras	Activations of a sensor/thermal camera happening at least 3 minutes one from the other	Situations in which wildlife was present near the roads (i.e. situation of potential AVC risk). The 3-minutes threshold represents the length of the "active period" of the system once it has been triggered for the first time.	D1
Activation of the acoustic deterrence device	MP3 Reproduction events happening at least 3 minutes one from the other	Situations in which both wildlife was present and vehicles were approaching at > 50 Km/h. The 3- minutes threshold represents the length of the "active period" of the system once it has been triggered for the first time.	D1
N of actual AVCs	Number of AVCs involving the target species and road stretch as explained in Table 1.	Situations in which the AVC PS failed in preventing the AVC because of the non-reaction of animals/drivers to the alarms or because temporarily off (e.g. during the daytime).	D1

The parameter that quantifies the vehicles speed reduction after the triggering of the flashing lights could not be used in PNM as the criteria followed by AVC PSs to store these data produced a dataset not representative of the reality (only cars reducing the speed for more than 20 Km/h were registered and no speed reductions were recorded if the vehicles travelled at >100 Km/h). AVC PSs installed after in the other countries were set in order to overcome this problem.

In order to have an additional insight on the AVC risk, together with students of the Florence and Bologna Universities, we developed a two case-studies analysis aimed at assessing the AVC risk overcoming one issue connected with the use of parameters stored by the AVC PSs: the absence of information about how many individuals determined the "wildlife presence" events. In fact, when thermal cameras/sensors are triggered by species living in group, for each triggering the AVC risk is not just 1 but depends on the number of individuals forming the group itself. To develop this analysis 3 camera traps were positioned right up/down the sensors (Picture 1) of the Device Majella 4 in order to match camera-trap-derived data on the number of individuals with data on the activation of the AVC PS stored by the system itself. Specifically, the following parameters were quantified:

- Number of individuals/species crossing the road as an indicator of AVC risk level for species living in groups;
- Number of activations of the acoustic deterrence by the individuals filmed with camera traps as an indicator of the actual AVC risk due to vehicles approaching at >50 km/h.

Periods chosen for the analysis were February-June (case study n.1) and July-August (case study n.2) 2022.

Picture 1. Example of a camera trap positioned up to a sensor in order to collect data for the two-case-studies analysis developed in PNM to have additional insights on the AVC risk where AVC PSs were installed.

Results of the before-after comparison (Table 5), show that the reduction in road mortality ranges between 25% and 100% depending on the device and the period considered as "before".

Table 5. Results of the before-after comparison of AVC of the target species happened in the road stretches where the 5 AVC PSs have been installed in PNM. BEFORE (1): 2009-31/03/2021; BEFORE (2): 2019-31/03/2021; AFTER:01/04/2021-31/08/2023.

AVC PS LOCATION (number of devices)	BEFORE (1)	BEFORE (2)	AFTER	REDUCTION OF ROAD MORTALITY
Majella 1 (n.1)	17	8	0	100%
Majella 2 (n.1)	20	12	9	25%-55%
Majella 3 (n.1)	0	0	0	N.A.
Majella 4 (n.2)	15	14	2	86%-87%

The best results have been obtained for the device Majella 1 (100% reduction) and the two concatenated devices Majella 4 (86-87%) followed by the up to 55% reduction of the device Majella 2. The analysis of this data for the device Majella 3 were instead unfruitful as no data of AVCs are available for the "before (1)" period due to the difficulty we had in gathering data collected before the starting of the project for that road stretch and no AVCs were reported during the A5 monitoring either. However, the location Majella 3 was chosen according to an expert evaluation of the PNM-ANAS staff based on both the risk of AVCs observed and the ecological meaning of this road segment (i.e. located in the narrowest part of the Altopiano delle Cinquemiglia plateau: the one with the highest probability of use by wildlife, especially bears, to cross the plateau). The importance of the AVC PS Majella 3 and its effectiveness is clearer observing results of the comparison between the AVC risk and the actual number of AVCs happened. In the same way, the results reported in Table 5 for the device Majella 2 have a different meaning if observed in light of the results the above-mentioned comparison (Figure 1).

Data stored by 4 out of 5 AVC PS have been used to compare the AVC risk and the actual AVCs happened: Majella 2 (n.1 device), Majella 3 (n.1 device) and Majella 4(n.2 devices). Data referring to the AVC PS Majella 1 could not be analysed as, due to a transmission problem based on poor internet connection in the site, data stored were too fragmented to be representative of the actual activity of this device. However, the percent mortality reduction in this location, as based on the before-after comparison (Table 5), is 100% a figure that can be considered itself a good indicator of the AVC PS Majella 1 effectiveness. Results obtained for the remaining 4 devices show a ratio actual AVC/risk equal to zero with potential risky events ranging from ~50 to ~5.000 and actual AVCs ranging from 0 to 4 (Figure 1). Majella 2 and Majella 4 are the devices with the potentially risky situations in the thousands, Majella 3 still has high potentially risky situations with a number of such events in the hundreds. The first part of this last statement highlights the extremely satisfying result of the prevention work associated with the 3 devices Majella 2 and Majella 4 while the second part highlights not only the satisfying result of the Majella 3 device work, but also how important it is too make expert-based choices when data are insufficient or are totally missing like in this case. Beyond the "0-0" result of the "before-after" comparison, results of the "AVC risk-actual AVC analysis" clearly show that this device is extremely efficiently preventing AVCs in a very important location from an ecologically point of you. In fact, results of the "AVC risk-actual AVC analysis" has to be considered a better indicator of the AVCs effectiveness than the results of the "before-after" comparison that can be strongly affected by bias due to several factors like the difficulties to gather data opportunistically collected, the actual possibility of finding carcasses along the roads before they are removed, the intensity of the systematic monitoring etc.

The two-case-studies analysis developed in Majella 4 provided astonishing data on the actual AVC risk determined by the number of individuals actually associated with a single “wildlife presence event”. In 7 months (February-August 2022) 996 individuals (mostly represented by wolves, foxes and wild boars, Figure 2) crossed the road at the Majella 4 crossing paths and the acoustic deterrence activated 240 times (99 times for wolves, 75 times for foxes, 17 times for wild boars and the rest for porcupines, roe deer, red deer, badgers, wild cats). No AVCs happened during this period.

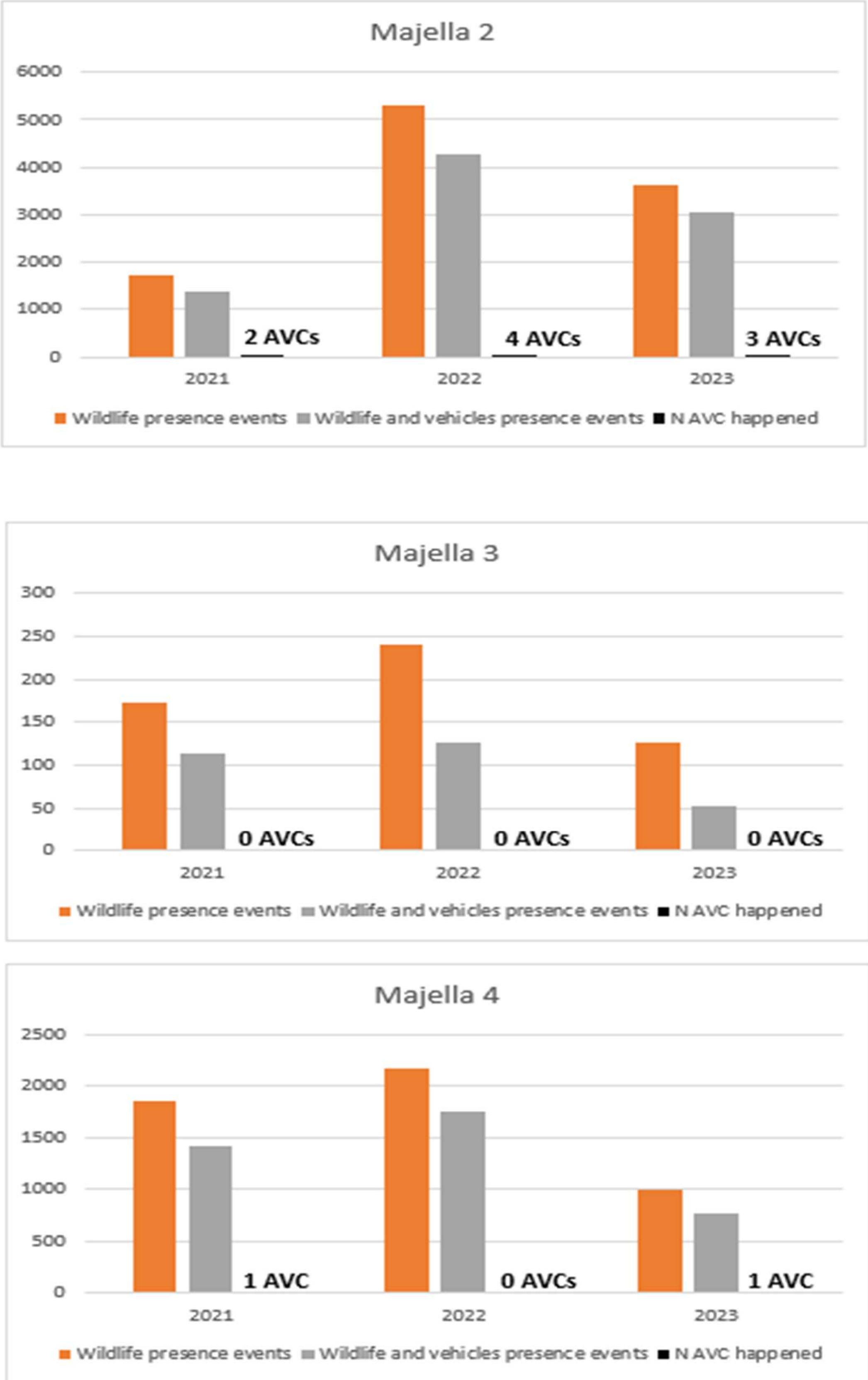
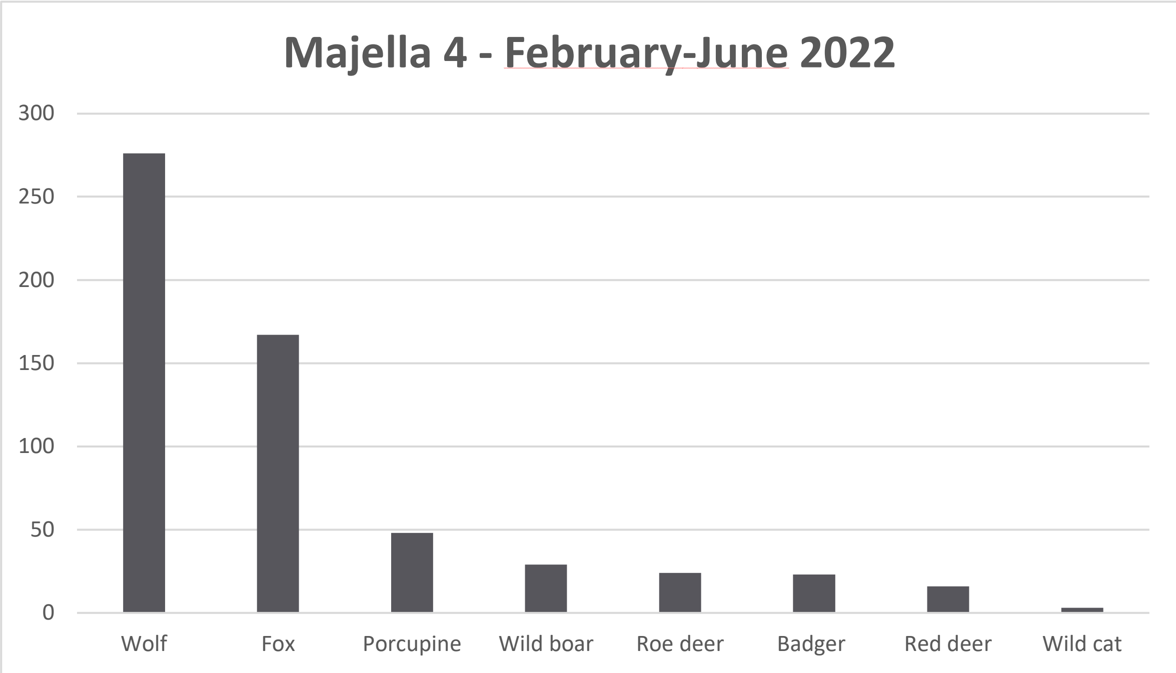


Figure 1. Results of the comparison between the AVC risk (i.e. presence of wildlife on the road side and presence of wildlife when vehicles are approaching) and the actual number of AVCs happened in PNM after the installation of the 4 AVC PS in the locations Majella 2 (n.1), Majella 3 (n.1) and Majella 4 (n.2). Period: 01/04/2021-31/08/2023.



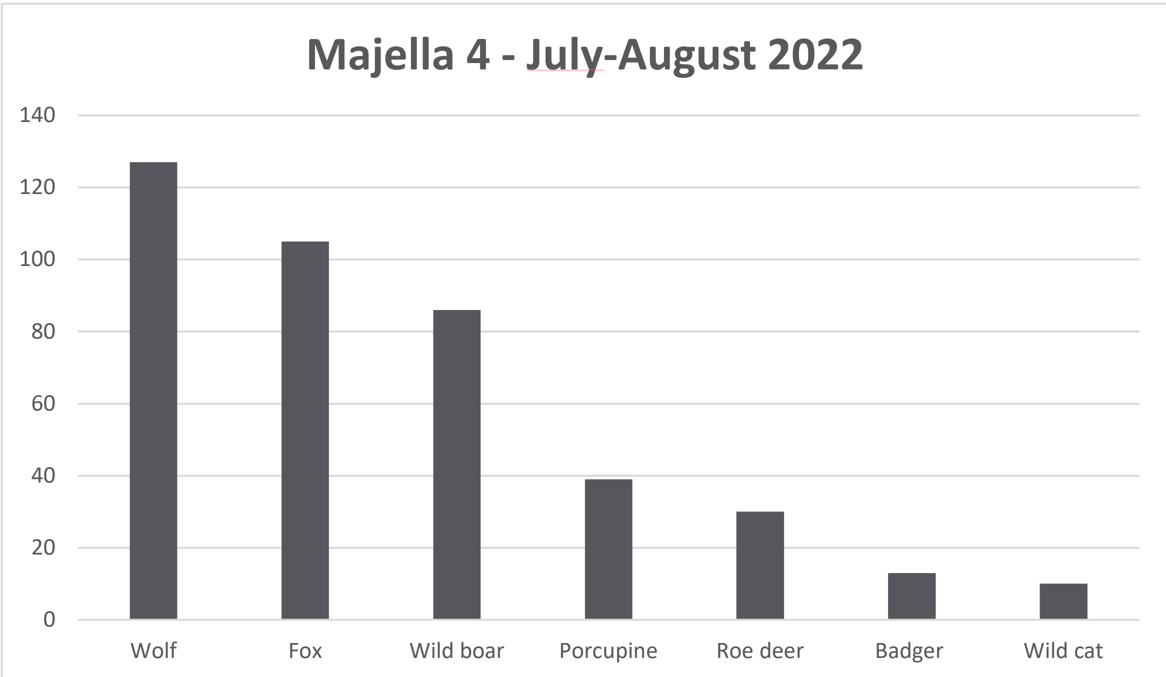


Figure 2. Results of the two case studies implemented in PNM and aimed at obtaining an additional insight on actual AVC risk assessing the number of individuals/species that crossed the road where the AVC PSs Majella 4 are positioned. These data were compared with the number of acoustic deterrence activations triggered by the individuals and stored by the AVC PS itself. See text for details.

Even though this results only refer to one AVC PS location and to only a 7-months period, we believe it is extremely informative as an indicator of how the AVC risk/actual AVC comparison only based on the parameters stored by the AVC PS represents an underestimate of the actual risk. This last consideration bolsters the results reported in Figure 1, finally confirming that AVC PSs have been positioned in highly risky segments and that they are highly effective in preventing AVCs.

To close the dissertation about AVC PS effectiveness, it is also important to underline that most the AVCs actually happened were determined by the fact that the AVC PS was turned off (i.e. during the daytime when AVC PSs are turned off to save battery) or by the fact that animals passed out of sensors/camera ranges or, possibly, by the fact that drivers did not slow down. These considerations, together with the results of camera trapping that show no habituation to the acoustic deterrence by wildlife, lead to the conclusion that the AVC PS systems are highly effective in preventing AVCs and that efforts should be concentrated in adjusting the system continuously (e.g. placing new sensors or moving them according to possible changes in wildlife use of crossing paths) and in implementing strong communication campaigns aimed at raising the awareness of drivers. Regarding the "behaviour" topic, it is interesting to report some side insights obtained with the camera trapping activity on how animals behave when crossing the roads. It is known and reported in literature that one of the features affecting the AVC probability is the variable "car-avoidance behaviour", a general term that refers to some sort of positive bias created by animals in an unknown way to avoid AVCs. Through the camera traps installed in the frame of Actions A5-D1 we recorded videos showing animals approaching the roads in a mindful and careful way, sometimes looking right and left before crossing the road. Even though a specific monitoring plan should be designed to better describe this behaviour, it is worth underling that wildlife is acting in the best way possible to avoid AVCs and this gives to us an even bigger duty in doing the best possible ourselves to avoid AVCs as well. The AVC PS system is an extremely powerful and effective prevention tool, animals behave in the best possible way avoiding vehicles and responding well to the tools used by the system (i.e. acoustic deterrence) so, at the moment, the variable that can give the highest margins of improvement of the all wildlife-AVC PS-drivers system is the drivers behaviour which needs to be considered a prior factor to work on in the frame of the after-LIFE period.

2.1.3 Monitoring of virtual fence effectiveness

The monitoring of Virtual Fence (VF) effectiveness has been a tough task of the LIFE SAFE-CROSSING as methods reported in the literature were not really suitable for a conservation project aimed at improving the status of endangered species. Especially in the case of the Apennine brown bear where conservation interventions cannot be based on numbers (a topic also presented by PNM during the side event of the IENE conference held in 2020, the LIFE AMYBEAR final congress held in Greece in 2021 and the final conference of the INTERREG-ADRION DINALPCONNECT project held in Slovenia in 2022), the assessment of the effectiveness of this measure following methods applied elsewhere can be prohibitive. In fact, the classic before-after comparison is not an option given the relatively low number of bears hit by vehicles (low as compared to other populations but extremely high and unbearable for the Apennine brown bear remnant population); in the same way the before-after comparison obtained by alternating VF "switch on" and "switch off" periods is not an option for a conservation project and, to our opinion, the ethic of its application is also questionable for pure investigation projects. In line with the choice made throughout the project, we did implement the before-after comparison of AVCs following the same methods applied for the evaluation of the AVC PS but we also decided to collect additional data to complement this analysis implementing a camera-trap monitoring activity aimed at acquiring qualitative data on animal behaviour and their reaction to the VF. The main problems to overcome to implement this task were the theft risk and the need to find a way to prevent vehicles from triggering the camera traps in order to avoid battery consumption and SD cards to get full in few hours. To solve this last issue, after several attempt we did find a way to install the camera traps right behind the guard rail making it work as a shield between the vehicles and the camera trap sensors thus impeding the triggering (Figure 3). To counter theft risk, instead, we used lockers and special covers (Figure 2) but still 2 camera traps were stolen during the activity.

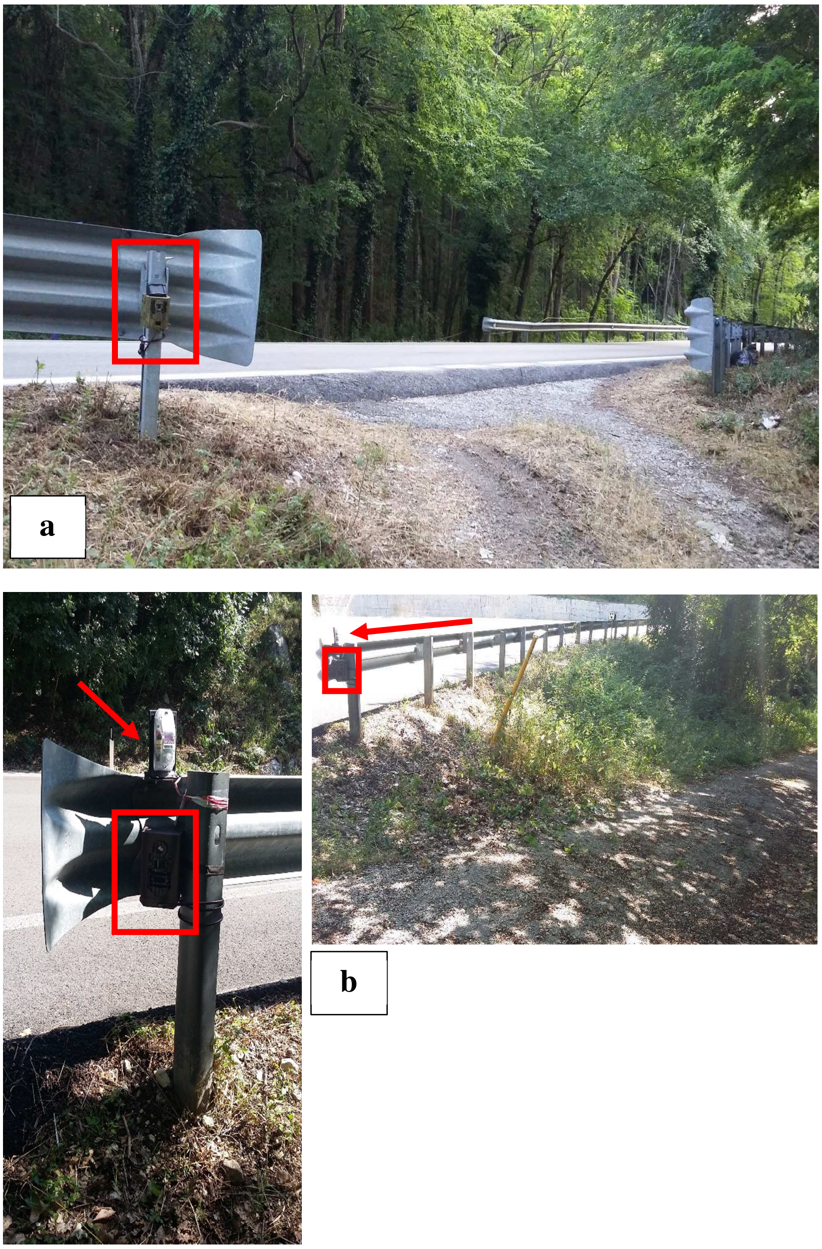


Figure 3. Solution found to install camera traps preventing the vehicles from triggering the cameras themselves: cameras are installed behind the guard rail that works as a shield between vehicles and the camera sensors. Red squares highlight the camera traps while red arrows highlight VF devices in: a) One camera trap along the SS5 before the installation of the VF; b) camera traps along the SS487 after the installation of the virtual fence. The lockers and the special anti-theft covers are clearly visible in the picture a.

Camera traps were thus installed were paths used by wildlife with the guard rails were present along the road stretches to be interested by this task of action C1 both before the installation of the devices (Figure 3a) and after (Figure 3b).
Methods to quantify the AVCs before and after the installation of the VF refer to: the selection of target animals, the assessment of the periods to be considered “before” and “after” and the assessment of the road stretch actually covered by the VF (Table 6).

Table 6. Methods used to quantify the effectiveness of the VF installed along ~20 Km of roads through the comparison of AVCs happened before and after its installation.

VARIABLE	**CRITERIA**	**EXPLANATION**	**ACTIONS INVOLVED IN DATA COLLECTION**
Selection of target animals	Bear, wolf, other wild carnivores, ungulates	Consistent with the choices made for Action A3.	A3-A5-D1
Assessment of "before" and "after"	The date of installation (DI) of each VF segment considered as the starting of the "after" period. 2009-DI as "before (1)" period 2019-DI as "before (2)" period	As opposed to AVC PSs, VF were 100% working right after the installation so that it can be considering officially working starting from the very date of installation. Before the LIFE SAFE-CROSSING starting no systematic collection of AVCs was carried out so that we decided to quantify the "before" period using both the whole data set and only the dataset collected with the systematic monitoring.	Opportunistic activity before the starting of the project A3-A5-D1

VARIABLE	CRITERIA	EXPLANATION	ACTIONS INVOLVED IN DATA COLLECTION
Assessment of the road stretch covered by the VF segment.	Road stretch encompassed between the first and last device.	Even though VF do have a “radius” of action, this segment represents a conservative choice of the minimum road stretch were VF devices work to prevent AVCs.	C1-D1

Results of the before-after comparison show that in 5 out of 8 road stretches the road mortality reduction is 100%, with no AVCs at all after the installation of the VF. In the three remaining stretches the figures change depending on the “before” monitoring period considered but still reached mortality reductions above 90% (Table 5).

