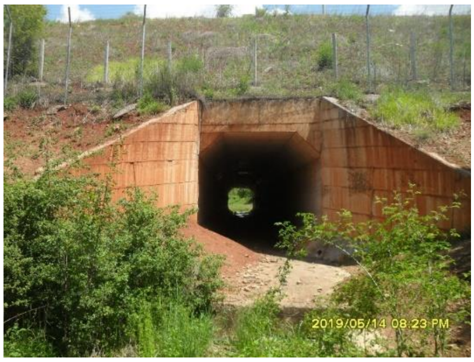
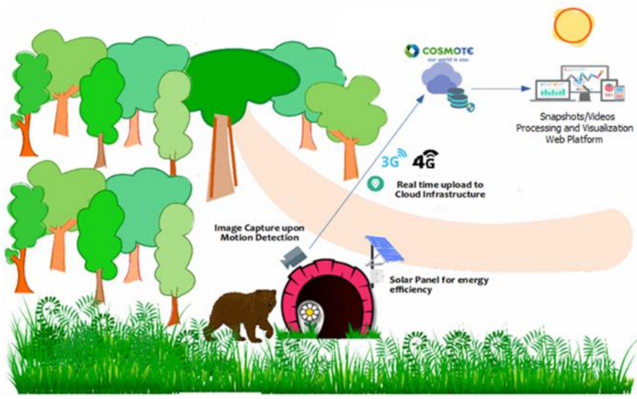
ACTION A4. ANALYSIS AND MAPPING OF EXISTING CROSSING STRUCTURES FOR POTENTIAL USE BY THE TARGET SPECIES AND OTHER INTERVENTIONS ON THE ROADS.

ACTION REPORT/2020 – Greece

AUTHORS: CALLISTO NGO, EOSA, COSMOTE





LIFE SAFE CROSSING
PREVENTING ANIMAL-VEHICLE COLLISIONS

Περιεχόμενα

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I. Executive summary:

This report presents the results of the preparatory action A4 which is part of the implementation of the LFE SAFE CROSSING program. The aim of this action is the identification, analysis and mapping of existing crossing structures on highways for their possible use by species of wild fauna with emphasis on the brown bear, as well as the management / upgrading of these technical passages / structures with special interventions in order to optimize their attractiveness for wildlife and consequently their use with the ultimate goal of maintaining highway permeability and consequently the geographical continuity of habitat and wildlife populations with emphasis on the brown bear (*Ursus arctos*) .

The area of implementation of the action is the vertical axis of Egnatia Odos A29 (I / C Siatista - Krystallopigi).

The implementation of this action included the combination of (3) stages and the cooperation of (3) key project actors and partners **COSMOTE, CALLISTO and EGNATIA ODOS SA** as follows:

(a) the development of an integrated electronic audiovisual system for the monitoring of technical passages using (45) special cameras with infrared (IR), autonomous power supply, with image storage system, sorting / re-sorting and processing of data and their diagrammatic representation (**COSMOTE**)

b) Typology of all (149) underpasses along A29 and the installation of a network (45) of IR cameras in a corresponding number of underground passages along the A29 following preselection. Systematic monitoring of the system operation, entry, classification and registration of data, per technical passage, per fauna taxa and in total. Re-sorting the data using a special algorithmic tool (developed by COSMOTE) and crosscheck of the automated sorting of cameras outcome. A total of 60,000 images were produced and processed (**CALLISTO**, COSMOTE).

c) Based on the data from (a) and (b) an initial identification and characterization of the most suitable underground passages was performed based on the frequency and intensity of their use by wildlife species with emphasis on the brown bear (target species). Additional in situ visits were carried out to confirm the suitability of the passages based on specific criteria but also to investigate additional suitable passages for potential or effective use by wildlife (total investigated crossing structures (90) including the (45) monitored by IR cameras). Formulation of specific proposals and management actions and measures for upgrading / improvement of the (56) finally selected underground technical passages (CALLISTO, **EOSA**)

This action is the main preparatory stage for the implementation of action C2 (always within the frame of the project) and which will involve appropriate planting techniques and other manipulations to improve the attractiveness and functionality of underpasses for their use by wild fauna and with emphasis on the target species and thus meet one of the main project's objectives which is to "***Improve connectivity and favor of movements for the target populations***" in a landscape which is disrupted by the linear barrier of a highway.