Table 7. Results of the before-after comparison of AVCs of the target species happened in the road stretches where the ~ 20 Km of VF have been installed in PNM. BEFORE (1): 2009-Date of installation; BEFORE (2): 2019-date of installation; AFTER: date of installation-31/08/2023.

VF LOCATION (Km)	BEFORE (1)	BEFORE (2)	AFTER	REDUCTION OF ROAD MORTALITY
Stretch 1 (3.20)	12	1	1	0%-92%
Stretch 3 (1.20)	20	1	0	100%
Stretch 2 (6.00)	83	41	10	76%-90%
Stretch 8 (2.30)	5	1	0	100%
Stretch 4 (1.40)	20	16	1	94%-95%
Stretch 5 (1.30)	5	1	0	100%
Stretch 7 (1.70)	4	2	0	100%
Stretch 6 (2.30)	3	0	0	100%

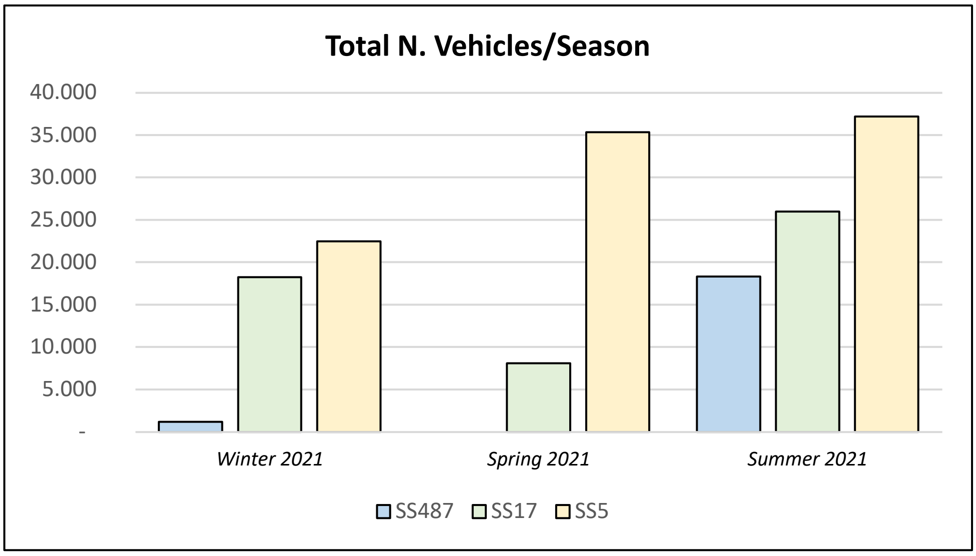
Even though the idea to position camera traps behind the guard rail worked and several video were collected recording animals’ behaviour, data gathered so far are not enough to perform significant comparison among behaviours with-without VF. So far only a qualitative result can be reported: wildlife tends to always approach the road in a mindful and careful way but the noise/light produced by the VF device is a signal that makes animals stop and evaluate the situation even more before deciding to cross the road. This is particularly true if we think that seldom animals have been filmed feeding on the road verges thus in a “low attention” mode or at least lower-attention mode that animals that approach the road just to cross it. Animals

that feeds on road verges, distracted by the feeding activity seem to have harder time in realizing the arrival of a vehicle and in those cases the "alarm" given by the VF devices really makes the difference between a low-attention to a high-attention (or flee) mode.
A continuation of the camera trap monitoring activity during the after-LIFE period will hopefully give the possibility to collect more data in order to have quantitative and significant results on these issues. In fact, beyond their importance in giving additional insight on the effectiveness of the VF, they also represent new data hardly present in the current literature that could contribute to better understand wildlife behaviour, awareness and mindfulness when crossing roads and ultimately give new insights for the road ecology studies.

2.1.4 Results of AVC PS and VF effectiveness monitoring in light of data on road traffic measurements

Traffic level monitoring activity was planned on a seasonal basis like in Action A5 with the addition of a spring monitoring session. However, due to some technical failures of the TMD and additional Covid restriction in spring 2022 some data are missing.
Data analysis was performed in the exact same way reported in the Action-specific report of Action A5 including the fact that, in order to standardize source data for all the TMD locations, data coming from 1 week-period were selected to be analysed even though monitoring sessions lasted up to 20 days. Details on the seasonal measurements duration and on the actual period used for data analysis are reported in Appendix 1.
Results confirm that SS5 is the road with the highest traffic volume followed by SS17 and the SS487 (Figure 4). From a seasonal point of view results of Action D1 also confirm that the summer is the season with the highest traffic volume with the SS487 confirmed as the road with the highest summer/other seasons ratio (1.4-1.7 against 1.2-1.4 of SS5 and SS17). An extremely high summer/other season ratio resulted for summer/winter 2021 of SS487 (15.5) but this figure is probably biased by the SARS-Cov2 pandemic restrictions that were very severe in Abruzzo in winter 2021-2022, especially along roads like SS487 that outside summer are mostly used by locals and have no commercial traffic (i.e. type of traffic not affected by restrictions of 2021-2022) like SS5 and SS17.
Comparing data on traffic measurements among years, including Action A5 monitoring results, the SS487 and SS17 seem to be the roads with the steadiest situation (exception given for the above-mentioned biased situation of winter 2021 for SS487) while for the SS5 a degree of traffic decrease can be observed for both summer and winter[2] (Figure 5).

[2] No data available to compare the Autumn among years.



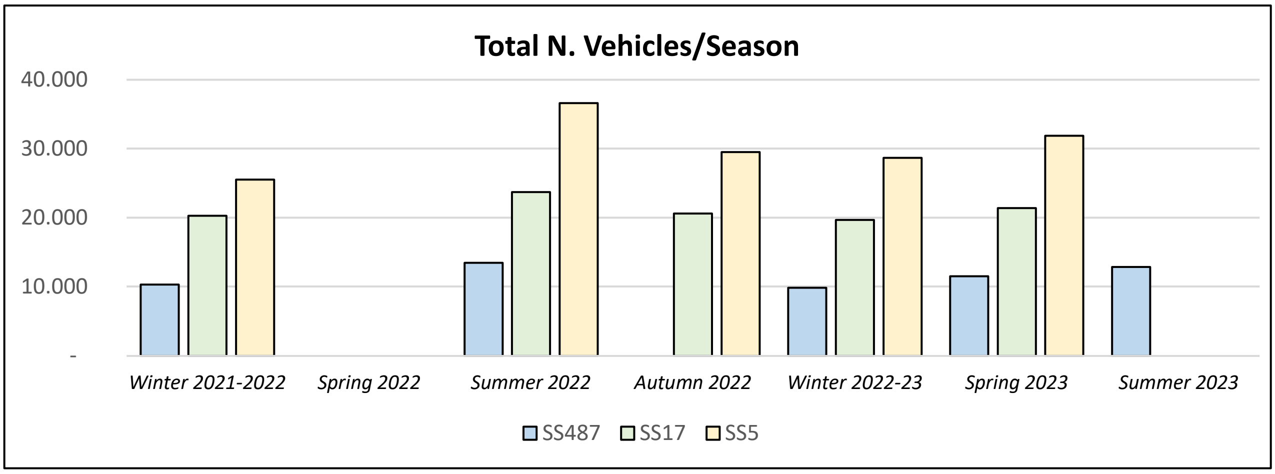
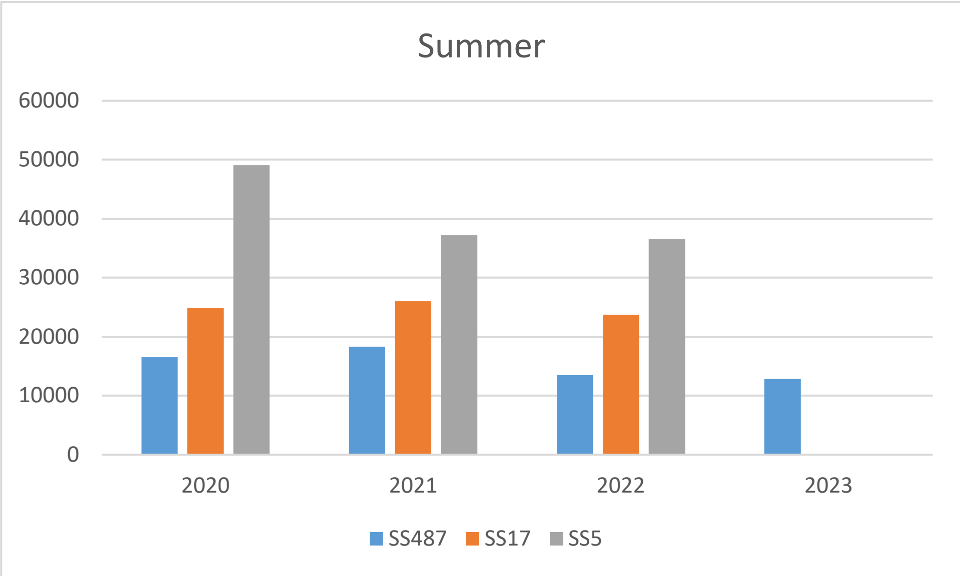


Figure 4. Number of vehicles/season registered along SS5, SS17 and SS487 during Action D1.



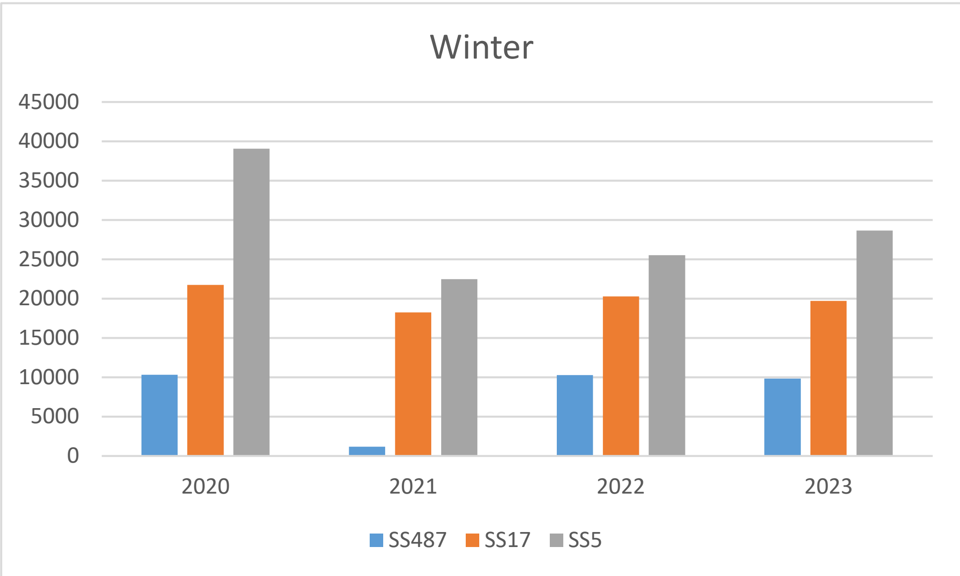


Figure 5. Comparison of data on total number of vehicles registered in summer and winter through the installation of a Traffic Measurement Device in PNM along SS5, SS17 and SS487 during Action A5 (2020) and D1 (2021-2023). Data referring to Autumn are too fragmented to be compared.

The analysis of the mean speed/season and its comparison among A5-C1 results show that no evident differences can be observed for the same road among seasons as well as for the same road/season among years (Figure 6). This means that, on average, people drove at the same speed during the whole project.

Results of the analysis of the number of vehicles/mean speed values suggest that traffic levels/mean seasonal speed did not play a role in reducing road mortality in the road segments where AVC PSs and VF were installed and that the high percentages of road mortality reduction observed are a direct consequence of the devices work.

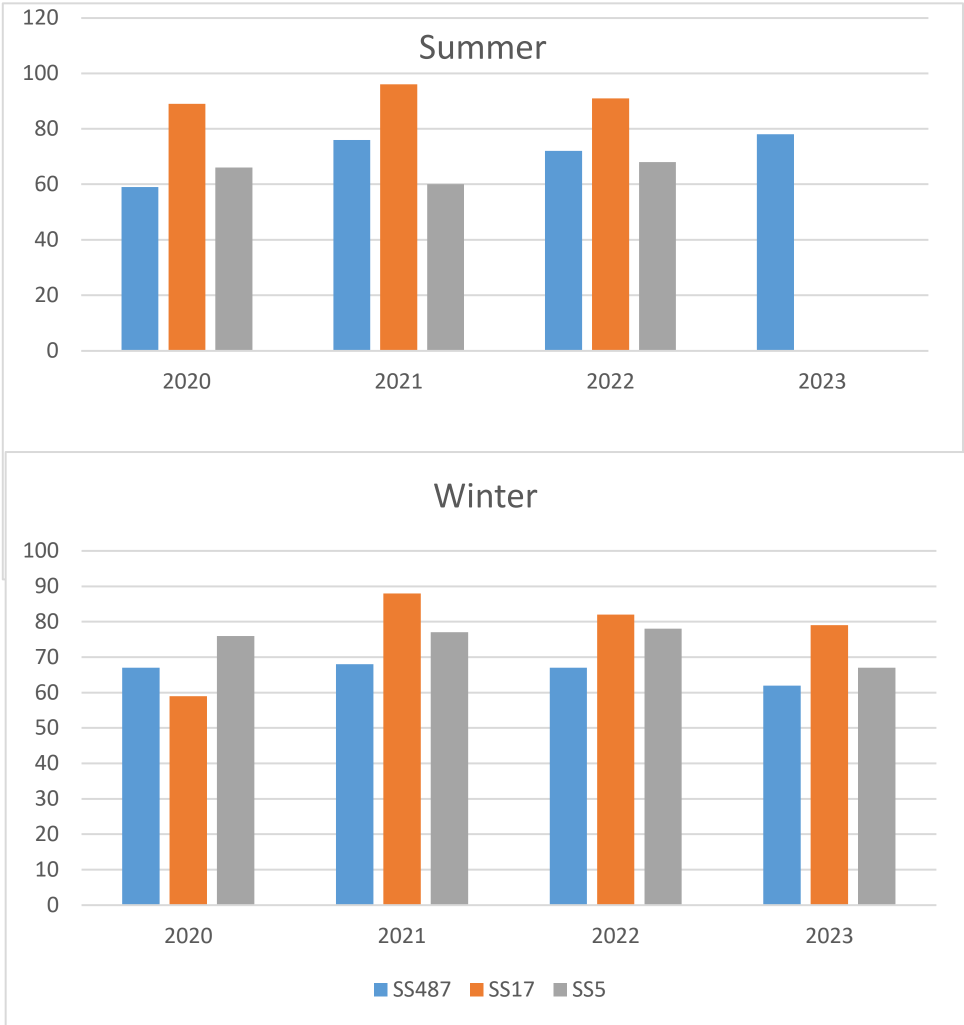


Figure 6. Comparison of data on the mean speed of vehicles registered in summer and winter through the installation of a Traffic Measurement Device in PNM along SS5, SS17 and SS487 during Action A5 (2020) and D1 (2021-2023). Data referring to Autumn are too fragmented to be compared. Numbers on the Y axis are Km/h.

Appendix 1 – Details of the Traffic Measurements Device monitoring sessions (seasonal measurements) implemented in PNM during Action D1 and details of data actually used to perform analysis.

Road Code	Season	Year	Monitored from	Monitored to	Analysis from	Analysis to
SS487	Winter	2020-2021	02/03/2021	16/03/2021	08/03/2021	14/03/2021
	Summer	2021	19/08/2021	31/08/2021	23/08/2021	29/08/2021
SS17	Winter	2020-2021	03/02/2021	12/02/2021	04/02/2021	10/02/2021
	Spring	2021	26/03/2021	10/04/2021	29/03/2021	04/04/2021
	Summer	2021	23/06/2021	06/07/2021	28/06/2021	04/07/2021
SS5	Winter	2020-2021	17/02/2021	01/03/2021	22/02/2021	28/02/2021
	Spring	2021	01/05/2021	15/05/2021	03/05/2021	09/05/2021
	Summer	2021	21/07/2021	04/08/2021	26/07/2021	01/08/2021
SS487	Winter	2021-2022	17/02/2022	01/03/2022	21/02/2022	27/02/2022
	Summer	2022	21/07/2022	02/08/2022	25/07/2022	31/07/2022
	Winter	2022-2023	15/12/2022	30/12/2022	19/12/2022	25/12/2022
SS17	Winter	2021-2022	03/03/2022	15/03/2022	07/03/2022	13/03/2022
	Summer	2022	05/07/2022	13/07/2022	06/07/2022	12/07/2022
	Autumn	2022	30/09/2022	15/10/2022	03/10/2022	09/10/2022
SS5	Winter	2021-2022	13/01/2022	24/01/2022	14/01/2022	20/01/2022
	Summer	2022	13/07/2022	20/07/2022	13/07/2022	20/07/2022
	Autumn	2022	11/11/2022	23/11/2022	14/11/2022	20/11/2022
SS487	Spring	2023	12/04/2023	25/04/2023	17/04/2023	23/04/2023
	Summer	2023	15/06/2023	30/06/2023	19/06/2023	25/06/2023
SS17	Winter	2022-2023	04/01/2023	16/01/2023	09/01/2023	15/01/2023
	Spring	2023	23/03/2023	06/04/2023	27/03/2023	02/04/2023
SS5	Winter	2022-2023	18/01/2023	30/01/2023	23/01/2023	29/01/2023
	Spring	2023	15/05/2023	24/05/2023	16/05/2023	22/05/2023

2.2 PNALM (Italy)

In the project area the following concrete interventions were carried out:

- Installation of 3 AVC-PS;
- Installation of 5 Km of virtual fence;
- Adaptation of 4 crossing structures;
- Installation of 25 road panels.

The road segments where the concrete conservation actions have been implemented were the ones already monitored in the frame of Action A5 (tab. 7).

Table 7. Distribution of the concrete conservation interventions on the monitored road segments in PNALM (Italy).

Transect code	Road segment	AVC-PS	Virtual fence (Km)	Adapted crossing structures	Road panels
PNALM A	SS 83 Km 35-41	1	-	-	4*
PNALM B	SS 83 Km 46-58	1	-	2	8*
PNALM C	SP 17 Km 15-31	-	5	1	6*
PNALM D	SP 509 Km 1-9	-	-	-	1*
PNALM E	SR 479 Km 24-29	-	-	-	4*
PNALM F	SS 17 Km 145-147, 200	1	-	1	2

**The road panels were installed not only on the road stretch monitored*

2.2.1 Road mortality monitoring sessions

In the frame of Action D1, the selected road segments were continuously monitored to record animals found dead on the road. Since October 2020, the road mortality monitoring sessions were carried following the same protocol applied in the Action A5.

In PNALM, from October 2020 to August 2023, we carried out 420 monitoring sessions on 6 road segments. Most of the dead animals were found outside the monitoring session, recorded by the Park's rangers. Overall, 30 road kills were detected including 12 wildlife species (fig. 7). 24 road kills (80%) were recorded on Road transect PNALM B, 5 (17%) on road transect PNALM A and 1 (3%) on PNALM F. No road kills were detected on the other 3 road segments. Wild bear was the species with highest frequency (20%) following by fox (17%) and badger (13%).

The Apennine brown bear was killed on SS17 road near the area where 1 AVC-PS (Abruzzo 3) was installed and a fence was built to guide the animals toward an underpass. This bear was an adult male named "Juan Carrito", and this case will be discussed later.

The monitoring of traffic volume and speed prosecuted on the road segments inside Park boundaries (PNALM A, PNALM B, PNALM C and PNALM E) and a total of 140 monitoring sessions were carried out. For the entire road sections investigated, the traffic volume doubled on weekends and tripled in the summer season, reaching more than 15000 vehicles (cars and motorcycles) per week. For all stretches and all seasons, 90% of vehicles did not comply with the imposed limits, with the highest speeds recorded along SS83 (PNALM A and PNALM B).

The problem was particularly pronounced on the road transect PNALM B, on SS83, where the proportion of vehicles traveling above 80 km/h, including heavy vehicles, was also high. A maximum speed of 210 km/h was recorded on this stretch of road by a motorcycle.

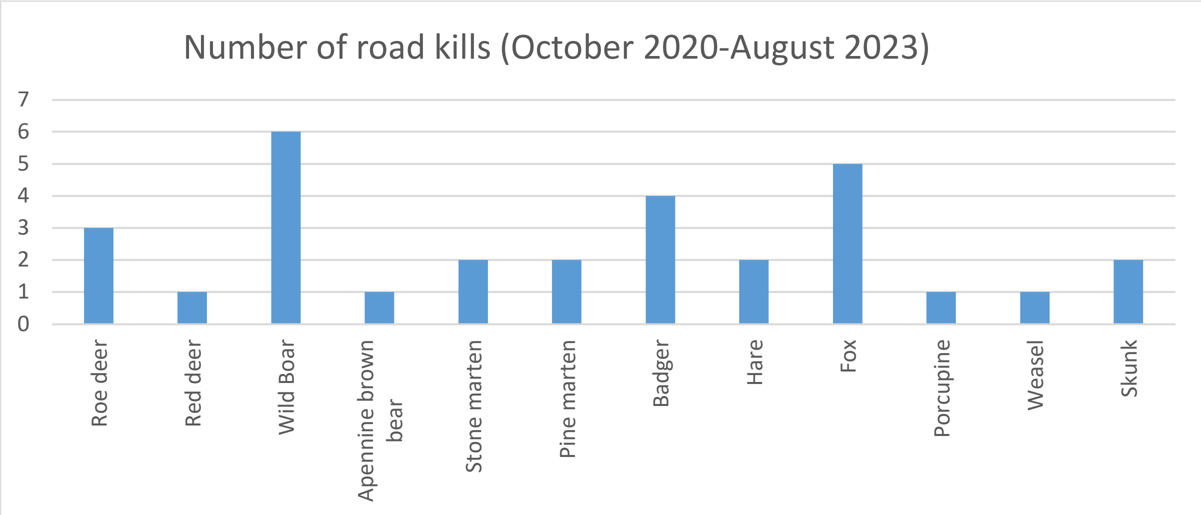


Figure 7. Wildlife species road killed in PNALM on the monitored segments (October 2020-August 2023).

2.2.2 AVC-PS

The installation of the 3 AVC-PS started on April 2021 and was finalized at the end of May.

The AVC-PS Abruzzo 1 was installed on the road SS 83 (PNALM A) and was equipped with a thermal camera and 4 PIR sensors. A second thermal camera was added in February 2022 to better cover the area used by animals to approach the road.

The activations of the AVC-PS are summarized in table 8. Wildlife species were constantly detected near the road and around 500 risky situations were recorded but no AVC occurred. Unfortunately, we encountered several technical problems in data transmission, due to poor Internet connection. In 2022, it was not possible to download the data in the months of April and May, while since October there has been a problem in the software of the central unit, so it was preferred to exclude this data. Although the system was properly functioning (as ascertained during field surveys), the problem persisted throughout 2023. For this reason, activation data could not be recorded. Several technical interventions were made, installing different types of modems, but no solution been found. The central unit was replaced in July 2023 and the monitoring of the AVC-PS will continue after the end of the project as it is specified in the afterlife plan.

Table 8. Number of activations of the AVC-PS Abruzzo 1 installed on the SS 83 road (PNALM A).

AVC-PS Abruzzo 1	Detection of wildlife near the road	Detection of vehicles ≥50 Km/h within 3 minutes after the detection of wildlife
May 2021-December 2021	265	116
January 2022-December 2022*	386	277

** Monitoring period didn't cover all months of the year (see text for explanation).*

The AVC-PS Abruzzo 2 included 1 thermal camera and 1 PIR sensor.
The analysis of activations of the system started in July 2022, once the system was properly set up (tab. 9).

Table 9. Number of activations of the AVC-PS Abruzzo 2 installed on the SS 83 road (PNALM B).

AVC-PS Abruzzo 2	Detection of wildlife near the road	Detection of vehicles ≥50 Km/h within 3 minutes after the detection of wildlife
July 2021-December 2021	588	217
January 2022-December 2022	2133	589
January 2023-August 2023	1627	286

The system worked properly during the monitoring period except in the months of October, November and December, when the same problem related to data transmission occurred in the AVC-PS Abruzzo 1. However, in this case, we were able to solve it replacing the modem. In 2023, data collection was not possible in the months of June - due to a problem in the software of the central unit - and in April, luckily only for a few days. Overall, a huge amount of data was collected and presence of wildlife was detected regularly during all months of the year. More than 1000 risky situations were recorded but no AVC happened on this site.

The AVC-PS Abruzzo 3 was installed in April 2021 on SS 17 road (PNALM F), where an adult female of Apennine brown bear was road killed on 24.12.2019.
The AVC-PS was equipped with a thermal camera to detect the animals approaching both sides of the road. The results of the activations of the system are summarized in table 10.
In the analysis of the activations of the system, in order to not include activations not related to wildlife presence, we excluded the first hours after sunset, since there was a house near the AVC-PS, risking counting the passage of domestic animals. Moreover, the passage of trucks sometimes caused the activation of the thermal camera, causing a misinterpretation o the data. Furthermore, data collection was not possible in November and December 2021, as well as March and April 202, due to malfunctioning of the battery and problems in data transmission. The AVC-PS was turned off in 2023, since a fence was built along the road stretch in order to guide the animals toward the underpass present in the area. The installation of this

AVC-PS was conceived as a mitigation measure before the work for the adaptation of the underpass. In July 2023, the AVC-PS was moved along the SS 83, where an AVC cluster was identified, and the monitoring of its functionality will continue after the end of the project as is foreseen in the afterlife plan.

Table 10. Number of activations of the AVC-PS Abruzzo 3 installed on the SS 17 road (PNALM F).

AVC-PS Abruzzo 3	Detection of wildlife near the road	Detection of vehicles ≥50 Km/h within 3 minutes after the detection of wildlife
May 2021-December 2021	174	112
January 2022-December 2022	496	145

In all 3 AVC-PS the central unit was programmed to measure speed reduction of the vehicles when the flashing light panels, but this calculation was not possible because data obtained where not reliable. In addition, changes are planned as part of the activities under the afterlife plan.

2.2.3 Number of road kills before and after the installation of AVC-PS

In the area where the AVC-PS were installed no AVC were recorded. The percentage of reduction of AVC after the installation of the 3 AVC-PS was always 100%, but it's true that the sample size is very small (tab. 11). It is important to underline that the number of AVC before the start of the project is an underestimation of the phenomenon, since no systematic monitoring was in place. Once again, the evaluation of the AVC-PS can be better assessed through the analysis of the activations of the systems considering that, despite the high number of risky situations, no road kills have been registered. The bear road killed on the SS 17 road in January 2023 was outside the detection area of the AVC-PS Abruzzo 3. The bear was found dead around 300 meters from the central unit where there was one of the flashing light panels.

Table 11. Number of road kills before and after the installation of the AVC-PS in PNALM.

AVC-PS code	Length (m)	AVC before the installation	AVC after the installation	% reduction
Abruzzo 1	521	6 (2010-2021)	0 (April 2021-August 2023)	100%
Abruzzo 2	346	3 (2010-2021)	0 (June 2021-August 2023)	100%
Abruzzo 3	581	1 bear road killed in December 2019	0 (April 2021-Decembre 2022)	100%

2.2.4 Virtual fence

The installation of VF was made in May 2021 on the SP 17 (PNALM C) and on two test sites on the road SS 83 (PNALM A and PNALM B). In spring 2022, all the units of VF were moved to SP 17. In fact, on the road SS83, some of them were stolen and other damaged. For this reason, we decided to concentrate them in only one road segments. The functioning of the devices

was regularly monitored at least one per month. The degree of functionality of VF was substantially good, even if we had to replace some broken devices and adjust the distance between the unit where we did not have new device for substitution.
Overall, along the 5 Km of the SP 17 where the VF was installed, no road kills where recorded. The effectiveness of the VF in terms of road kill reduction was 100%, even if only 6 AVC occurred before their installation between 2010-2021 (tab. 12). A cluster of crossing points has been identified in this road segment under Action A3; in fact, the road is frequently crossed by radio-collared bears.

Table 12. Number of road kills before and after the installation of VF on SP 17 road in PNALM.

VF installed	Length (Km)	AVC Before the installation	AVC After the installation	% reduction
SP 17 (PNALM C)	5	6 (2010-2021)	0 (May 2021-August 2023)	100%

In order to evaluate the reaction of animals to the triggering of the VF unit a camera trap was installed on the SS 83 road where there were 3 units of VF. The monitoring period lasted from 12 May 2021 until 20 November 2021 (130 days). In 38 events it was possible to record the passage of animals when the units were active. Overall, 6 wildlife species were recorded, wild boar was the species most frequently detected (58% of the events) but the animals didn't show any reaction toward the activation of the devices, while reactions were observed - at least in some circumstances - by wolf (11% of the events) and red deer (8% of the events) (fig. 8). Further investigations are needed to evaluate the reactions to the triggering of the VF units also in terms of sample size because this are preliminary data and no conclusion can be drawn. Unfortunately, on SP 17, where 5 Km of VF were installed, there were no conditions to carry out this kind of study. New possibilities will be evaluated during the activities foreseen in the afterlife plan. One major problem is the positioning of the camera trap in a way that it is possible to detect the activation of the device and the approaching animal, avoiding at the same time that the camera trap is activated by the light of the approaching vehicle.

Figure 8. Wolf detected through a camera trap during the monitoring of virtual fence in PNALM.

2.2.5 Use of adapted crossing structures

In the project area 4 crossing structures were adapted to favour their use by wildlife species. The monitoring to evaluate the effectiveness of the interventions carried out was made on the two crossing structures on SS 83 (PNALM B) Casone Antonucci (Km 55,800 of SS83 road) and Crugnale (Km 56,600 of SS83 road) through the installation of camera traps, in this way we have been able to compare the number of passages before and after the intervention.

Casone Antonucci

The intervention consisted in the cutting and management of the vegetation in order to clean the entrances of the culvert and the installation of 450 meters of a metal fence. 2 camera traps, both set up to take 30 seconds videos, were installed to monitor the entrances of the crossing structure. The culvert was monitored in the frame of Action A4 between 2019 and 2020, before the adaptation of the crossing structure.
Before the intervention we recorded the use of the culvert by bears in 8 events, while in 4 events the bears didn't use the culvert. Since 2021, after the installation of the metal fence, we recorded 40 events out of 43, in which bears used the culvert, with an increase of its use of 41%. Bear were detected to use the culvert to cross the road in all time slots, including during daylight (fig. 9). The increase use of the culvert was recorded also for wolves and wild boars. Wolves were detected to use the culvert on 24 events, 79% of which after the installation of the fence. Among large ungulates, we recorded the use of the structures only by wild boars, all the events occurred after the construction of the fence. No increase of use of the structure was detected by small mammals (fox and mustelids).

Figure 9. Bear detected at the improved culvert "Casone Antonucci" on the SS 83 road, PNALM.

Crugnale

The intervention to adapt this crossing structure was finalized in Summer 2022. A wood fence was installed to guide the animals toward the entrances. The approachability of the structure was also improved as well as the substratum of the culvert.

Before the intervention, on 8 occasions, the bears never used the crossing structure, preferring to cross the road. After the end of the intervention, the use of the structure by bears was detected 4 times (fig. 10).

The increase in the use of the crossing structure after the improvement was also detected for wolves. Before the intervention, the species was found 14 times to never use the structure. After the intervention, again out of 14 occurrences, the wolf used the structure 10 times (71%). The same trend was detected for wild boar. Indeed, before the intervention, the species always crossed the road without using the culvert, while, after the improvement, wild boars used the culvert on 17 occasions. The use of the culvert was also recorded on 218 times by small mammals.

Figure 10. Bear detected at the improved culvert “Crugnale” on the SS 83 road, PNALM.

On the adapted crossing structure on the SS 17 road, it was not possible to carry out a systematic monitoring through camera trapping, because the camera trap was stolen one week after its installation. The use of the structures was then monitored recording the animal tracks, but the camera trapping monitoring is already foreseen in the afterlife plan.

As we previously said on the SS 17 road the bear M20 named Juan Carrito was road killed on 23/01/2023. M20 died about 300 m away from the site where, on 24/12/2019, a female bear had been run over and died as a result of the impact. It was precisely the death of this female that had prompted PNALM to install 1 AVC-PS (Abruzzo 3) on this site. On October 2022 a metal fence was installed to guide the animals toward the underpass located in the area. Tracks on snow found during the inspection carried out the morning after the accident involving M20 indicated that the bear followed the fence without crossing the road, but when it reached the intersection, which couldn’t be fenced, it jumped into the road, and there was killed. The last intervention was made in July 2023 on a crossing structure on SP 17, not far from the area where the AVC-PS Abruzzo 1 was installed. Camera traps were installed to monitor the use of this adapted crossing structure and the monitoring is ongoing and it is included in the afterlife plan.

2.3 Terni Province (Italy)

In the project area the following concrete interventions were carried out:

- Installation of 2 AVC-PS;
- Installation of 12 road panels;

The road segments where the concrete conservation actions have been implemented were SP 38, and SR 205 already monitored in the frame of Action A5 (tab. 13). The other road panels have been installed on the surrounding roads to improve their visibility by people circulating in the area.

Table 13. Distribution of the concrete conservation interventions on the selected road segments in Terni Province

Road segment	AVC-PS	Road panels
SP 38	1	2
SR 205	1	4

2.3.1 Road mortality monitoring sessions

In the frame of Action D1 the 2 selected road segments were continuously monitored to record animals found dead on the road. Since October 2020 the road mortality monitoring sessions were carried following the same protocol applied in the Action A5.

In Terni Province from October 2020 to August 2023 we carried out 92 monitoring sessions, 46 for each monitoring segment. Overall, 16 animals, including 5 species, were found dead: 69% on SP 38 and the remaining 31% on SR 205 (tab. 14). The species with the highest frequency was wild boar (31%) followed badger (25%) and fox (25%), while the remaining animals were porcupine (13%) and squirrel (6%).

Table 14. Road mortality monitoring sessions on the selected road segments in Terni Province.

Road segment	Length of the road segments (Km)	Number of monitoring sessions (October 2020 - August 2023)	Number of animals found dead
SP 38	10,32	46	11
A-3001	10,97	46	5

Comparing these results obtained with the ones obtained in the frame of Action A5, when 10 animals were found dead in 13 months, there was a decrease of 44% in the road kills recorded.

This result could be in some way related to the effectiveness of the concrete interventions implemented. The first road panels were installed at the end of 2020, while the first AVC-PS in February 2022.

In the frame of Action D1 4 traffic volume and speed monitoring sessions were carried out, 2 for each road segment. The results of these sessions will be present in the following pages, when it will be discussed the effectiveness of the road panels.

2.3.2 AVC-PS

Two AVC-PS were installed in Terni province, 1 on the road SP 38 and 1 on the road SR 205.

The installation of AVC-PS was made on the SP 38 in February 2022. The system was equipped with 2 thermal cameras in order to detect animal approaching both sides of the road. The system was regularly checked remotely, as well as through field survey - especially when technical problems were detected. The activations of the AVC-PS installed on SP 38 road is summarized in table 15.

Table 15. Number of activations of AVC-PS installed on SP 38 road in Terni Province.

AVC-PS Amelia 1 (SP 38)	Detection of wildlife near the road	Detection of vehicles ≥50 Km/h within 3 minutes after the detection of wildlife
March 2022-December 2022	799	575
January 2023-August 2023	303	153

In August 2022, there was no data transmission due to poor Internet connection and problems related to the charge of the battery occurred partially in November and for the whole month of December.

Despite the technical problems, we recorded more then 700 risky situations but no AVC was registered. The AVC-PS Amelia 2 was installed in May on SR 205 road. The system was equipped with 11 PIR sensors, and all the of activations of the system are showed in table 16.

Table 16. Number of activations of AVC-PS installed on SR 205 road in Terni Province.

AVC-PS Amelia 2 (R 205)	Detection of wildlife near the road	Detection of vehicles ≥50 Km/h within 3 minutes after the detection of wildlife
June 2022-December 2022	188	126
January 2023-August 2023	603	205

In 2022 data transmission was interrupted from August to November probably due to work for the transition to 5G. In 2023 data flow was regular, but in May, due to a massive forest cutting, there was a decrease in the use of the area by wildlife (fig. 11).

In February 2023, two camera traps were installed on the pole of the PIR sensors to assess the species detected by these devices (fig. 12). Over a period of 30 days, all the species detected by the camera traps (porcupine, badger, wild boar, fox and pine/stone marten) corresponded to the activations of the PIR sensors of the AVC-PS, and when the camera trap had false activations the PIR sensors were unactive.

Figure 11. Forest cutting operation in the area of the AVC-PS Amelia 2 in Terni Province (the white device is a PIR sensor.

Figure 12. Camera trap installation on the pole of a PIR sensor in Terni Province (AVC-PS Amelia 2).

Wildlife was regularly detected rnear the road and over 300 risky situations were recorded but no road kill occurred on the road stretch where AVC-PS was effective.
The reduction of road kills was 100% for both AVC-PS. The number of road kills before the installation was 9 in the period 2015-2022 in the AVC-PS Amelia 1 (SP 38) while 8 in the period 2011-2022 in Amelia 2 (tab. 17).

Table 17. Number of road kills before and after the installation of AVC-PS in Terni Province.

AVC-PS code	Length (m)	AVC before the installation	AVC after the installation	% reduction
Amelia 1 (SP 38)	560	8 (2015-2022)	0 (February 2022- August 2023)	100%
Amelia 2 (SR 205)	370	8 (2011-2022)	0 (May 2022-August 2023)	100%

In Terni Province in order to invite drivers to slow down on the road stretch where the 2 AVC-PS were installed slowdown stripes have been painted on the asphalt at the height of the flashing light panels (fig. 13).

Figure 13. Slow down stripes on the road SR 205 where the AVC-PS Amelia 2 was installed.

2.3.3 Road panels

In Terni Province, 12 road panels developed through the neuromarketing technique were installed in the project area.

In order to try to measure the effectiveness of this action, traffic volume and speed monitoring sessions were carried on SP 38 before and after the installation of the panels that on this road was made in October 2022.

The ex-ante monitoring sessions lasted from 24/02/2022 to 27/02/2022. A total of 3896 vehicles were recorded, the mean number of vehicles per day was 986, the mean speed 91 Km/h, while the maximum speed 184 Km/h. The distribution of the classes of speed recorded is presented in table 18.

Table 18. Results of the traffic volume and speed monitoring session (February 2022) on the SP 38 before the installation of road panels.

Speed km/h	N. of vehicles	%
0-50	77	2.27
51-60	118	3.48
61-70	294	8.68
71-80	500	14.7
81-90	687	20.2
91-100	638	18.8
101-110	494	14.5
111-120	303	8.94
121-130	150	4.43
131-140	66	1.94
141-150	33	0.97
> 150	23	0.67

The first ex-post monitoring session was made on February 2023 one year later the ex-ante session. The monitoring sessions lasted from 21/02/2023 to 27/02/2022. A total of 6312 vehicles were recorded, the mean number of vehicles per day was 901, the mean speed 76 Km/h, while the maximum speed 142 Km/h. The distribution of the classes of speed recorded is presented in table 19.

Table 19. Results of the traffic volume and speed monitoring session (February 2023) on the SP 38 after the installation of road panels.

Speed km/h	N. of vehicles	%
0-50	302	4.48
51-60	734	11.6
61-70	1293	20.4
71-80	1574	24.9
81-90	1232	19.5
91-100	669	10.5
101-110	344	5.44
111-120	110	1.74
121-130	41	0.64
131-140	11	0.17
141-150	2	0.03
> 150	0	0

The second ex-post monitoring session was made on May 2023.
The monitoring sessions lasted from 21/05/2023 to 09/05/2023. A total of 7899 vehicles were recorded, the mean number of vehicles per day was 987, the mean speed 77 Km/h, while the maximum speed 164 Km/h. The distribution of the classes of speed recorded is presented in table 20.

Table 20. Results of the traffic volume and speed monitoring session (May 2023) on the SP 38 after the installation of road panels.

Speed km/h	N. of vehicles	%
0-50	336	4.25
51-60	748	9.46
61-70	1612	20.4
71-80	2062	26.1
81-90	1636	20.7
91-100	847	10.7
101-110	390	4.93
111-120	170	2.15
121-130	68	0.86
131-140	17	0.21
141-150	9	0.11
> 150	4	0.05

It is important to underline that, in both monitoring sessions, after the installation of road panels there was a reduction of the mean speed of the vehicles from 76 Km/h (February 2023) and 77 Km/h (May 2023) compared to 91 Km/h detected before the installation (February 2022) of the road panels. The analysis of the distribution of the classes of speed showed a similar trend, with a highest frequency of the lower classes of speed in the ex-post monitoring sessions (tab. 18, 19 and 20).

Clearly, these are only preliminary results but they seem to show that the installation of road panels influenced the driving behaviour resulting in a reduced speed of the vehicles circulating in the area.

2.4 Romania

In the project area the following concrete interventions were carried out:

- Installation of 5 AVC-PS;
- Installation of 7 Km of virtual fence;
- Adaptation of 30 crossing structures;
- Installation of 8 road panels.

The road segments where we implemented the concrete conservation actions where the ones already monitored in the frame of Action A5 plus the road segments DN 73 A Paraul race (Romania 2). This road segment was added in October 2020, because DN 73 A is a road that crosses important bear habitat area, and where several AVC occurred in the last years.
Moreover in 2023, on the basis of the AVC registered on the road DN 11, 2 Km of Virtual fence was installed there, replacing 1 of the AVC-PS already foreseen in the project proposal (tab. 21).

Table 21. Distribution of the concrete conservation interventions on the monitored road segments in Romania.

Transect code	Road segment	AVC-PS	Virtual fence (Km)	Adapted crossing structures	Road panels
Romania 1	DN 1 Brasov-Comarnic	1	3	15	2
Romania 2	DN73 A Paraul Race	1	_	_	
Romania 3	DN1 A Cheia-Brasov	1	_	5	2
Romania 4	DN 13 Padurea-Bogatii	4	_	5	2
Romania 5	E 68, DN1 Brasov-Vladeni	1	2	5	2
Romania 6	DN 11 Braov - Lunca Calnicului	_	2	_	_

2.4.1 Road mortality monitoring sessions

In the frame of Action D1 the selected road segments were continuously monitored to record animals found dead on the road. Since October 2020 the road mortality monitoring sessions were carried out 2 times per month following the same methodology applied in the Action A5.
In Romania, from October 2020 to August 2023, we carried out 350 monitoring sessions on the five selected road segments. Compared to what has been done in Action A5, we added the road segment DN73 A Paraul Race (tab. 22).

Table 22. Road mortality monitoring session in Romania.

Transect code	Road segment	Length of the road segments (Km)	Number of monitoring sessions (October 2020-August 2023)	Number of animals found dead
Romania 1	DN 1 Brasov-Comarnic	40	70	5 2 roe deer 3 wild boars
Romania 2	DN73 A Paraul Race	10	70	3 foxes
Romania 3	DN1 A Cheia-Brasov	40	70	2 1 roe deer 1 fox
Romania 4	DN 13 Padurea-Bogatii	20	70	2 1 fox 1 bear
Romania 5	E 68, DN1 Brasov-Vladeni	20	70	6 2 bears 1 hare 3 foxes

Overall, 18 animals were found dead: 8 foxes (44%), 3 wild boars (17%), 3 roe deer (17%), 3 bears (17%) and 1 hare (6%). Bears were found dead on the road transects Romania 5 and Romania 4. In the calculation, we didn't consider 10 stray dogs found dead on the 5 road segments.
Considering the wild animals found dead during the Action A5 (19 on 36 monitoring sessions for each road segment from January 2019 to September 2020), in comparison the ones found dead during Action D1 (15 on 70 monitoring sessions from October 2020 to August 2023), there was a reduction of 59%. This reduction could be in some way related to all conservation actions carried out in the frame of the project. Of course, we are conscious that a lot of parameters can influence this datum, therefore cannot be considered a conclusive result. In this comparison, we didn't include the road segment Romania 2 because it was monitored only in the frame of Action D1.

2.4.2 AVC-PS

The installation of the 5 AVC-PS started in November 2022 and was finalized in January 2023. All the systems were equipped with thermal cameras. The monitoring of the systems was made on a regularly basis through field surveys and through the analysis of the activations of the system stored in the dedicated web portal, as it was explained in the deliverable of the Action C1. In the analysis, we included only those months once the system was properly set up. In the first months, we had to fix correctly the orientation of the thermal cameras, because we had problems related to passages of the big volume trucks that entered in the detection area of the thermal camera, causing the activations of the systems.

Another issue was related to the sensitivity of the thermal camera, especially in Romania 3 and Romania 5, recording also the presence of small rodents. Therefore, in some months taken in consideration, we had hundreds of activations, which were excluded from the analysis. The data collected from the 5 AVC-PS were presented in table 23.

Table 23. Number of activations of the AVC-PS installed in Romania

AVC-PS code	Monitoring period 2023	Detection of wildlife near the road	Detection of vehicles ≥50 Km/h within 3 minutes after the detection of wildlife
Romania 1	March-August	169	249
Romania 2	April-August	407	493
Romania 3	May-August	502	242
Romania 4	March-August	292	428
Romania 5	June-August	137	229

The wildlife species were constantly detected in each road segment, and the number of detections per moth varied from 42 to 99 per month.

The number of risky situations was always extremely high, because for each animal detection, in the following 3 minutes, there were always multiple passages of vehicles, reflecting huge traffic volume during night hours in all the road segments; the only exception was Romania 3.

Through the analysis of video collected by the thermal camera of each system the presence of bear was recorded 26 times in Romania 2, 14 in Romania 4, 4 in Romania 5 and 3 in Romania 3.

In Romania speed reduction was measured as the % of vehicles reducing their speed of at least 10 Km/h when the flashing light panels of the AVC-PS were triggered, independent of the initial speed of the approaching (a substantial difference respect to the programming of the AVC-PS in Italy). Speed reduction ranged from 20% to 48%, but this parameter was not registered constantly and in the AVC-PS Romania, 5 due to technical problem, we were not able to record it (tab. 24).

Table 24. Percentage of vehicles slowing down when the flashing light panels of the AVC-PS were active.

AVC-PS code	Monitoring period 2023	Number of vehicles detected ≥50 Km/h	Number of vehicles Slowing down	% of vehicles reducing the speed (≥10 Km/h)
Romania 1	March-August	1090	527	48%
Romania 2	April-May	185	37	20%
Romania 3	May-August	438	164	37%
Romania 4	March-August	732	154	21%

2.4.3 Number of road kills before and after the installation of AVC-PS

In all the AVC-PS only 2 foxes were road killed, 1 in Romania 2 and 1 in Romania 4. In the period before the installation the number of road kills in the area of around 2 Km, where the AVC-PS were installed, was higher in Romania 1 (10 AVC in 24 months, 5AVC/year) and 29 in 30 months Romania 5 (around 12 AVC/year). The AVC-PS Romania 1 and Romania 5 were installed in the same road segment where respectively 3 and 2 Km of virtual fence were installed, therefore for these road segments, the data analysis was discussed below. In the other areas, the number of road kills in the period before the installation of the AVC-PS was 6 in Romania 2 (around 3 AVC/year), 4 in Romania 3 (2AVC/year), and 6 In Romania 4 (3 AVC/year) (tab. 25). Unfortunately, we don't have the precise coordinates of the road kills occurred in the period before the installation of the AVC-PS, consequently, we had to use a broader length than the one where the AVC-PS is effective. In any case, the relevance of the sites selected for the installation of the AVC-PS was witnessed by the fact that 8 bears were road killed where the systems Romania 2, Romania 3 and Romania 4 were installed (tab. 25). The precise sites for the installation were selected along the area where the AVC were recorded, considering the landscape characteristics suitable for the proper functioning of the AVC-PS.

Even if the monitoring period is short, it is important to underline that respect to the huge number of risky situations recorded in all the 5 systems only two road kills (2 foxes) occurred.

Table 25: Number of road kills before and after the installation of the AVC-PS in Romania.

AVC-PS code	Length (m)	AVC before the installation*	AVC after the installation	% reduction
Romania 1	390	10 (24 months) Including 4 bears	0 (8 months)	100%
Romania 2	328	6 (29 months) Including 2 bears	1 fox (8 months)	38%
Romania 3	382	4 (24 months) Including 2 bears	0 (8 months)	100%
Romania 4	430	6 (24 months) Including 4 bears	1 fox (8 months)	48%
Romania 5	485	29 (42 months) Including 14 bears	0 (8 months)	100%

*AVC registered within the 2 Km from the point of the central unit

2.4.4 Virtual fence

In the project area 7 Km of VF were installed.
On DN 1 Brasov-Comarnic, starting from July 2020 3 Km of VF were installed. A total of 161 devices were used to cover this road stretch. The VF was monitored systematically during the day to check the charging of the units and during the night to check the proper activation of the devices by the headlight of the cars. A total of 84 monitoring sessions were carried out, despite the theft of two sensors near a parking lot, and some vandalism acts to other units. The stolen and damaged devices were in some cases replaced, even though we preferred to adjust the distance between them, according to the terrain configuration in order to keep the effectiveness of the VF.
In this area we made several observation sessions with thermal camera in order to monitor the reaction of animals to the triggering of the units, but it was difficult to find a good observation point, and no significant data were collected. The AVC-PS Romania 1 was installed at the end of the segment covered with VF. 2 Km of VF was also installed on E 68, DN1 Brasov-Vladeni on 24/03/2022. A total of 58 devices were installed and 56 monitoring sessions were carried out, during which no particular problems were encountered. In this area, in the observations made with thermal camera we recorded the presence of ungulates and fox, but it was difficult to collect specific videos to analyse the reaction of animals to the triggering of the device. In this road segment, at the end of 2023, the AVC-PS Romania 5 was installed.
On 27/07/2023 2 Km of VF were installed on DN 11 in the municipality of Prejmer where 30 roe deer and 5 bears were road killed from 1/01/2022 to 1/01/2023. The installation of AVC-PS was not possible, because the road segment to be covered was too long, therefore we opted to install VF.

2.4.5 Number of road kills before and after the installation of VF

The reduction of AVC, on the two road stretches where the devices of VF were installed, ranged from 87% on the 3Km of transect Romania 1 to 93% on the 2 Km of transect Romania 5 (tab. 26).

Table 26: Number of AVC recorded before and after the installation of VF in Romania.

VF installed	Length (Km)	AVC Before the installation	AVC After the installation	% AVC reduction
DN 1 Brasov-Comarnic (Romania 1)	3	10 (24 months)	2* (37 months)	87%
E 68, DN1 Brasov-Vladeni (Romania 5)	2	29 (42 months)	2 (17 months)	93%

**See text below for the explanation*

On the road transect Romania 1, 10 road kills were registered from July 2018 to July 2020: 3 wild boars, 2 roe deer, 4 bears and 1 wolf, while after the installation of the 3 Km of virtual fence only 1 fox and 1 bear cub. It's important to underline that the fox was road killed during the day when the VF was not active, while the bear cub was attracted on the road side by food left for stray dog on the road side.
On the road transect Romania 2, 29 road kills were registered from October 2017 to March 2022: 14 bears, 10 roe deer, 3 wild boars and 1 fox, while after the installation of the 2 Km of virtual fence only 2 foxes (tab. 26).
Considering only the number of bears road killed before and after the installation, the reduction of road kills was 84% on transect Romania 1 and 100% on transect Romania 2 (tab. 27). In the DN 11 road since the installation, no road kills were recorded.

Table 27: Number of bears road killed before and after the installation of VF in Romania.

VF installed	Length (Km)	Bears road killed Before the installation	Bears road killed After the installation	% AVC reduction
DN 1 Brasov-Comarnic (Romania 1)	3	4 (24 months)	1* (37 months)	84%
E 68, DN1 Brasov-Vladeni (Romania 5)	2	14 (42 months)	0 (17 months)	100%

2.4.6 Use of the adapted crossing structures

In the project area, 30 crossing structures were adapted to favour their use by wildlife species. 20 out of these 30 crossing structures were monitored through the installation of camera traps. The 20 crossing structures to be monitored were selected on the basis of the feasibility of the installation of the Relink cameras. Out of a total of 20 monitored crossing structures, 12 were located on the road segment DN 1 Brasov-Comarnic (Romania 1), 2 on the road segment DN1 A Cheia-Brasov (Romania 3), 3 on the road segment DN 13 Padurea-Bogatii (Romania 4) and 3 on the road segment E 68, DN1 Brasov-Vladeni (Romania 5) (tab. 28).

Table 28. Adapted crossing structures monitored with camera traps in Romania

Transect code	Road code	Adapted crossing structures monitored through camera trapping
Romania 1	DN 1 Brasov-Comarnic	12
Romania 3	DN1 A Cheia-Brasov	2
Romania 4	DN 13 Padurea-Bogatii	3
Romania 5	E 68, DN1 Brasov-Vladeni	3

The first monitoring sessions were carried out in the frame of Action A4, while since February2022 until August 2023 a systematic monitoring was carried out through the installation of Reolink cameras (fig. 14).

Figure 14: Installation of Reolink camera to monitor the adapted crossing structures in Romani.

The results of the monitoring sessions are summarized in table 29. Unfortunately, the data from 7 cameras could not have been retrieved because bear individuals broke three cameras, and four were stolen. In these cases, it was not possible to replace the camera. Therefore, we made a qualitative monitoring recording animal tracks.

Overall, we recorded the use of the adapted crossing structures by 437 mammals including 9 species (fig. 15, 16 and 17). The 123 bears were detected in all the adapted crossing structures, with 54% of the individuals detected on two crossing structures along the DN 1 Brasov-Comarnic (tab. 29). This result is very important because this road segment is the one with highest volume between the monitored ones, underlying the important conservation impact of this action. We excluded from the analysis the detection of dogs (1059), cows (233), birds (31) and people (150).
In all the crossing structures, where the monitoring with camera traps was not possible or had to be suspended, for the reasons previously mentioned, bear tracks were regularly detected in all of them.
As we specified in the final report, in Romania we started the work for the adaptation of crossing structures since July 2019, therefore we could not make a quantitative comparison of their use before and after the interventions. However, the results obtained show the effectiveness of the interventions carried out not only for the target species but for all species. Most of the crossing structures were almost inaccessible before the interventions.

Table 29. Number of animals detected on the adapted crossing structures in Romania from February 2022 to March 2023.

ID Crossing structure	Transect Road code	roe deer	beaver	red deer	pine marten	wolf	wild cat	bear	otter	fox
22	Romania 3					2	16	2		5
23	Romania 3						1	3		
2	Romania 1	23			2	1	0	31		52
4	Romania 1				8		5	3		16
3	Romania 1				10		0	13		62
1	Romania 4				3		0	2		5
3	Romania 4						0	2		
11	Romania 1	2			4		2	4	1	12
1	Romania 1		1		4		10	6	4	8
2	Romania 4	2		4			0	5		3
10	Romania 1	1					0	9		
8	Romania 1	3					1	36		39
7	Romania 1						0	7		2
TOTAL	**437**	**31**	**1**	**4**	**31**	**3**	**35**	**123**	**5**	**204**

Figure 15. Pine martens with cubs using the crossing structures nr 1 from the road sector Romania 4.

Figure 16. Wolf using the crossing structure nr 2 from the road sector Romania 1.

Figure 17. Bear female with cub using the crossing structure nr 7 from the road sector Romania.

2.4.7 Analysis of movements of radiocollared bears

In Romania, in the frame of action D1, was foreseen the capture of 5 bears in order to analyze their movements in relation to the concrete conservation actions implemented in the project area. Overall, we were able to capture 9 bears, 4 more than foreseen in the project proposal. The bears were captured with a tube trap, and then were anesthetized, in order to take the main physical parameters. 6 females and 3 males were trapped of age between 3 and 12 years (tab. 30).

Table 30. Bears radio collared in the project area in Romania.

ID Bear	Date of capture	Sex	Age	Municipality
1	13.03.2023	F	3	Brasov
2	24.05.2023	F	3	Bran
3	09.06.2023	F	12	Brasov
4	21.06.2023	M	8	Cheia
5	22.06.2023	M	5	Maneciu
6	24.06.2023	F	6	Brasov
7	24.06.2023	F	7	Predeal
8	24.06.2023	M	5	Maneciu
9	28.06.2023	F	3	Sacele

For each bear, we registered the road crossing points during the monitoring period, highlighting the road crossing points where the concrete conservation actions were carried out (AVC-PS, virtual fence, and adapted crossing structures). Road crossings were estimated considering two consecutive points on opposite sides of the road. We also estimated the percentage of radio locations near the road for each bear, considering a buffer of 100 meters on each side of the roads included in the home range. For each radio collared bear, the results are summarized in table 31, and its movements are shown in the following figures (fig. 18, 19, 20, 21, 22, 23, 24, 25 and 26).

Even if the analysis in still in progress, it is important to underline that this action is already providing very useful information in order to evaluate the interventions carried out as well as possible future interventions. Except for ID bear 1 and bear 7, all the other animals use to cross the selected road segments in the project area, and in the case of ID bear 2 it was recorded the use of one of the adapted crossing structures. The prosecution of the monitoring of radio collared bears will be implemented in the following months as is foreseen in the afterlife plan.

Table 31. Home range, % of radio locations near the road and number of times (value in brackets) the radio collared bears crossed the selected road segment in the project area.

ID Bear	Monitoring period	MCP (95%) Km^2	% of locations near the road	N. of crossing point on the selected road segment
1	March-August	7	75	_
2	May-August	320	80	Romania 1 (2 in AVC-PS and VF area)
3	June-August	44	90	Romania 1 (>10)
4	June-August	65	15	Romania 2 (14)
5	June-August	127	40	Romania 3 (>30)
6	June-August	15	55	Romania 3 (3)
7	24.06.2023	50	65	_
8	24.06.2023	10	95	Romania 3 (>50)
9	28.06.2023	20	95	Romania 1 (>30)

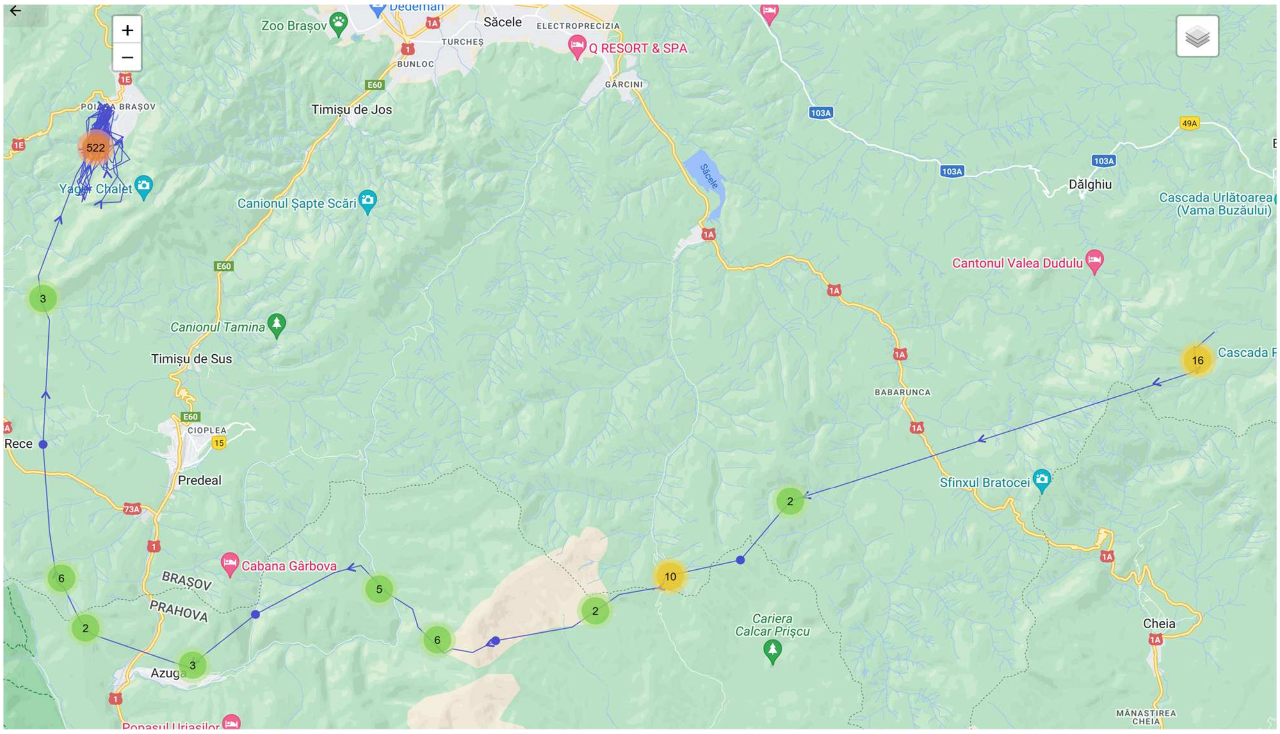


Figure 18. Radio location (in the circles) of bear ID 1.

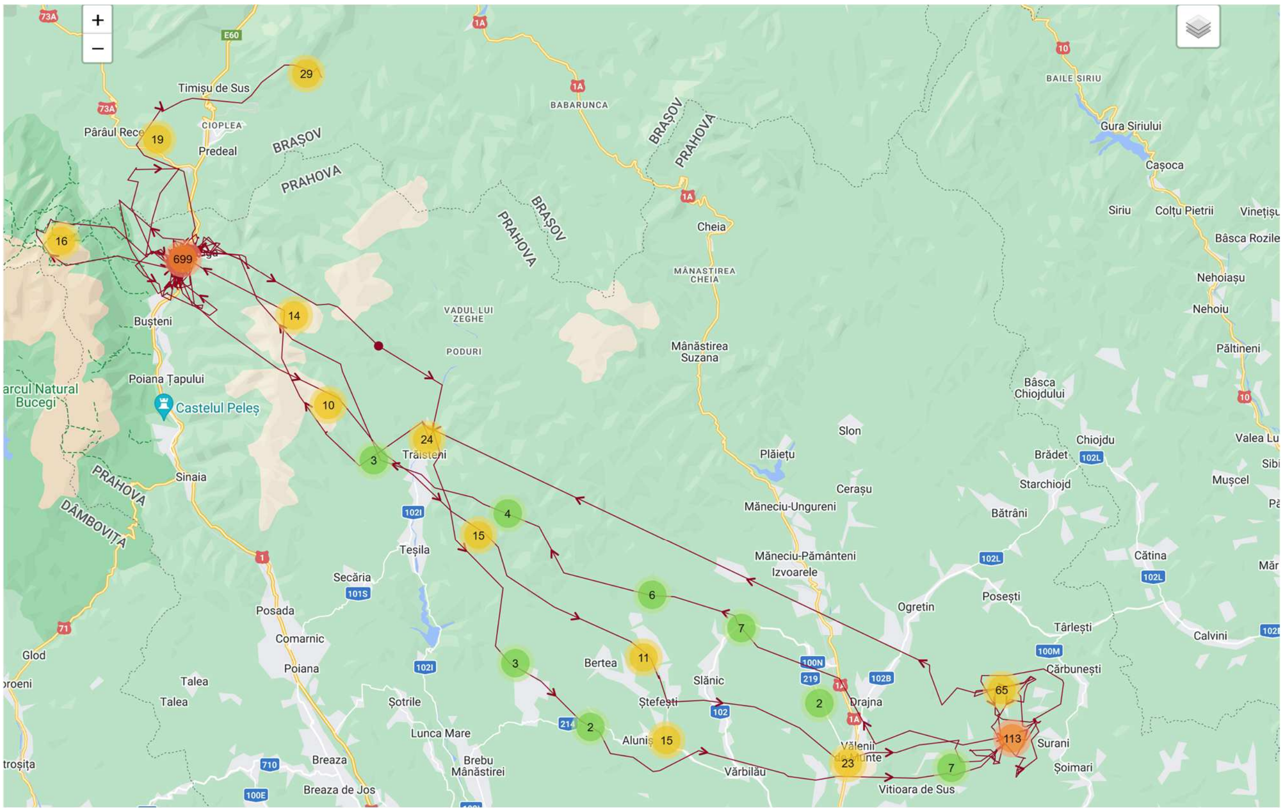


Figure 19. Radio location (in the circles) of bear ID 2.

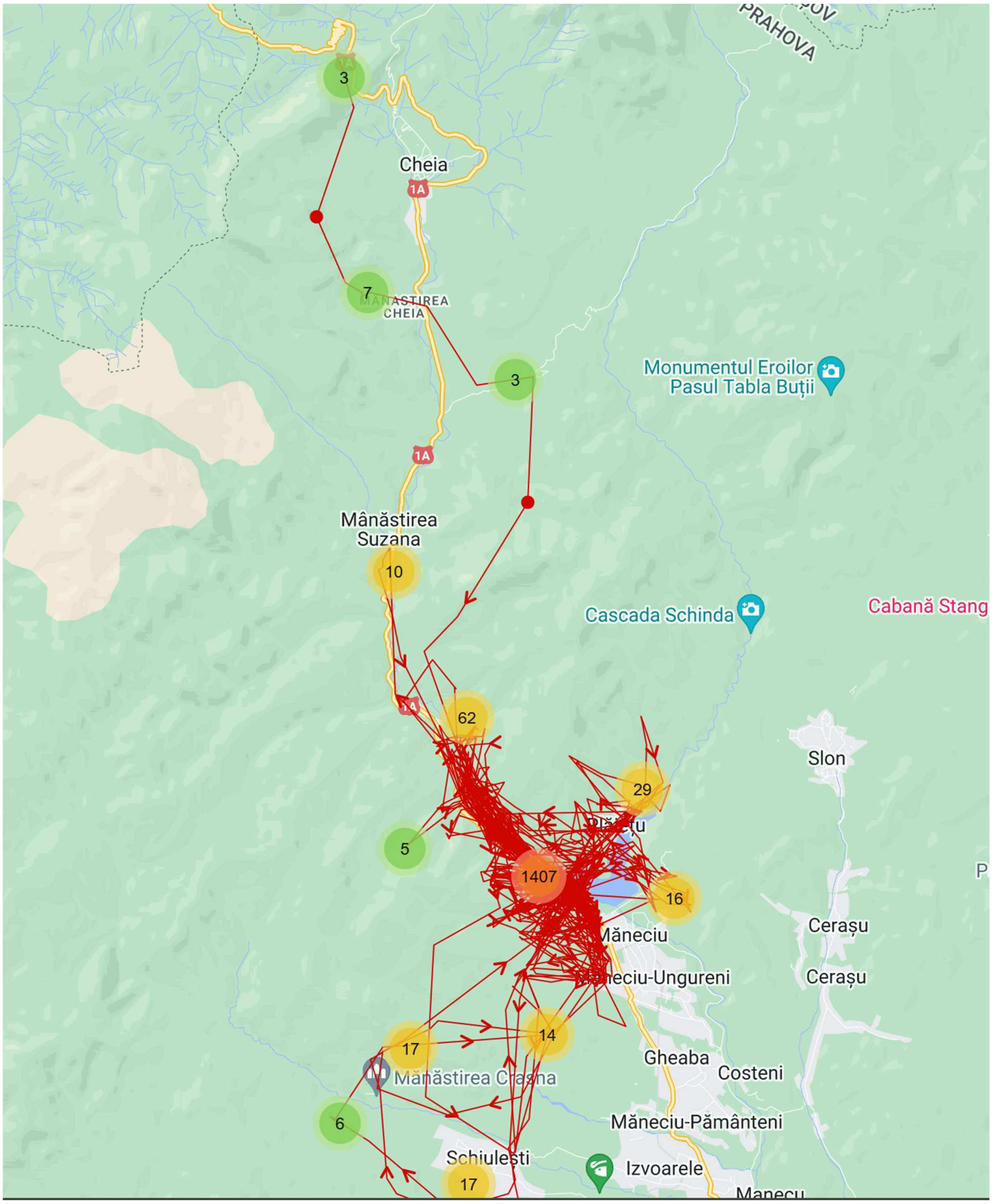


Figure 20. Radio location (in the circles) of bear ID 3.

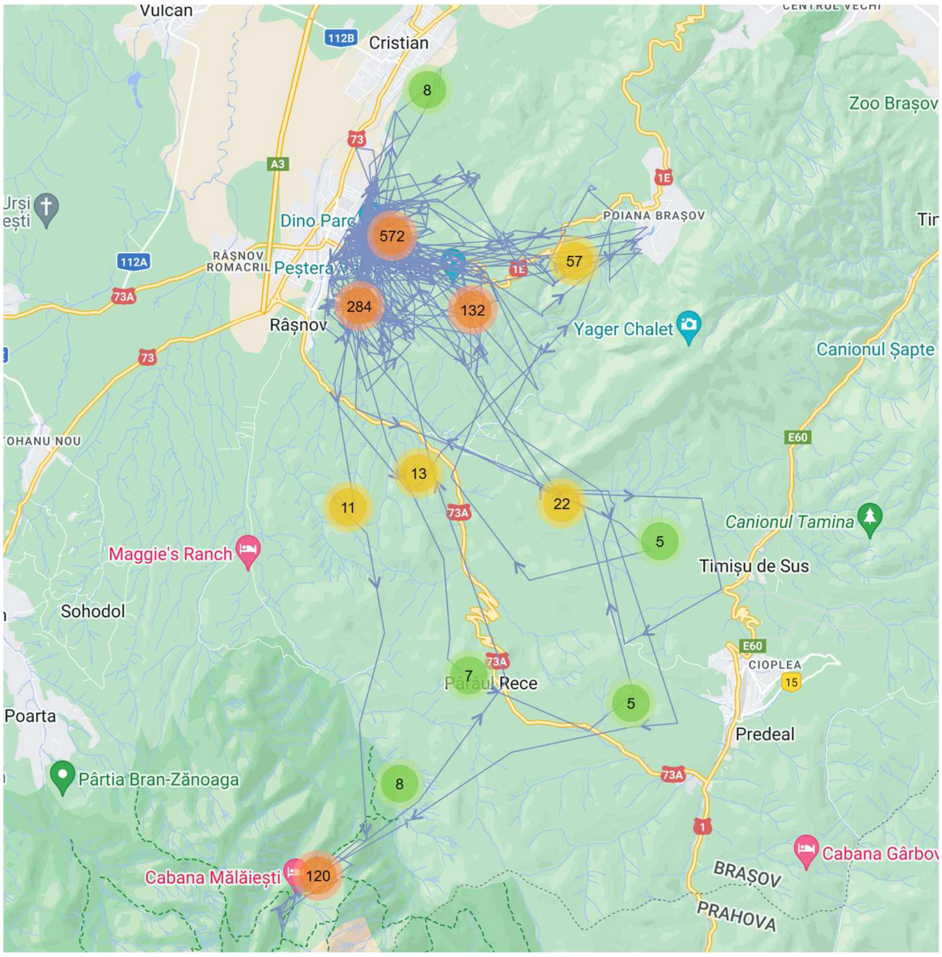


Figure 21. Radio location (in the circles) of bear ID 4

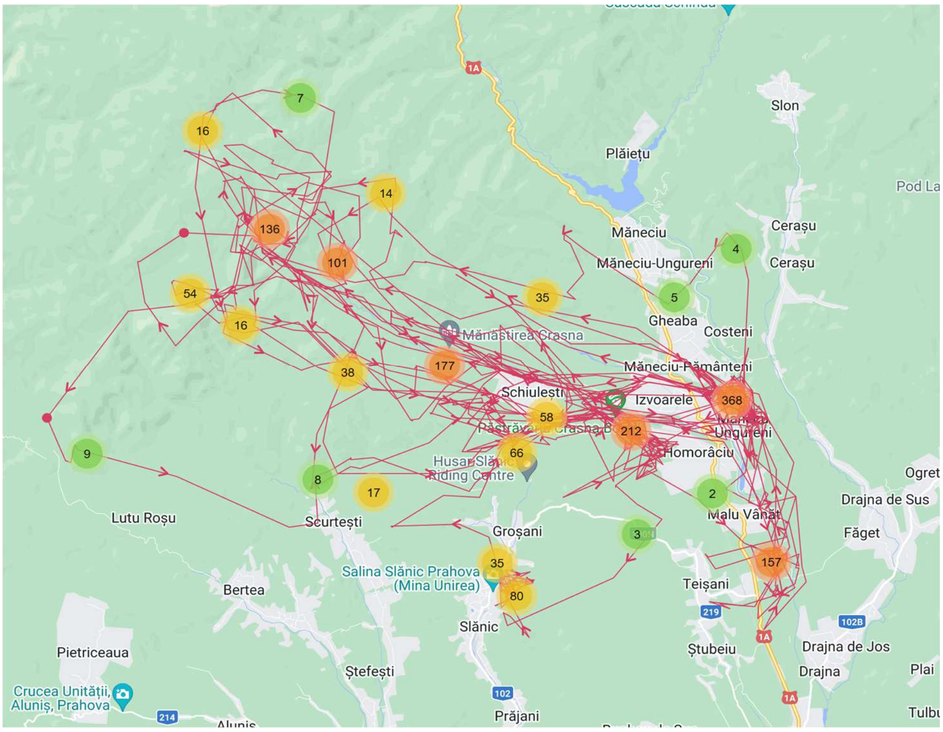


Figure 22. Radio location (in the circles) of bear ID 5.

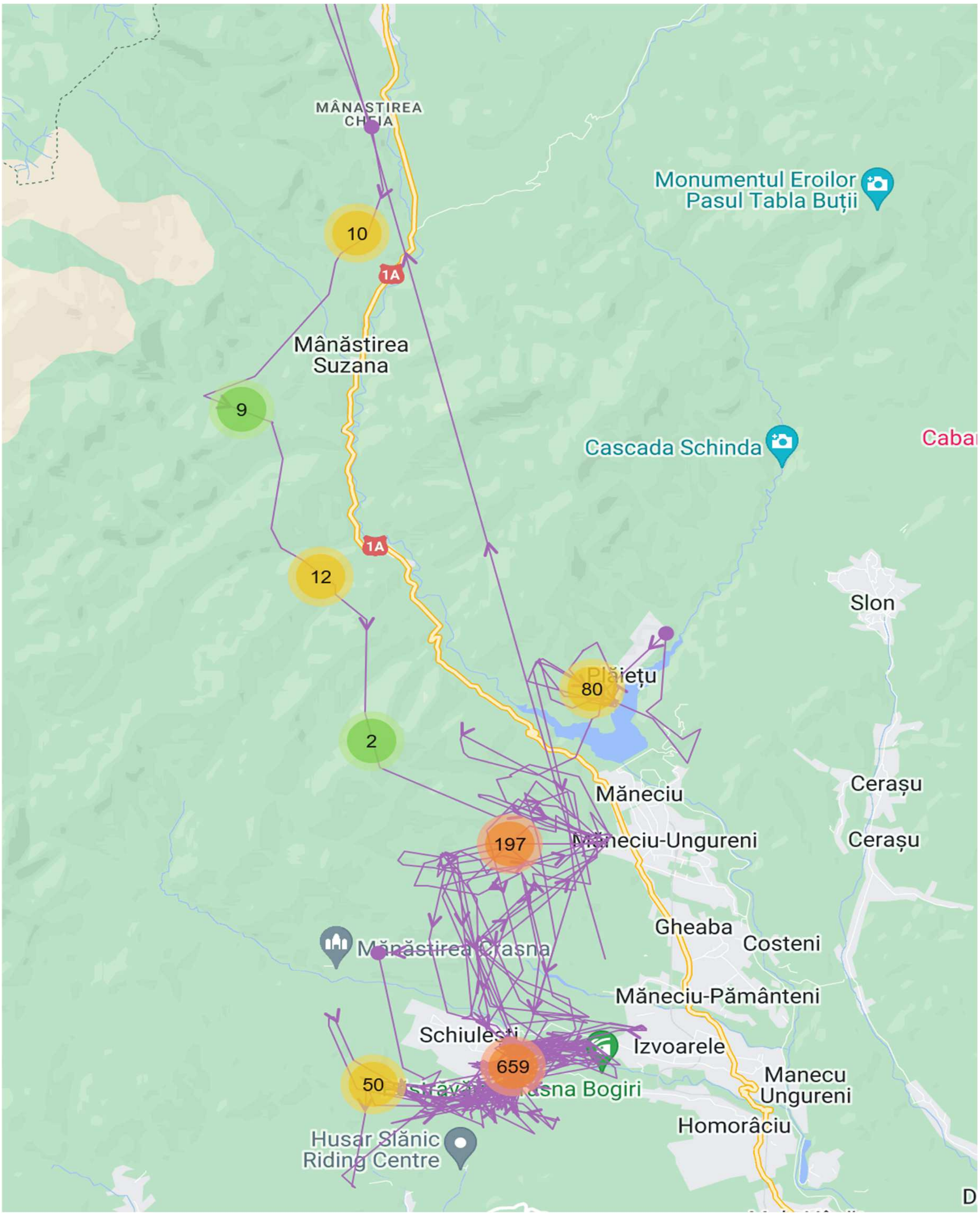


Figure 23. Radio location (in the circles) of bear ID 6.

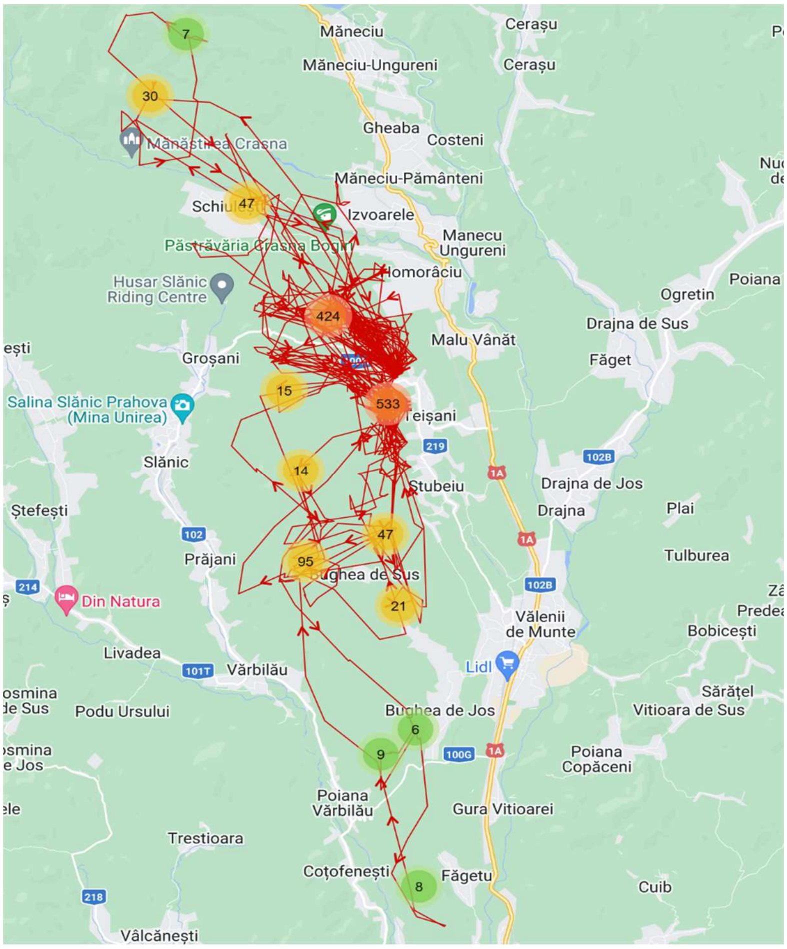


Figure 24. Radio location (in the circles) of bear ID 7.

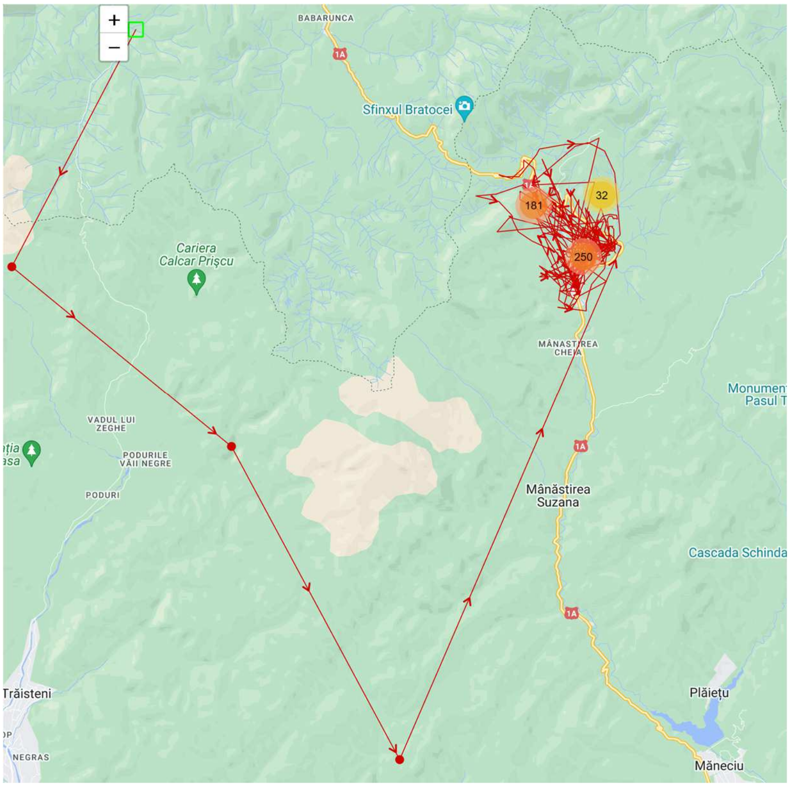


Figure 25. Radio location (in the circles) of bear ID 8.

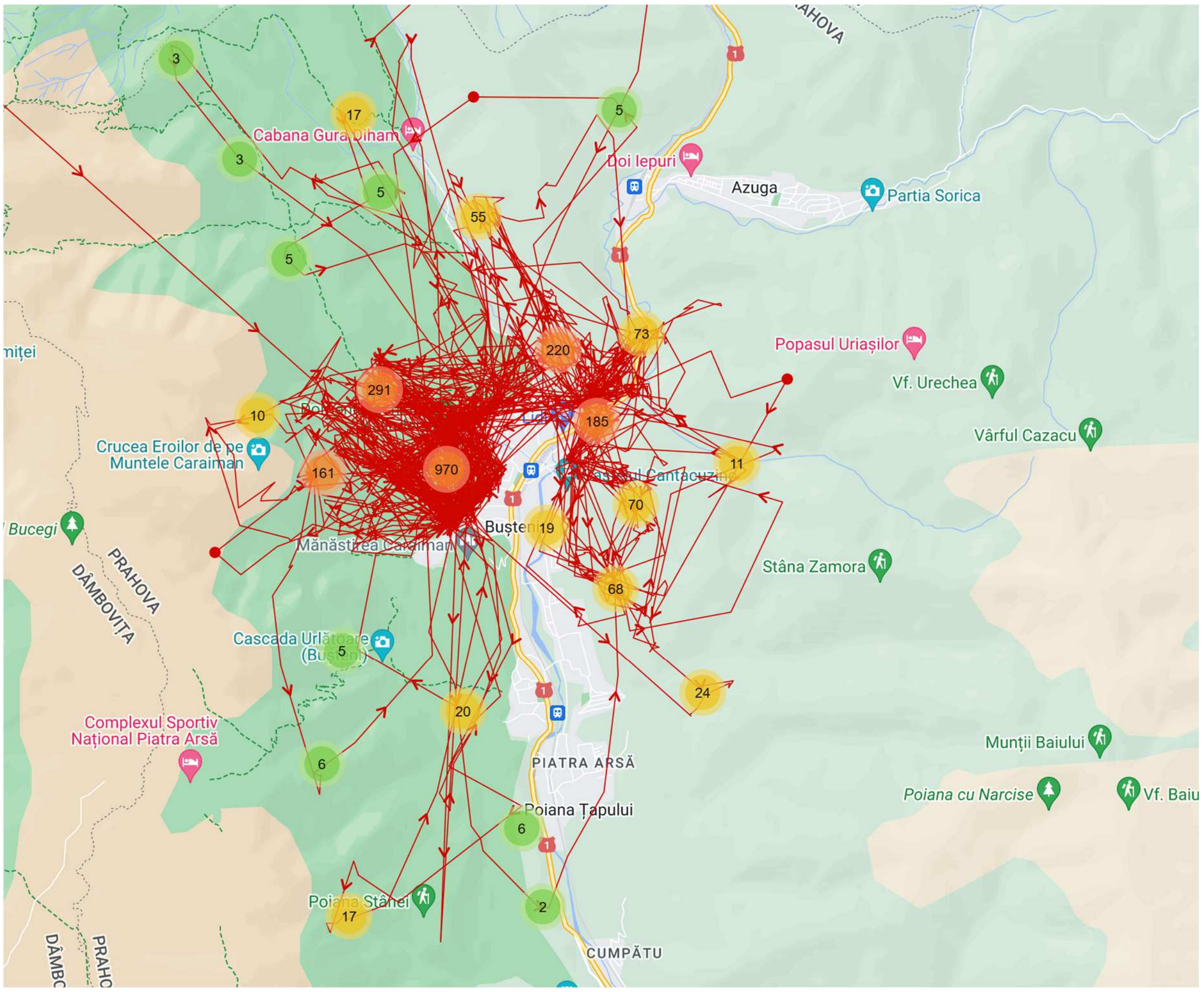


Figure 26. Radio location (in the circles) of bear ID 9.

2.4. Spain

In the project area the following concrete interventions were carried out:

- Installation of 5 AVC-PS;
- Installation of 4,5 Km of virtual fence;
- Interventions on 27 Km on road sides to increase to increase drivers' visibility;
- Installation of 24 road panels.

The road segments where we implemented the concrete conservation actions were the ones already monitored in the frame of Action A5: A481, SE-MA 01; CO-3102, plus the road segments A-301, and A 312 and the road segments where the intervention on the road sides was made by the Ministry of Public work under the supervision of the staff of the project (tab. 32).

Table 32. Distribution of the concrete conservation interventions on the selected road segments in Spain.

Road segment	AVC-PS	Virtual fence (Km)	Interventions on road sides	Road panels
A 301	1	_	_	6
A 312	_	4,5	_	4
A 481	2	_	3,25	6
CO-3102	2	_	3,6	4
SE-MA-01	_	_	7,4	4
N-420	_	_	_	12,3

The new road segments were added in relation to the evolution of the distribution of the Iberian lynx. Since 2015 population dynamics of the Iberian lynx has shown a clearly significant improvement. This change has led to the appearance of new areas of conflict from the point of view of habitat fragmentation and connectivity between populations, especially in the Sierra Morena area, which has experienced the greatest growth in area with Iberian lynx distribution in the last decade. For this reason, the road sections initially proposed for the installation of AVC-PS and virtual fencing have been modified and the A-312 and A-301 were respectively selected for the installation of virtual fence, AVC-PS and road panels.

2.4.1 Road mortality monitoring sessions

In the frame of Action D1 the selected road segments were continuously monitored to record animals found dead on the road. Since October 2020 the road mortality monitoring sessions were carried the same protocol applied in the Action A5.

In Spain from October 2020 to August 2023 we carried out 32 monitoring sessions on 7 road segments. Respect to what has been done in Action A5, in Sierra Morena, we added the road segment A-301 where we installed one AVC-PS (Spain 1), and the road segment A-312 where we installed the VF. The monitoring of the road CO-3103 and CO-3105 done in the frame of Action A5 was interrupted. The road segment A-3001 was monitored only once and then also in this case the monitory activity was suspended (tab. 33). These changes were made in order to include in Sierra Morena the road segments more important in relation to the evolution of the Iberian Lynx distribution including the segment with greater importance not only to reduce the road kills but also in terms of ecological connectivity.

Table 33. List of monitored segments in the frame of Action D1 in Spain

Road segment	Length of the road segments (Km)	Number of monitoring sessions (October 2020-August 2023)	Number of animals found dead
SE-MA-01	7,3	17	1
A-3001	20	1	0
A-301	13	13	9
A-312	27	15	5
A-421	25	10	4
A-481	14,2	21	10
CO-3102	10	11	3

Since October 2020 8 traffic volume and speed monitoring sessions were carried out on the roads A-481 (n = 4), CO 3102 (n = 1), A-312 (n = 2) and A-301 (n = 1), where the AVC-PS and virtual fence have been installed.

2.4.2 AVC-PS

The installation of the 5 AVC-PS started in April 2023. All the systems were equipped with PIR sensors, since these devices are the best solutions to detect the animals approaching the road in the selected areas. A double system was installed on the road CO-3102 where the road stretch was too long to be covered by one single system. The data collected by the 5 AVC-PS are summarized in table 33.

Table 33. Number of activations of the AVC-PS installed in Spain.

AVC-PS code	Monitoring period 2023	Detection of wildlife near the road	Detection of vehicles ≥50 Km/h within 3 minutes after the detection of wildlife
Spain 1	July-August	466	318
Spain 3	May-August	854	496
Spain 4	June-July	186	147

In the AVC-PS Spain 2, we encountered several problems with the SIM card therefore we were not able to collect the data of the activations of the system. Nevertheless, the AVC-PS was properly working as was assessed during the field survey.

In Spain 1, the system started to function in May, but there was a problem in the software of the central unit that didn’t allow to correctly store the data since the beginning.

In Spain 4, the double system, we didn’t include the month of August because there were too many activations of one PIR sensor that would have biased the results.

In general, in the data analysis we excluded those hours when the activations of PIR sensors could be related to the passages of vehicles, because in all the systems, some PIR sensors were also installed on dirty roads, used also by people living in the area, but regularly used by Iberian lynx.

In Spain 3, camera traps were installed near the PIR sensors (fig. 27), but after the theft of one of camera, we decided to take them off. The use of camera would allow to exclude those activations not related to animal passage.

Nevertheless, even if the data collected could include some biased activations, they clearly show that the area where we installed the AVC-PS were regularly frequented by wildlife and the number of risky situations were very high. This result shows the effectiveness of the AVC-PS because no road killed were recorded since their installation.

Figure 27. Iberian Lynx filmed in the area of the AVC-PS Spain3 passing in front of a PIR sensor (the white device installed on the metal pole).

2.4.3 Number of road kills before and after the installation of AVC-PS

Even if the monitoring period after the installation of the systems was limited, it's interesting to analyze the data about number of Iberian lynx road kills before and after the installation of the AVC-PS (tab. 34).

Table 34. Number of Iberian lynx road killed in the area where AVC-PS were installed in Spain.

AVC-PS code	Length (m)	AVC before the installation	AVC after the installation	% reduction
Spain 1	560	3 (02/2021-04/2023)	0 (4 months)	100%
Spain 2	581	4 (06/2013-04/2023)	0 (4 months)	100%
Spain 3	590	4 (06/2013-05/2023)	0 (4 months)	100%
Spain 4	650	4 (08/2017-05/2023)	0 (4months)	100%

Even thought we had some problems to collect the data about the activations of the systems, all of them were properly working and since their installation no AVC was recorded, despite the high number of risky situations. Monitoring of the system will continue after the end of the project therefore there will be the possibility to assess the effectiveness of the system in the long term.

In Spain the percentage of vehicles reducing their speed (≥10 Km/h), when the flashing light panels were triggered, resulted to be very high (78-81%) (tab. 35). This parameter could be evaluated only on 2 AVC-PS and not for the whole monitoring period. Therefore, it has to be evaluated in the long term to assess its reliability, but in any case it seems to be very promising.

Table 34. Percentage of vehicles slowing down when the flashing light panels of the AVC-PS were active.

AVC-PS code	Monitoring period 2023	Number of vehicles detected ≥50 Km/h	Number of vehicles Slowing down	% of vehicles reducing the speed (≥10 Km/h)
Spain 1	July-August	306	247	81%
Spain 3	May-August	202	157	78%

2.4.4 Virtual fence

4,5 Km of virtual fence was installed on September 2022 on the road A 312. A total of 160 units of VF were used to cover this road stretch. The functioning of the VF was regularly monitored, and no particular problem were encountered. Only a device was stolen, but it was promptly replaced. The degree of functionality of the units during the night controls was satisfactory and the headlight of the approaching vehicles regularly triggered almost every unit. 6 camera traps were installed in the area to evaluate the reactions of animals to the triggering of the devices.

2.4.5 Number of road kills before and after the installation of VF

The reduction of Iberian lynx road killed, on the road stretch where the devices of VF were installed, was 100% (tab. 35). In the period before the installation the number of Iberian lynx road killed was 1,38/year while after the installation was 0. Clearly due to the short monitoring period this result must be evaluated in the long term, but anyway it is very promising.

Table 35. Number of Iberian lynx road killed before and after the installation of VF on A-312 road, Spain.

VF installed	Length (Km)	Iberian lynx road killed Before the installation	Iberian lynx road killed After the installation	% reduction
A-312	4,5	6 (52 months) (04/2018-08/2022)	0 (12 months) (09-2022-08/2023)	100%

In this case, the comparison was limited to the Iberian lynx because we did not have data for the other wildlife species before the start of the project.
In order to try to obtain more detailed information about the reactions of animals to the triggering of the devices, as we said before, 10 cameras trapping monitoring session were carried out installing 5-6 camera traps. A total of 112 crossing events were recorded: 94 took place at night and 18 during the day. Nine species of carnivores, were detected, 6 wild including Iberian lynx and 2 domestic species (fig. 28 and 29). In 71 cases the VF was active and thus we were able to register the reaction of animals. In 70% (n = 50) of the cases the animals changed their behaviour when the VF was active, while in the remaining 30% (n = 21) they seemed to ignore the triggering of the device.
Considering only the reaction of Iberian lynx in 38 cases we were able to assess the reaction of the species to the triggering of the VF. In 60% (n = 23) of the cases, the Iberian lynx altered its behaviour in response to activation of the device, while in 30% (n = 15) no change was recorded. The species that showed a most “cautious” behaviour when the VF was active has been the badger.
These results, even thought preliminary, are very interesting because not a lot of data of this kind are actually available, and they could also be useful for future improvements of the VF.
The monitoring of the VF trough camera traps will continue after the end of the project.

Figure 28. Iberian Lynx filmed by camera trap on A-312 during the monitoring of VF.

Figure 29. Badger filmed by camera trap on A-312 during the monitoring of VF.

2.4.6 Interventions on road sides

The interventions on road sides to increase the visibility of drivers were carried out on the road segment SE-MA01 (Km = 7,4 on October-December 2021), A 481 (Km 3,2 on October-December 2022) and CO-312 (Km 3,6 on October 2021), plus on the road N 420 (Km 12,3 on 201 and 2022) where the works were carried out by the Ministry of Public Work in coordination with the staff of the project.

Figure 30. Interventions on road sides in Spain.

The number of Iberian lynx road killed before and after the interventions has been compared in order to evaluate the effectiveness of the interventions (tab. 36).
In all the 3 road segments no road kills were recorded after the interventions, but the sample size, except for A-481 is limited, therefore this result must be interpreted with caution, anyway it seems to indicate the effectiveness of this action.

Table 36. Number of Iberian lynx road killed before and after the interventions on the road sides in Spain.

Road segment	Iberian lynx road killed Before the intervention	Iberian lynx road killed After the intervention	% of reduction
SE-MA01	1 (721 days)	0 (645 days)	100
A-481	8 (1163 days)	0 (299 days)	100
CO-3102	1 (448 days)	0 (711 days)	100

2.5 Greece

In the project area the following concrete interventions were carried out:

- Installation of 6 AVC-PS;
- Adaptation of 55 crossing structures;
- Installation of 38 road panels.

The monitoring of the effectiveness of the AVC-PS is still in progress because the systems were installed in August 2023.

2.5.1 Evaluation of the use of the adapted crossing structures

This action aimed at assessing the effectiveness of the activities carried out in the frame of action C2 and namely the structural and functional improvement of the selected wildlife underpasses along motorway A29 performed. For this ex-post monitoring purposes, the end-to-end wildlife monitoring system developed by COSMOTE from scratch (composed of wireless 4G cameras and an ICT cloud backend solution for cameras' material storage, visualization, categorization and statistics extraction), was deployed by the project partners (COSMOTE, Callisto) at selected crossing structures in order to monitor their use by brown bears and other wildlife after their improvement by EOSA.
The specific objectives of Action D1 included:

- Evaluation of the effectiveness of the improvement works at the selected crossing structures utilizing COSMOTE's end-to-end wildlife monitoring system for monitoring their use by brown bears and other wildlife.
- Organization of field visits for data retrieval for cameras where cellular/4G coverage was not available.
- Processing and analysis of the overall obtained data (by COSMOTE, EOSA and CALLISTO project partners) and reporting.

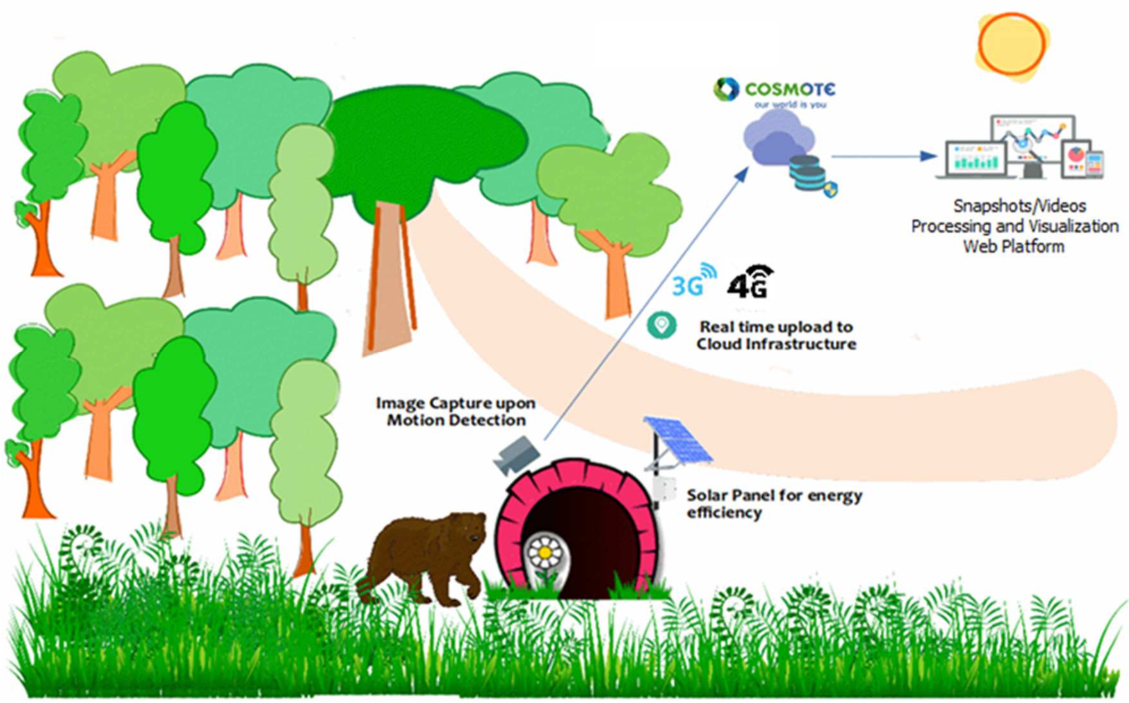
COSMOTE

The end-to-end wildlife monitoring solution developed by COSMOTE for the selected underpasses monitoring with wireless/IR cameras was again used for the ex-post evaluation composed of the following parts and devices (see sketch 1):

- 4G (wireless) battery-powered, ultra-low consumption cameras equipped with small but very efficient solar panels for long operation[3]. A SIM card is also required for: (a) the (automated) uploading of snapshots/videos to a cloud infrastructure, (b) remote access to cameras for e.g., configuration purposes, playback, (c) alerting, etc.

[3] A camera may operate for more than a month without being charged from the solar panel.

- Cloud infrastructure (i.e., servers, VMs, routers/switches) utilized for the:
- Automated storage of the cameras' content (snapshots, videos) to specific folders
- Automated processing of the cameras' content (using Artificial Intelligence /Deep Learning Techniques for objects/species detection and classification)
- Automated statistics/graphs extraction through scripting (python, shell/bash, etc.)
- Near real-time alerting via push notifications to smartphones/tablets when e.g., a bear detected at an underpass
- Hosting of a Web portal for snapshots visualization, underpasses information, statistics presentation, etc. (using node.js, javascript, html/css, python, mysql, grafana, etc.).



Sketch 1. The overall, end-to-end, solution architecture developed by COSMOTE.

2.5.2 Objects/Species Detection/Classification Tool

Quite early in the project we realized that a huge overhead would be required for the manual classification (into species, objects) of the vast number of "wildlife" snapshots to be collected by the 45 cameras. Note that in less than a year, more than 60.000 images and 60.000 videos were collected and processed.

To be capable of extracting valuable information regarding the use of the underpasses by the wildlife (e.g., frequency of use per underpass and by which species), the collected "images" should be classified into wildlife related (e.g., bears, foxes, dogs, livestock, reptiles, mammals, wolves, etc.) and/or other "objects" - irrelevant to wildlife- e.g., humans, vehicles, tractors, "false alarms".

On top of that, these "images" must be "assigned" to the specific passage the specific species passed through. This process, i.e., the statistics' extraction, necessitates a huge overhead as well.

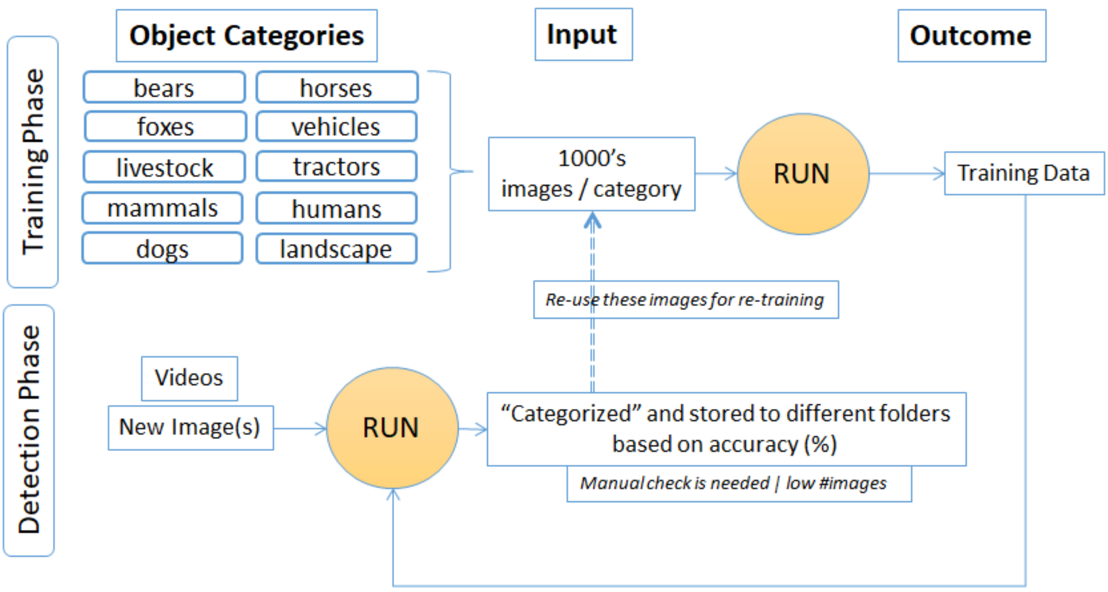
This tool, utilizing Artificial Intelligence / Machine Learning / Deep Learning techniques, it:

- Processes, in an automated way, the snapshots collected by the installed cameras
- Detects the "object" (bear, fox, person, car, tractor, other) with high accuracy and
- Saves the snapshot to the relevant/specific folder (e.g., bears, foxes), thus minimizing the manual (classification) effort.

The tool operates as follows (see flowchart 1):

1. Phase A: Dataset (images) Collection. During this phase, 100's of images (the so-called dataset) of a specific species/objects of interest are being collected and stored under specific folders in order to feed the "model" (see Phase B), that is the learning algorithm.
2. Phase B: Training phase. During this phase we're training the (selected) algorithm to evaluate and remember an image, by creating a model that can then be applied to other (new) images (transferring i.e., the characteristics from one image to another algorithmically).
3. Phase C: Model's Effectiveness Evaluation. During this phase, the model's effectiveness is assessed using sample (new) images. If its accuracy is satisfactory, we proceed to the next phase.

4. Phase D: Running the Model. During this phase we utilize the model for making predictions (object detection and classification). The model is fed by the snapshots/videos collected by the cameras which are then stored to specific folders based on the species/objects detected.
5. Phase E: Improving the Model's Accuracy. During this phase we re-train the model (see Phase A->B->C->D) by adding additional images to the dataset (Phase A).



Flowchart 1. Configuration of the algorithm classification tool. (by COSMOTE)

There are though a list of factors that are hindering the classification of the wildlife:

- The majority of the species snapshots are "night shots", that is the snapshots/images collected by the cameras are of low quality, blurred (not crispy), etc.
- More than one species –need to be identified- may be present at a certain snapshot (e.g., sheep and dogs, sheep and humans, humans and dogs)
- There are only a few samples of some species e.g., deer, wildcats, cats available and as such the available dataset is not "adequate" to feed the model properly. As a result, such species cannot be detected/classified.
- There are also other "difficulties" in species' detection/classification e.g., when species are partly presented; there are behind vegetation.

CALLISTO (wireless/IR cameras installation, data collection and processing)

The following tasks have been implemented by Callisto's team:

- Wireless/IR cameras installation at (37) pre-selected underpasses performed by a (2) membered field team.
- IR cameras status monitoring 24/7 which was performed by the field team using the specific mobile application https://play.google.com/store/apps/details?id=com.mcu.reolink&hl=en_US&gl=US.
- IR cameras data download and storage (automated for 30 cameras and manually for (7) cameras) over a nine months period (from June 2022 to February 2023 (performed by field team).
- Cameras data entry and final screening for re-entry, performed by all field team members with the assistance of internship/volunteer students.
- Final data processing statistical analyses with emphasis on the target species *Ursus arctos*.

EOSA

- Evaluation and processing of ex-post monitoring data from the (37) monitored crossing structures provided by COSMOTE.
- Data processing following input from COSMOTE and CALLISTO project partners
- In situ visits at specific crossing structures

2.5.3 Final results of the monitoring of the crossing structures

Overall, during the ex-post monitoring phase of the (36) crossing structures using cameras, the results of the monitoring of the selected improved crossing structures used by brown bear and other wildlife species according to the stored data records from the cameras developed by COSMOTE and installed by Callisto are presented in table 38. These results are camera data that have been selected from the overall extensive data sample for the following representative species: carnivores (of which brown bear is the target species see figures 31, 32 and 33), ungulates, and smaller mammals. In particular, the selected species and taxa are: Brown Bear, Wolf, Wild Boar, Roe Deer, Fox and Mustelids.

Figures 31, 32 and 33: Three different events with brown bears at three different periods at the same camera/crossing structure.

Table 38. Results of the cameras' monitoring at improved crossing structures used by the wildlife in A29 Motorway. Monitoring data before the improvements (ex-ante) have been collected over ~r a 12 months period (July 2019 – June 2020) while the data after the improvements (ex-post) have been collected over a nine months period (July 2022 – February 2023) (EOSA).

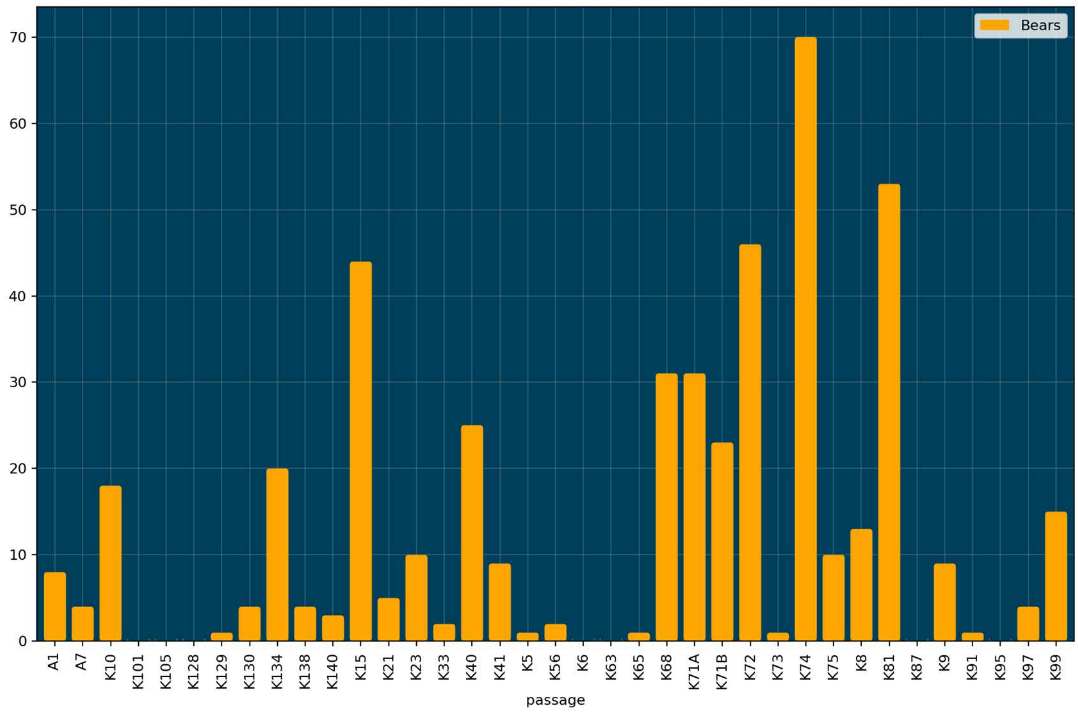
# (All)	# (After)	Passage	Type	O.I.	Bear Before	Bear After	Wolf Before	Wolf After	Wild Boar Before	Wild Boar After	Roe Deer Before	Roe Deer After	Fox Before	Fox After	Mustelids Before	Mustelids After	Sum Before	Sum After
1		K140	UNP	0,25	105		41		0		0		33		5		184	0
2		K140B	UNP	0,25	14		7		0		0		17		1		39	0
3	1	K138	CUV	0,12	9	4	0	0	0	0	0	0	13	16	42	16	64	36
4	2	K134	BRIDGE	2,4	20	20	0	2	0	0	0	0	5	31	22	1	47	54
5		K130	CUV	0,14	4		2		0		0		100		10		116	0
6	3	K129	CUV	0,13		1		1		0		0		34		7		
7	4	K128	CUV	0,07	2	0	0	0	0	0	0	0	52	0	1	0	55	0
8		K118	CUV	0,07	3		0		0		0		3		0		6	0
9		K115	CUV	0,07	0		0		0		0		2		0		2	0
10		K110	CUV	0,1	1		1		0		0		7		0		9	0
11	5	K105	CUV	0,1		0		0		0		0		6		0		
12	6	K101	CUV	0,12	0	0	0	0	2	0	0	0	9	58	2	3	13	61
13	7	K99	CUV	0,03	3	15	2	0	0	0	0	0	93	101	15	5	113	121
14	8	K97	CUV	0,12	3	4	2	14	0	0	0	0	44	241	1	28	50	287
15	9	K95	CUV	0,4	0	0	0	7	0	0	0	0	0	41	0	0	0	48
16	10	K91	CUV	0,09	0	1	4	0	0	3	0	0	58	4	3	5	65	13
17	11	K87	CUV	0,01	0	0	3	1	0	0	0	0	21	8	2	1	26	10
18	12	A7	CUV	0,08	0	4	3	3	0	0	0	0	3	2	0	0	6	9
19		A4	UNP	0,09	0		0		0		0		0		0		0	0
20		A2	CUV	0,02	0		0		0		0		0		0		0	0
21	13	A1	CUV	0,02		8		0		0		0		0		0		
22	14	A13	CUV	0,1	2	3	0	0	0	0	0	0	0	0	0	0	2	3
23	15	K81	UNP	0,22	2	53	6	10	0	0	0	0	57	163	4	14	69	240
24	16	K75	CUV	0,08	2	10	1	0	0	0	0	0	39	40	5	2	47	52
25	17	K74	VIA	10,5	51	70	0	0	1	0	0	0	5	3	1	0	58	73
26	18	K73	CUV	0,12		1		0		0				3		0		4
27	19	K72	CUV	0,08	7	46	1	7	0	0	0	0	35	24	5	33	48	110
28	20	K71A	CUV	0,19	19	31	23	7	0	0	0	0	109	34	14	4	165	76
29	21	K71B	CUV	0,19	2	23	4	2	0	0	0	0	0	30	0	9	6	64
30		K69	UNP	0,55	133		60		0		0		152		34		379	0
31		K69B	UNP	0,55	20		15		0		0		5		0		40	0
32	22	K68	CUV	0,07	11	31	1	1	11	5	0	0	61	67	50	70	134	174
33		K67	CUV	0,06	0		0		0		0		1		3		4	0
34	23	K65	CUV	0,14	5	1	1	0	0	0	0	0	12	0	0	0	18	1
35	24	K63	CUV	0,03	12	0	0	0	5	1	14	0	27	4	6	6	64	11
36		K59	CUV	0,07	93		1		1		4		61		158		318	0
37	25	K56	CUV	NA	2	2	6	0	3	0	0	0	11	3	1	0	23	5
38		K45	CUV	0,1	2		0		1		0		60		1		64	0
39	26	K41	CUV	0,08	4	9	1	0	0	0	0	0	30	38	14	5	49	52
40	27	K40	CUV	NA		25		0		0		0		0		0		25
41	28	K33	CUV	0,04	1	2	0	0	0	0	0	0	110	35	9	26	120	63
42	29	K23	CUV	0,11	11	10	1	0	36	3	0	0	236	76	247	23	531	112
43	30	K21	CUV	0,56	10	5	25	44	4	1	0	0	20	16	2	0	61	66
44	31	K15	CUV	0,04	2	44	0	4	6	0	0	0	161	87	7	35	176	170
45	32	K10	CUV	0,08	9	18	6	1	0	0	0	0	43	11	16	4	74	34
46	33	K9	CUV	0,06	0	9	1	0	0	0	0	0	20	5	9	1	30	15
47	34	K8	UNP	0,4	0	13	23	2	0	0	0	0	26	24	1	1	50	40

# (All)	# (After)	Passage	Type	O.I.	Bear Before	Bear After	Wolf Before	Wolf After	Wild Boar Before	Wild Boar After	Roe Deer Before	Roe Deer After	Fox Before	Fox After	Mustelids Before	Mustelids After	Sum Before	Sum After
48	35	K6	CUV	0,09	0	0	14	3	0	0	0	0	24	9	3	0	41	12
49	36	K5	CUV	0,22	0	1	0	0	0	0	0	0	28	44	3	1	31	46
Comparable Sum of crossings with improvements:					189	464	128	109	68	13	14	0	1352	1258	485	300	2236	2.087
All crosings before improvements:					564		255		70		18		1793		697		3.397	2.144
Crossings with increased use after improvements:						23		8		1		0		15		10		
Crossings with the same use after improvements:						7		14		27		35		3		10		
Crossings with decreased use after improvements:						6		14		8		1		18		16		
				Sum:		36		36		36		36		36		36		
Used crossings:					22	29	20	14	8	5	1	0	28	31	27	23		
Use of the 5 new crossings:						4 (35)		1(1)		0		0		3 (43)		1 (7)		

Table legend:

- Lines in grey are the crossings monitored after the improvements.
- Boxes in blue are data of the crossings without data before the improvements.
- Boxes in green are crossings with increased use by the species.
- Boxes in orange are crossings with the same use by the species.
- Boxes in red are crossings with decreased use by the species.
- CUV: Culvert
- UNP: Under pass
- The order of the structure is from the North to the South

Overall data processing from the expost monitoring session was also performed by COSMOTE project partner with the use of the automated applications incorporated in the end- to- end cameras system. The most indicative results focusing on the target species (brown bear) are presented in the following figures (34, 35, 36).



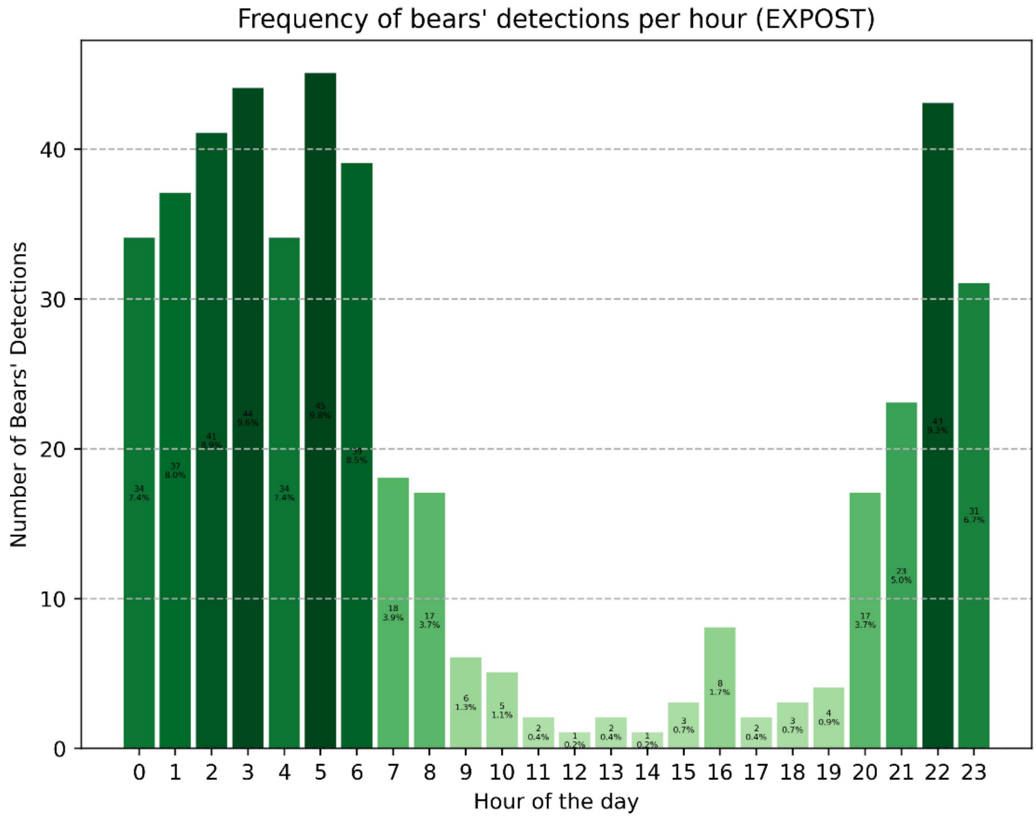


Figure 34:

Frequency of brown bear use of all (37) monitored crossing structures

Frequency of bears' detections per passage (EXPOST)

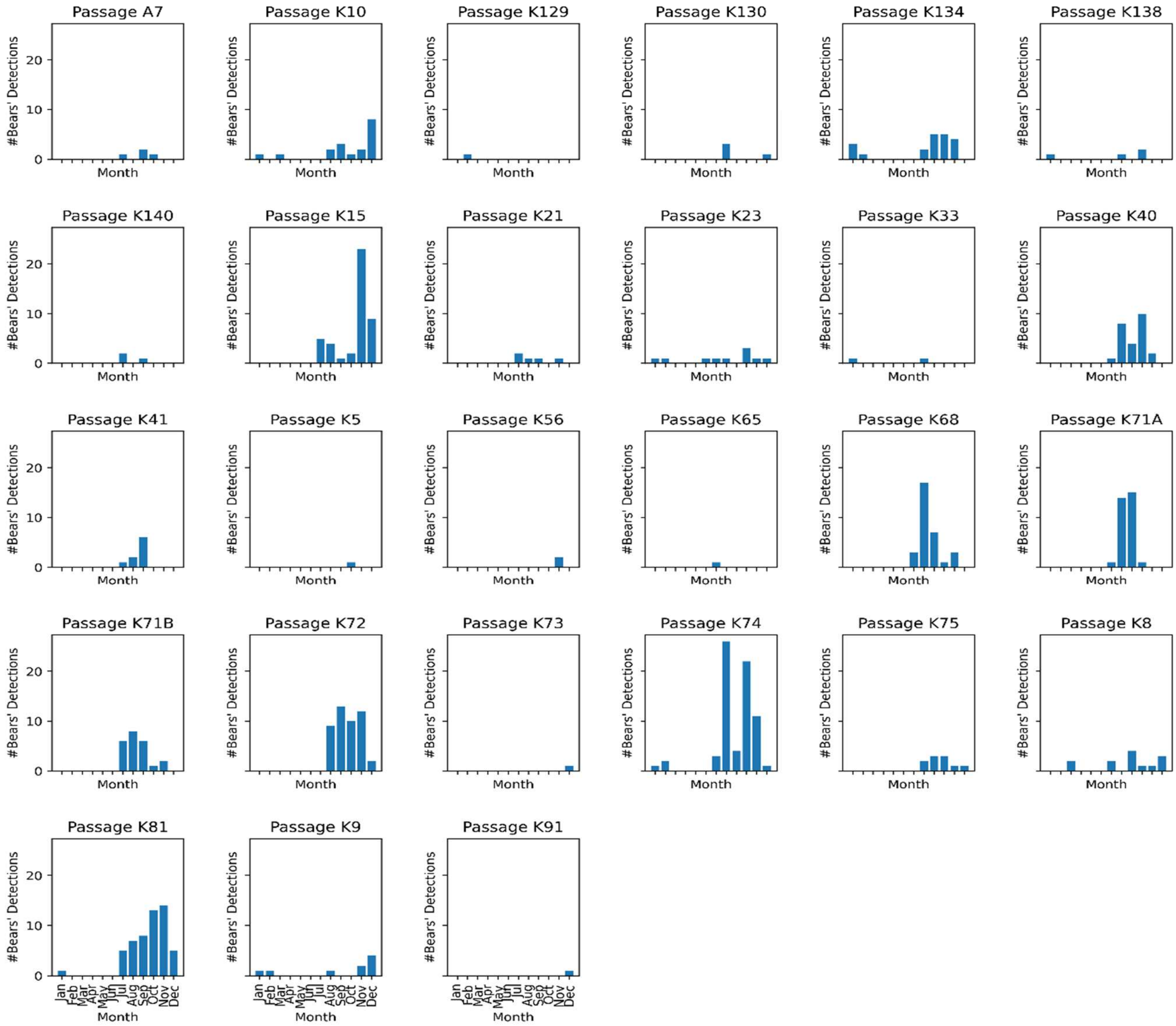


Figure 36. Number of bears' detections per underpass on a monthly basis

Towards shaping the correct and comparable overview of the status of permeability of the crossing structures by the target species (brown bear) and other wildlife species, two basic factors must be taken under consideration presented also in table (34):

A. The total number of structures which have been monitored before the improvements was 49 (column "# all" – Table 1), while after the improvements (ex-post phase) 36 structures were monitored. The reason for this difference is the fact that the remaining 13 crossing structures features were judged of adequate attractiveness for brown bear and other wildlife as it was evidenced by the cameras during the ex-ante event. In fact in the ex-ante monitoring phase these (13) crossing structures showed regular and heavy use by the target species as well as by other wildlife species. Therefore, the comparison between the ex-ante and ex-post monitoring periods has been performed and is valuable only for these (36) structures that yielded data both before (exante period) and after the improvements (expost period) and for the same (time overlapping) duration of 8 months. Additionally, 5 more crossing structures were selected for improvements as they presented specific interest in terms of connectivity in the study area showing evidence that wildlife had tried to use them unsuccessfully before the improvements.
B. The fact that the camera data before the improvements cover a period of 12 months from July 2019 until June 2020, while camera data after the improvements cover a period of eight (8) months from July 2022 until February 2023 for the technical reasons explained above. The missing data from spring 2023 is the only gap between the two monitoring sessions, considering at the same time, that winter is an inactive season for the Brown Bear. However bear movements at crossing structures were detected even in the winter period (also females with yearlings) during the ex-ante monitoring phase. This proves that data from the winter period and from both monitoring sessions have also been part of the comparison process.

According to data presented in the table 34 and as general point of view, all species show a reduced use of the crossing structures. However a notable difference is observed for brown bears, which show a much higher use (more than double) of the improved crossing structures. In fact after the improvements of the crossing structures, (464) bears crossings were recorded compared to (189) before the improvements (fig. 37).

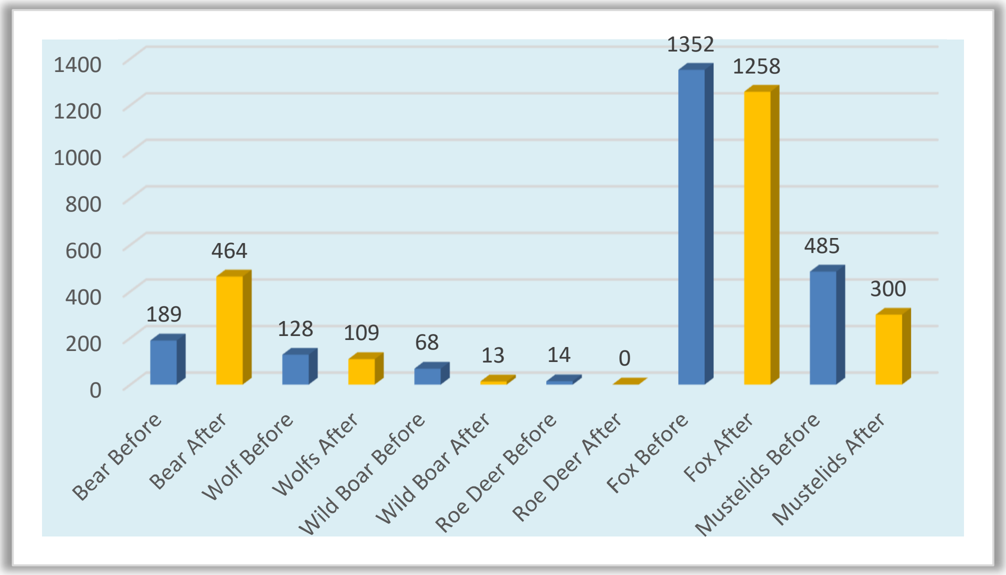


Figure 37. Differences in use of the crossing structures by wildlife species in A29 Motorway before and after the improvements of the crossing structures (EOSA).

A further analysis was carried out regarding changes of use of the 36 structures by brown bears and the other wildlife species. Brown Bear is the species showing an increased use at (23) structures, while at (7) structures the use level remained unchanged and at 6 structures the use decreased (fig. 38).

The Wild boar and Roe deer have a more stable pattern of use bearing in mind that the total frequencies of use are very low especially those concerning the Roe deer (14 uses of two structures before the improvements and 0 after the improvements).

Foxes and mustelids show a similar level of decrease (decreased use at 16 and 18 structures respectively) while wolves show a more balanced status of uses (8 structures with increased use, 14 with the same use and 14 with decreased use).

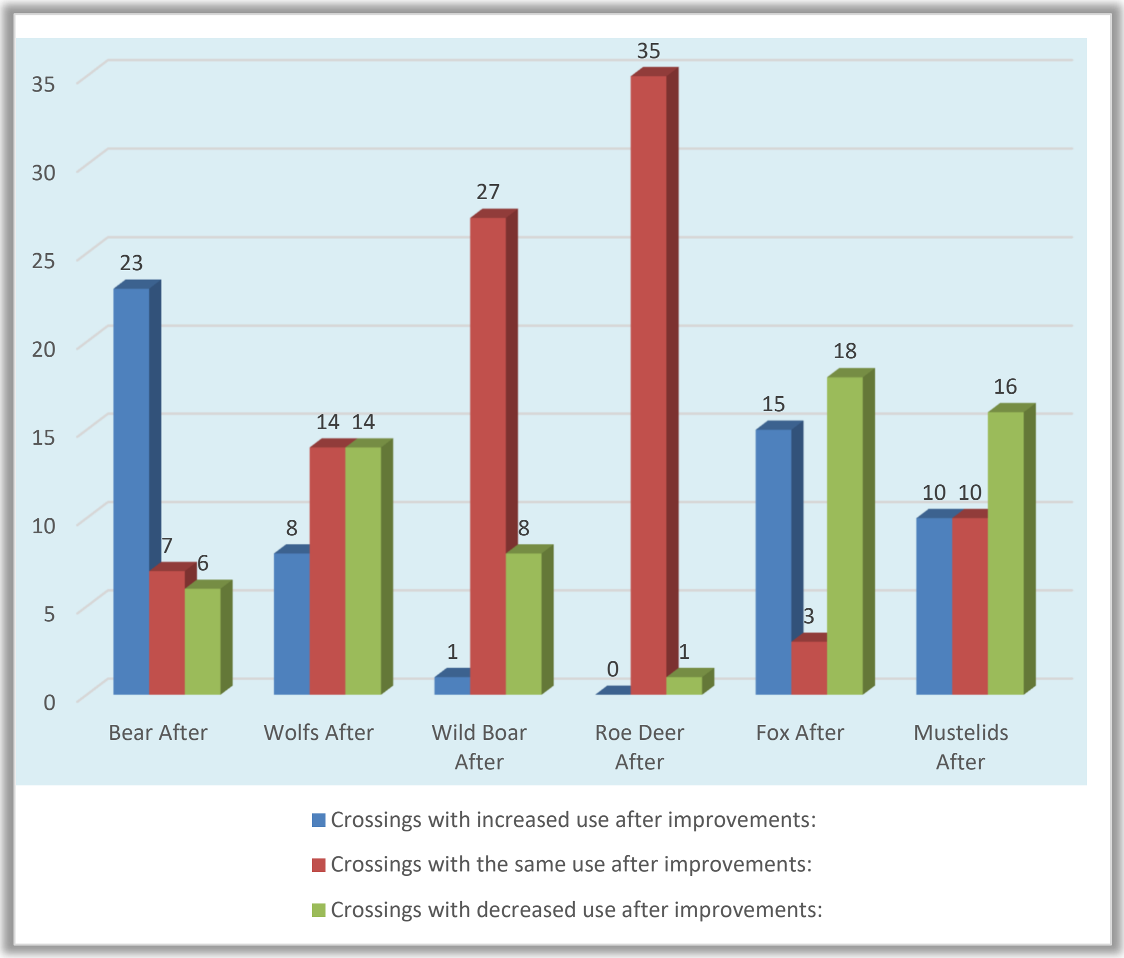


Figure 38. Changes of the status of use of the 36 monitored structures by the wildlife species (EOSA).

Also, except from the number of uses per animal it's important to distinguish how many of the structures have been used independently of the number of uses by species. According to this approach as figure 39 shows, (31) out of (36) structures have been used by the fox after the improvements instead of (28) before the improvements. In the same approach, the Brown Bear shows the best increase of numbers of the used structures, as after the improvements: (29) structures have been used by the species, instead of (22) before the improvements.

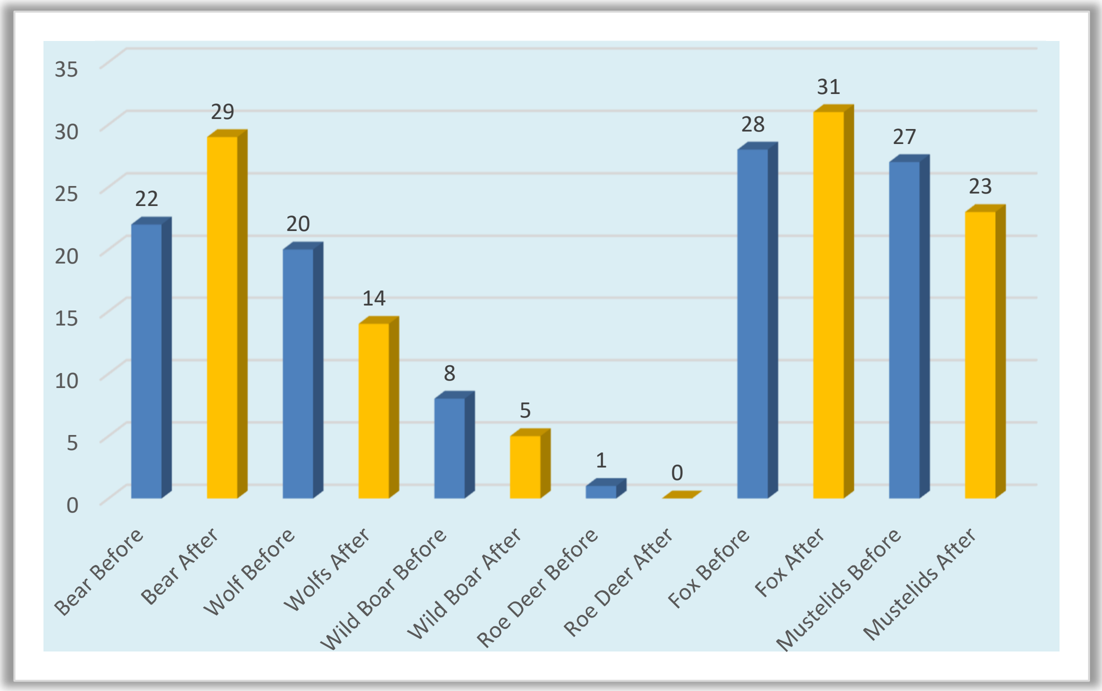


Figure 39. Number of structures used by the wildlife species before and after the improvements (EOSA).

Additionally, towards understanding better the status of ecological behavior of the species and the permeability of the structures, an analysis of the use of structures especially for the Brown Bear as key species for the project is important in relation with the Openness Index (O.I.) of the structures. As figure 40 shows, the use of the structures by Brown Bear has been increased after the improvements in all the spectrum of the O.I. Also, it's noticeable to highlight that most of the 36 monitored structures have small O.I.:

- 16 have O.I. <0,01 (culverts)
- 9 have O.I. >0,1 and <0,2 (culverts)
- 4 have O.I. >0,2 and <0,5 (2 underpasses, 2 culverts)
- 1 has O.I. 0,56 (culvert)
- 1 has O.I. 2,4 (bridge)
- 1 has O.I. 10,5 (viaduct)

Characteristic examples of use of structures with small O.I. are the cases of the following structures:

- K99 with O.I. 0,03 and 15 uses
- K15 with O.I. 0,04 and 44 uses
- K68 with O.I. 0,07 and 31 uses
- K72 with O.I. 0,08 and 46 uses
- K10 with O.I. 0,08 and 18 uses

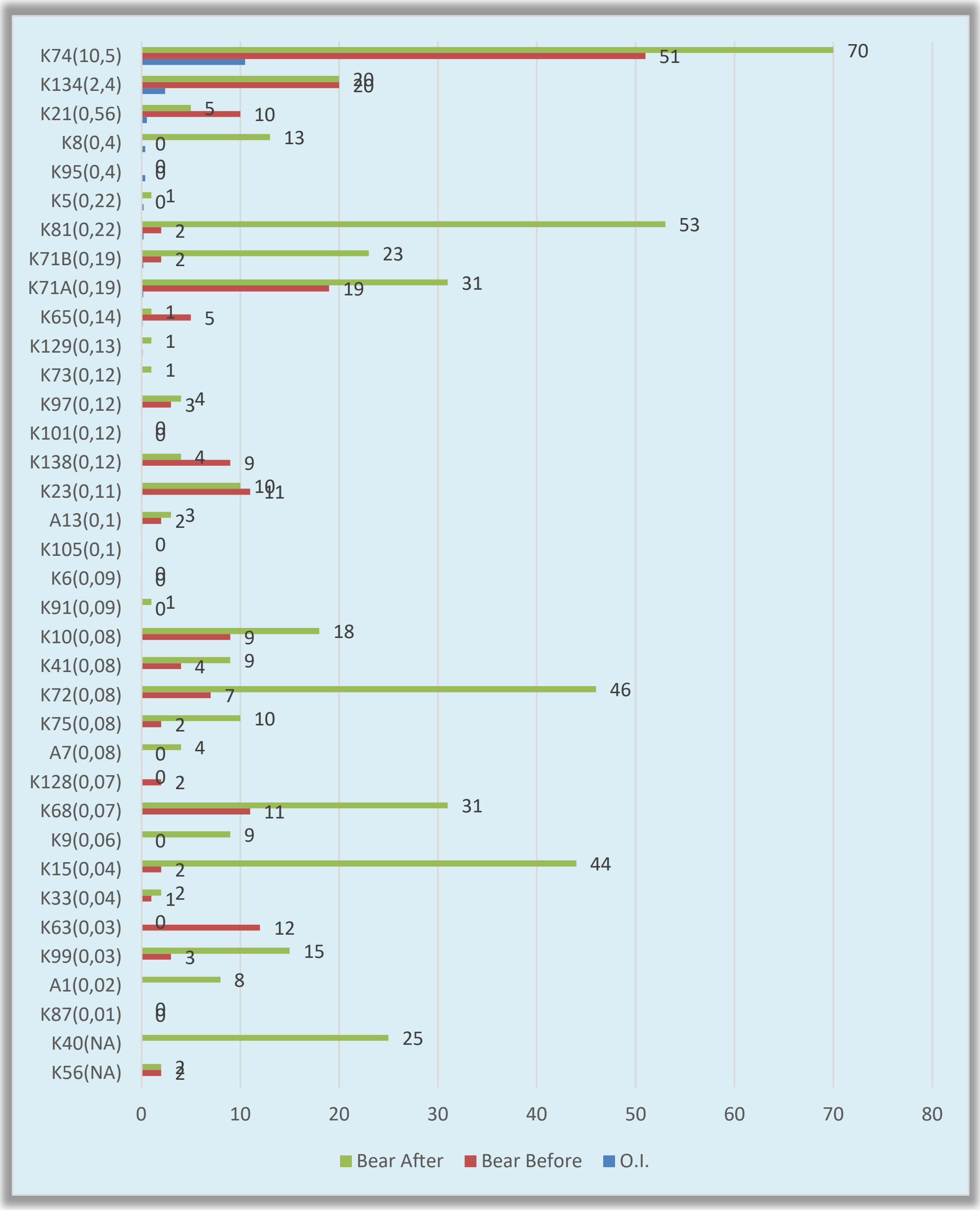


Figure 40. Use of the crossing structures by the Brown Bear before and after the improvements in relation to their Openness Index (O.I.). The order of the structures (on y axis) follows the size of the O.I. (in brackets) . It's obvious that the use of the structures by the Brown Bears has increased after the improvements over the whole range of O.I.values. Note that the majority of the structures have a small O.I.value (16 out of 36 have O.I. <0,01; 9 have O.I. >0,1 and <0,2; 4 have O.I. >0,2 and <0,5; 1 has O.I. 0,56, 1 has O.I. has O.I. 2,4 and 1 has O.I. 10,5.

In order to statistically validate the preferential use by brown bears of specific improved crossing structures a statistical analysis was performed by CALLISTO project partner using

"One-way Anova" and "Welch two sample t-test" statistical tools. The results are presented in the following figure (41) and table (39).

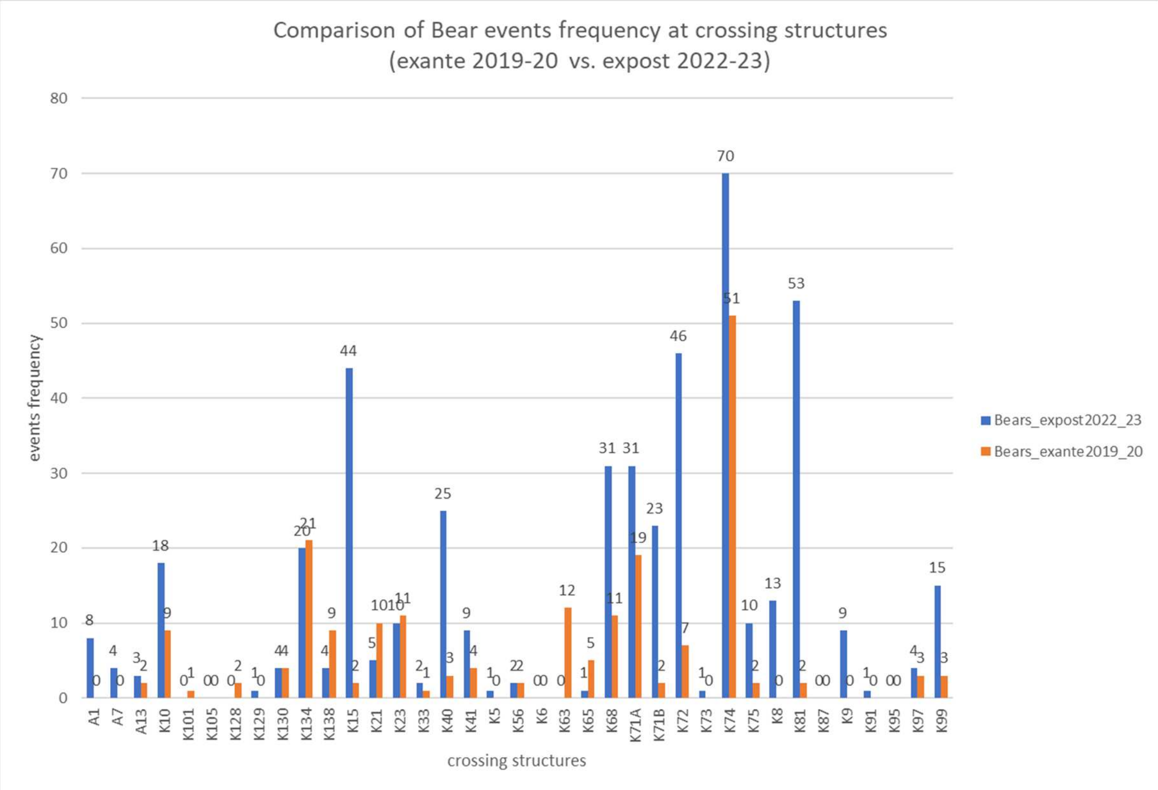


Figure 41. Comparison of bear use of crossing structures before and after improvements (CALLISTO).

one-way anova			Df	Sum sq	Mean sq	F value	Pr(>F)
		Year	1	771	771,1	3,856	0,0537
		Residuals	68	13598	200		
		Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Welch Two Sample t-test			t = -2.0229	df = 58.158	p-value = 0.04769		
			alternative hypothesis: true difference in means is not equal to 0				
			95 percent confidence interval: -13.22743306 -0.06986424				
			sample estimates:		mean of x	mean of y	
					6,0000	12,64865	

Table 39. Statistical analyses results showing statistically significant higher use by brown bears of the improved crossing structures

Special emphasis was given to (5) crossing structures that were selected to be monitored only at the expost phase (boxes in blue in table 38). These crossing structures were revealed to be of crucial importance for brown bears but still problematic because of structural problems (impermeable obstacles and mainly vertical surfaces of concrete), obturating their way through. These structures showed clear signs of bears unsuccessful attempts to cross through (claw marks etc.) illustrated in figures 42 and 43.


Figure 42. The culvert K73 had two vertical surfaces impermeable for the wildlife (photo L. Georgiadis).


Figure 43. Claw marks of a Brown Bear trying to climb over the middle vertical surface in culvert K73 (Photo by L. Georgiadis- EOSA).

As table 38 shows, these five culverts have been used by wildlife species and especially by brown bears after the construction of special rumps with stairs which facilitate their permeability (figures 44 and 45). More specifically:

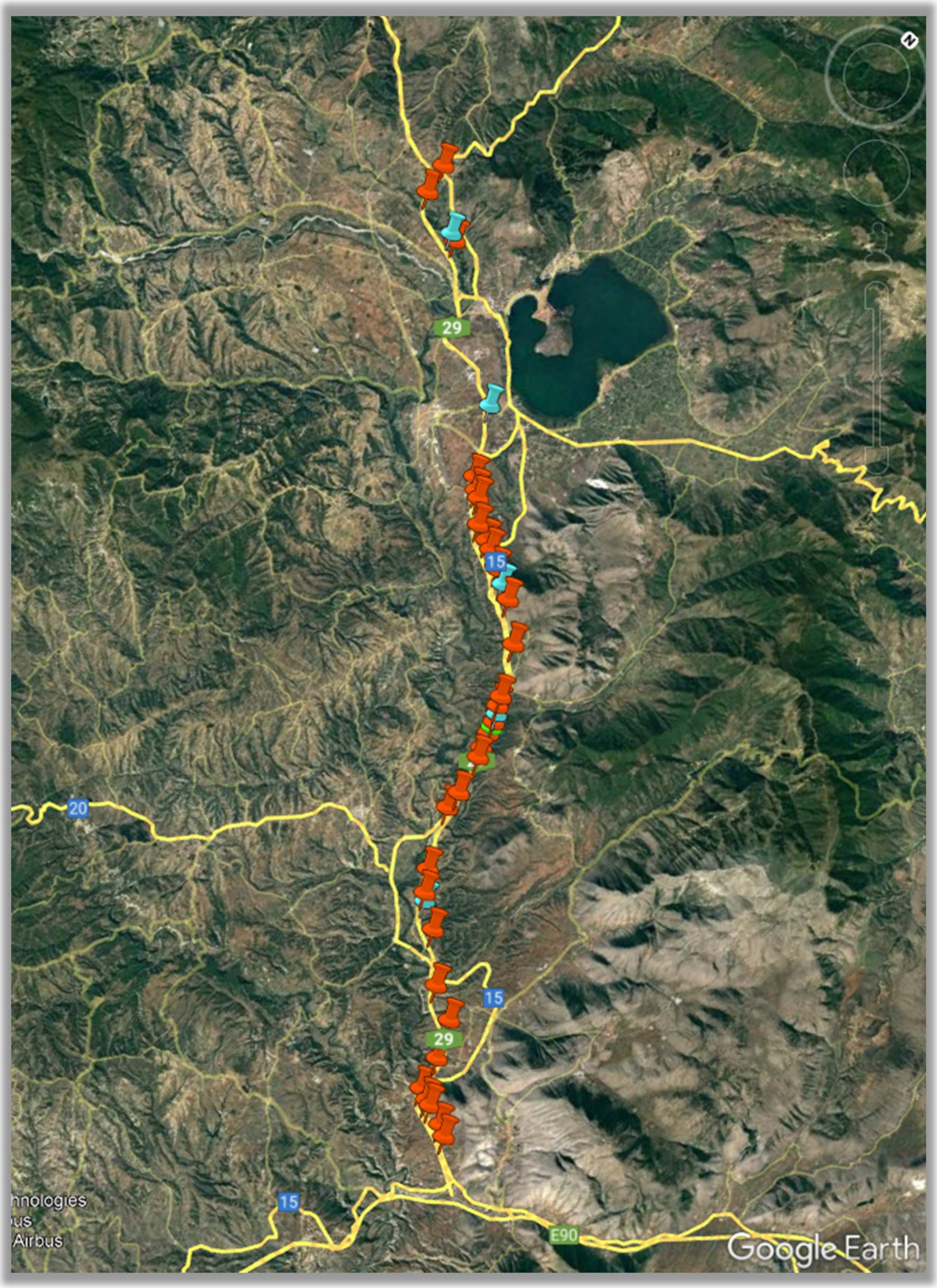
- K129 has been used 1 time by the Brown Bear, 1 by the Wolf, 34 times by the Fox and 7 times by mustelids.
- K105 has been used 6 times by the Fox.
- A1 has been used 8 times be the Brown Bear.
- K73 has been used 1 time by the Brown Bear and 3 times by the Fox.

- K40 has been used 25 times be the Brown Bear.

Map (1) illustrates the position of these (5) structures along motorway A29 is blue colour.

Figure 44. Construction of stairs in the culvert K73 in the A29 Highway (Photo by L. Georgiadis).

Figure 45. A fox using the new constructed stairs inside of the culvert K129 in the A29 Highway recorded by the camera of COSMOTE.



Map 1: Motorway A29 with the distribution of the 36 crossing structures monitored after their improvements. With blue color the 5 structures monitored after improving interventions and without exante monitoring.

2.5.4 Final considerations

Some general conclusions can be drawn as follows:

- While most of the species show a decreased use of the monitored crossing structures after the improvements, the use by Brown Bears has increased with a statistically significant difference.
- Brown Bears seems to have a quite interesting ecological behavior in terms of adaptability and flexibility to crossing structures use especially after the improvements. More specifically the use of a wide variety of structures with relatively small O.I. and distributed over the entire length of the A29 Highway from Siatista to the south until Kastoria to the north validates one of the main project's objectives aiming at increasing the permeability of motorway A29 through the improvement of the crossing structures, thus optimizing the overall landscape and habitat connectivity for brown bears in both sides of motorway A29.
- Special interventions and the improvement of additional (5) crossing structures seem to be very effective, as they have started to be used by wildlife and especially by Brown Bears.
- Ungulates and specially the Roe Deer seem to be more sensitive to the small size of O.I. Therefore, Roe Deer can be used as the representative indicator species which can cover the demand for ecological connectivity for the whole spectrum of wildlife species in the area. Special interest must be dedicated to the ungulates, to evaluate the framework of their needs for structure permeability, that is necessary to be covered.
- Further monitoring efforts are necessary over a longer period of time using also genetics in order to better understand brown bears adaptive behavioral process in regards to the improved attractiveness of the crossing structures and the overall permeability improvement of the A29 motorway to the species. This is also necessary for all the other wildlife species using the same area and crossing structures.

2.5.5 Road mortality monitoring sessions

In the project area before the installation of the 6 AVC-PS, 68 monitoring sessions were carried out on the selected road segments monitored in the frame of Action A5. In December 2022 we added the road segment Fothini-Lithia following the road killing of an adult brown bear on 19/12/2022 (tab 40).

Table 40. Road mortality monitoring session along the selected road segments in Greece

Transect code	Road segment	Length of the road segments (Km)	Number of monitoring sessions (November 2022-August 2023)	Number of animals found dead
Greece 1	New National Road Amyndaio-Vevi – R.U. Florina) E86-E65	11	14	2*
Greece 2	Old National Road Amyndaio-Kleidi – R.U. Florina	11	14	2
Greece 3	SubsegmentPedino-Aetos-Agrapidies- Sklithro-Asprogeia – R.U. Florina	11	15	4
Greece 4	Fotini - Metamorfosi - subsitute to Neapoli - Kastoria old national road-R.U Kastoria	4	14	3
Greece 5	Fothini-Lithia- R.U Kastoria	9,4	11	1

**On 13/01/2023 a brown bear was road killed between the Road transect Greece 1 and Greece 2.*

Overall, 12 animals were found dead including 5 wildlife species. Two brown bears were road killed during the monitoring period, 1 already mentioned on the road transect Greece 5, while the other on 13/01/2023 between the road transect Greece 1 and Greece 2. Among the large carnivores 1 wolf was found dead on the road transect Greece 3 on 28/02/2023. The other species found road killed were: fox (n = 6), hedgehog (n = 2) and badger (n =1).

The monitoring activity will continue in the frame of the afterlife plan and these data will be used to evaluate the effectiveness of the 6 AVC-PS, installed on August 2023: 2 on the road transect Greece 1, and 1 respectively on the other road transects.

3. Monitoring of road panels effectiveness

In the frame of Action C3 a total of 167 road panels have been installed, 38 in Greece, 97 in Italy, 8 in Romania and 24 in Spain.

The road panels were developed through the application of the neuromarketing techniques, that for the first time were used in the frame of a LIFE project.

In order to understand the impact of these panels (and thus monitor their effectiveness) we decided to administrate a questionnaire to people and assess their reaction to the panels while driving. This task was not foreseen in the project but all the partners convened that it was the only way to monitor road panels effectiveness as they are a measure aimed at addressing people attitude and thoughts, two variables only assessable collecting people opinions.

The questionnaire administrated consisted on 12 questions, plus data on sex, age and residence, divided as the following: 3 general questions on traffic accidents; 3 questions on the already-existing measures to reduce road kills; 1 question about the impact of road kills on the target species conservation; 5 specific questions on C3 road panels addressing their visibility and effectiveness. Minor differences in the questionnaire administrated in different countries are present due to the fact that in Greece and Spain only one layout was installed so all the questions related in assessing possible differences among the two layouts have been omitted. The questionnaire was submitted to the people during the meeting and events organized by the project as well as it was distributed online. A specific google format was developed to collect the replies in order to facilitate data analysis (Appendix 2)

Altogether 1,319 respondents filled out the questionnaires from the four project countries, it is important to note that not all respondents answered every question, which was expected due to small variations in questionnaires distributed across different countries

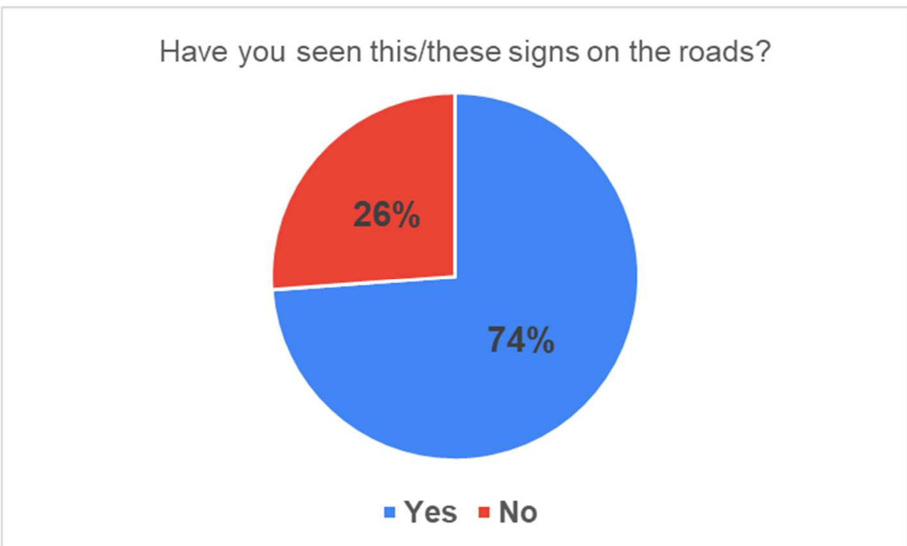
Concerning all respondents from each location, most of the respondents (92%) heard about traffic accidents with wildlife, 5% of them did not hear about it, and 3% of the respondents had direct experience. Respondents indicated that mainly small mammals (57%) and wild boars (23%) are the victims of the collisions. In most respondents' view, the main reason for the accidents is "*High speed and low attention*" since on average 61% of them selected this option.

1.039-1.314 of the replies refer to the 5 questions directly related with C3 panels effectiveness. Answers provided by people clearly show that panels are visible, people that see them change their behaviour, people think they are effective in changing people attitude, both the layouts ("car" and "crossing") are considered effective to make drivers drive carefully and, finally, that panels are considered an effective conservation tool for the target species (Figure 46).

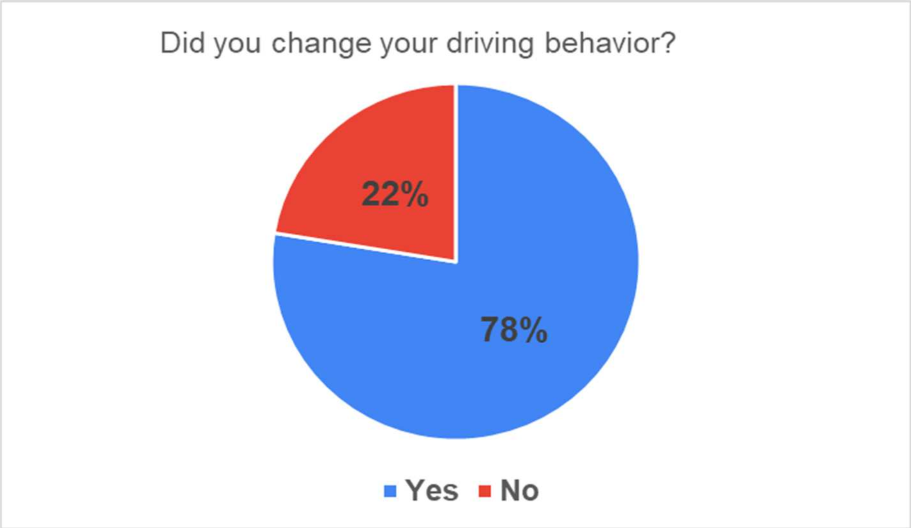
Seventy-five percent of people said that they could see the panels along the road (Figure 46a) and 78% of them also said to have changed behaviour (Figure 46b) slowing down and/or paying more attention while driving. Eighty-nine percent of people believe that, on a scale from 1 to 5, the panels are >3 effective in encouraging responsible driving (Figure 46c) and, for those countries where more than one layout was installed more than 50% of the people believed that they were equally effective (Figure 46d). Finally, 90% of people believe that, on a scale from 1 to 5, these panels are >3 useful to protect the target species (Figure 46e). Regarding the socio-demographic backgrounds of the respondents, an equal distribution of male and female participants was observed. Concerning age distribution, 40% and 39% of respondents were in the 21-40 and 41-60 age groups, respectively.

The administration of questionnaires has been extremely successful both in terms of number of responses gained and in terms of feedback given by people. As it has been administrated anonymously, answers provided are considered representative of the actual opinion of the persons reached and the answers provided clearly state that road panels are a tool highly appreciated by people and considered to be effective to raise drivers' awareness on the importance of driving carefully and respecting wildlife as well as effective to help the conservation of the target species.
These results clearly underline the impact and the importance of this action, even if it doesn't mean that the installation of road panels can solve alone the problem of a driving behaviour, that too often doesn't take into account the presence of wildlife near the road, this is a first step to raise the awareness of people. The winning message of the road panels is to make people think that the problem of road accidents with wildlife is an issue of species conservation but also of driver safety. The success and appreciation of the road panels expressed by people also show the added value of the use of the neuromarketing techniques in their development.

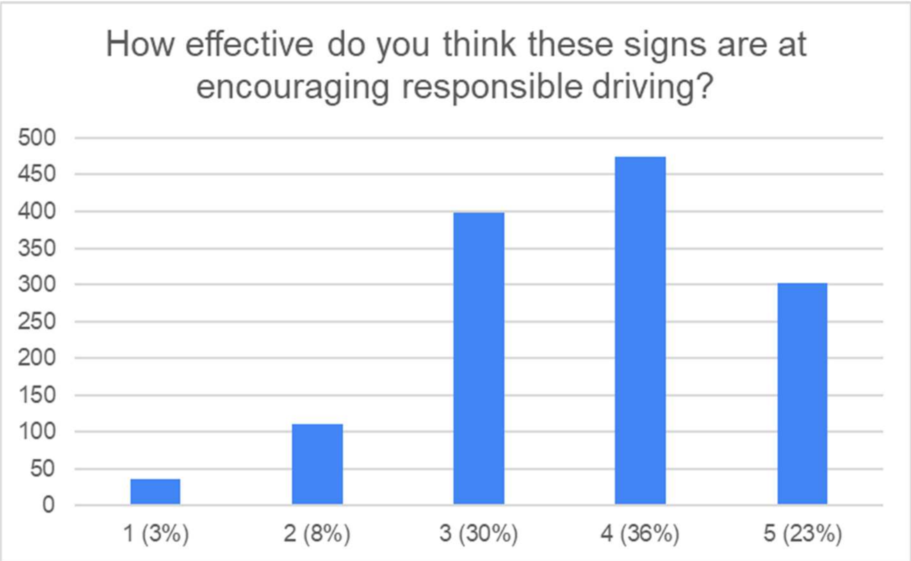
46a.



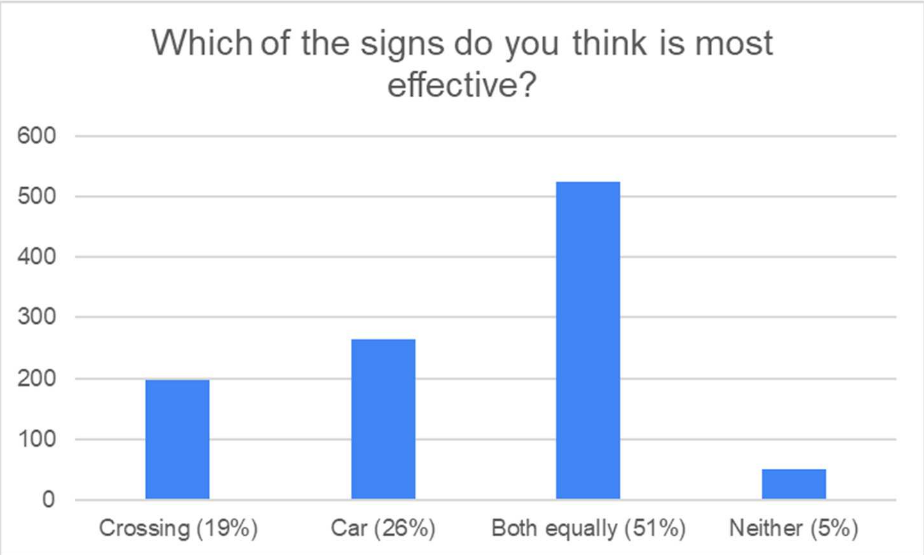
46b.


Did you change your driving behavior?
22%
78%
Yes
No

46c.


How effective do you think these signs are at encouraging responsible driving?
500
450
400
350
300
250
200
150
100
50
0
1 (3%)
2 (8%)
3 (30%)
4 (36%)
5 (23%)

46d.


Which of the signs do you think is most effective?
600
500
400
300
200
100
0
Crossing (19%)
Car (26%)
Both equally (51%)
Neither (5%)

46e.

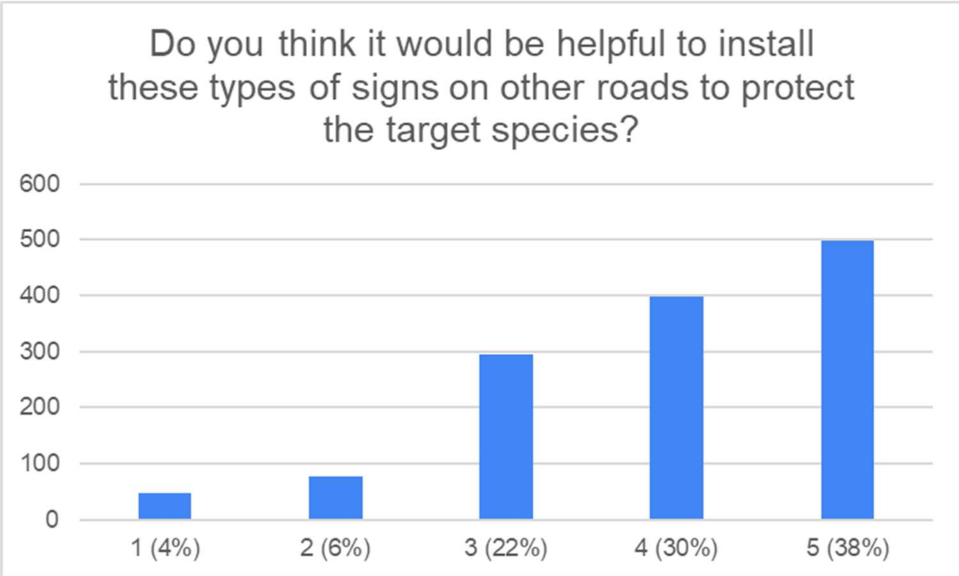


Figure 46. Results of the survey administrated to people to assess the effectiveness of panels installed in the frame of Action C3. Graphics a-e reports answers that people gave to the 5 questions directly related to the panels effectiveness.

Appendix 2. Questionnaire administrated to monitor the effectiveness of Action C3: example of the Google Form created (PNM).

Welcome! Your contribution will help the conservation of the Apennine brown bear

The LIFE SAFE-CROSSING Project is funded with the contribution of the LIFE programme of the European Union.

Survey

29/11/23, 18:36 LIFE SAFE-CROSSING

25. 2. In your opinion, which wild animals are most involved in traffic accidents? (mark the most relevant option)

Mark only one oval.

- ◯ Bear
- ◯ Red deer
- ◯ Roe deer
- ◯ Small mammals (hare, fox, marten etc.)
- ◯ Wild boars
- ◯ Wolf
- ◯ Other: ____________

27. 4. In your opinion, is this "wildlife crossing" sign an effective tool to communicate the risk of accidents with wildlife?

Mark only one oval.

- Yes
- No

28. Why? Briefly explain your answer.

29. 5. In your opinion, what should be done to reduce the number of wildlife-traffic accidents? (mark the most important option)

Mark only one oval.

- Promote information campaigns to raise the awareness about the importance to drive safely
- Change road signs
- Install roadside fences
- Build underpasses and overpasses
- Ridurre il numero di animali vicino alle strade
- Lower speed limits in risky areas
- Other: ______

30. 6. In your opinion, has the solution you indicated already been applied?

Mark only one oval.

- Yes
- No

31. If your answer was "No", what do you think are the main reasons for not applying the solution you indicated?

32. 7. In your opinion, on a scale of 1 to 5, how much do roads and vehicular traffic represent a threat to the conservation of the Apennine brown bear?

Mark only one oval.

	1	2	3	4	5	
Not						A lot

33. 8. Have you ever seen one of these signs while driving?

LAYOUT «CROSSING»

LAYOUT «CAR»

Mark only one oval.

- Yes, both of them
- No
- Yes, only "Crossing"
- Yes, only "Car"

34. 9. If you answered "Yes" to question 8, did your driving behavior (e.g. speed, level of attention) change after seeing the signs?

Mark only one oval.

- Yes
- No

35. How? briefly explain your answer

36. 10. On a scale of 1 to 5, how effective do you think these signs are in promoting responsible driving behavior?

Mark only one oval.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very effective

37. 11. In your opinion, which of these two signs is the most effective in inducing people to drive carefully?

Mark only one oval.

- ◯ "Crossing"
- ◯ "Car"
- ◯ Both of them equally
- ◯ Neither

38. 12. On a scale of 1 to 5, how useful do you think it would be to install these signs on the roads to protect the Apennine brown bear?

Mark only one oval.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very useful

Your data

The questionnaire is anonymous, we only ask you for some general information for statistical data processing

39. Sex *

Mark only one oval.

- ◯ F
- ◯ M

40. Age *

Mark only one oval.

- Up to 20 years
- 21-40 years
- 41-60 years
- Over 60

41. State of residence *

THANK YOU!

Your contribution has been precious, send your answers and spread the voice!

Invite your friends to fill out this questionnaire!

4. Conclusion

The action was successfully implemented in all the project countries and all the concrete interventions carried out were properly evaluated. We were able to collect and analyse a huge amount of data.

The results obtained demonstrated the effectiveness of the installed mitigation measures (AVC-PS and VF) on the selected road segments in terms of reducing road mortality of the target species and all other mammal species. The observed percentage of reduction, in several cases, was up to 100% and it is important to consider the impact of the actions implemented not only in terms of reduced numbers, but also in terms of risky situations avoided. This is the case of the installation of the AVC-PSs. In fact, pooling together the data coming out from all the countries, more than 10000 risky situations were detected by the systems, and only 13 road kills were recorded. Also, the installation of VF was very positive and, where the devices were installed, there was a marked decrease of reduction of road kills. We are conscious that, the evaluation of the mitigation measures needed a long monitoring period and cannot be made only comparing the results before and after their installation. As was explained in this document, this is what we could do and the results obtained are very positive. Surely, the prosecution of the monitoring of the effectiveness of the mitigation measures implemented, already foreseen in the afterlife plan, will be very important to continue data collection in order to assess the effectiveness of the AVC-PS and VF in the long term. Nevertheless, the data already collected by the study carried out by PNM staff with camera trapping in the area of the AVC-PS confirm and strengthen the results obtained. Moreover, it is also important to underline that the data related to the road kills in the period before the installation of the mitigation measures can be an underestimation of the phenomenon, since no systematic monitoring was in place in the project area.

In conclusion, even if the results obtained have to be evaluated in the long term, and can suffer from different potential confounding factors, they are extremely important as they are the result of an international collaboration and different expertise.

Likewise, one must interpret what has been done in terms of improving ecological connectivity. The work done in Greece along the Egnatia Highway was really impressive because it produced important results as the significant increased use of the adapted crossing structures by brown bear, and also the “creation” of new passages along one of the most important barrier to the movements of the species in the area. The accurate monitoring of the effectiveness of the adaptation of the crossing structures was possible through the use of the “Monitoring and Species’ Classification” prototype solution developed by Cosmote, which represented an added value not only for the project implementation, but also for its replication potential in similar initiatives. Important results, as witnessed by the monitoring activities, were obtained in Romania regarding the improvement of 30 crossing structures in the project area most of them located on DN1 road one of the busiest roads of the country. In Italy, all the interventions carried out on the SS 17 road represent a significant improvement for the conservation of the Apennine brown bear, as well as the interventions made in Spain for the Iberian lynx, also because they can be replicated in the projects and initiatives already in place for the conservation of this endangered species.

Last but not least, the evaluation of the effectiveness of the road panels developed by the neuromarketing techniques through the survey carried out in all the project countries, showed the great value of the action to promote a responsible driving behavior.

Once again, we have to underline that it is always difficult to measure the conservation impact of the interventions carried out in such a short time, the normal duration of a LIFE project, but the sampling protocol applied, allowed us to produce an accurate evaluation of all the concrete conservation actions.

Finally, it is important to remember that, despite some delays and some technical problems, we were able to evaluate all the concrete conservation actions implemented during a very critical period due to pandemic period and the strong economic crisis that affected the economy all over the world mainly related to the war in Ukraine.