II. Περίληψη:

Η παρούσα αναφορά παραθέτει τα αποτελέσματα της προπαρασκευαστικής δράσης Α4 η οποία εντάσσεται στο πλαίσιο υλοποίησης του προγράμματος LIFE SAFE CROSSING. Ο στόχος της εν λόγω δράσης είναι ο προσδιορισμός, η ανάλυση και η χαρτογράφηση υφιστάμενων δομών διέλευσης σε αυτοκινητοδρόμους για πιθανή χρήση τους από είδη της άγριας πανίδας με έμφαση στην καφέ αρκούδα, καθώς και η διαχείριση/αναβάθμιση αυτών των τεχνικών περασμάτων/κατασκευών με ειδικές παρεμβάσεις προκειμένου να βελτιστοποιηθεί η ελκυστικότητά τους για την άγρια πανίδα και κατ'επέκταση η χρήση τους με απώτερο στόχο την διατήρηση της διαπερατότητας του αυτοκινητοδρόμου και συνεπακόλουθα της γεωγραφικής συνέχειας του ενδιαιτήματος και των πληθυσμών από είδη της άγριας πανίδας με έμφαση στην καφέ αρκούδα (*Ursus arctos*).
Η περιοχή υλοποίησης της δράσης είναι ο κάθετος άξονας της Εγνατίας Οδού Α29 (I/C Σιάτιστας – Κρυσταλλοπηγή).

Η υλοποίηση αυτής της δράσης περιελάμβανε τον συνδυασμό (3) φάσεων καθώς και την συνεργασία (3) βασικών εταίρων στο έργο: **COSMOTE, ΚΑΛΛΙΣΤΩ και ΕΓΝΑΤΙΑ ΟΔΟΣ ΑΕ**, ως εξής:

(α) την ανάπτυξη ενός ολοκληρωμένου ηλεκτρονικού οπτικο-ακουστικού συστήματος παρακολούθησης των τεχνικών περασμάτων με την χρήση (45) ειδικών καμερών με υπέρυθρες (IR), αυτόνομης τροφοδοσίας, με σύστημα αποθήκευσης εικόνας, ταξινόμησης/επανα-ταξινόμησης και επεξεργασίας δεδομένων και διαγραμματικής τους απεικόνισης (**COSMOTE**)

β) Τυπολογία του συνόλου των (149) υπόγειων περασμάτων στον Α29, και εγκατάσταση ενός δικτύου (45) καμερών IR σε αντίστοιχο αριθμό προεπιλεγμένων υπόγειων περασμάτων κατά μήκος του Α29, συστηματική παρακολούθηση της λειτουργίας του συστήματος, λήψη, ταξινόμηση και καταχώρηση δεδομένων, ανά τεχνικό πέρασμα, ανά taxa πανίδας αλλά και συνολικά. Επανα-ταξινόμηση των δεδομένων με τη χρήση ειδικού αλγόριθμου από COSMOTE και επανέλεγχος των αποτελεσμάτων αυτοματοποιημένης ταξινόμησης. Συλλέχθηκαν συνολικά ~60.000 εικόνες (**ΚΑΛΛΙΣΤΩ** , COSMOTE)

γ) Με βάση τα δεδομένα από (β) έναν αρχικό προσδιορισμό και ταυτοποίηση των καταλληλότερων υπόγειων περασμάτων με βάση την συχνότητα και ένταση χρήσης τους από τα είδη της άγριας πανίδας με έμφαση στην καφέ αρκούδα. Διενέργεια πρόσθετων αυτοψιών για επιβεβαίωση της καταλληλότητας των περασμάτων με βάση συγκεκριμένα κριτήρια αλλά και στην διερεύνηση πρόσθετων κατάλληλων περασμάτων που δεν είχαν σύστημα παρακολούθησης χρήσης (σύνολο 90 συμπεριλαμβανομένων και των 45 με εγκατεστημένες κάμερες). Διατύπωση συγκεκριμένων προτάσεων και διαχειριστικών ενεργειών και μέτρων αναβάθμισης/βελτίωσης των (56) τελικώς επιλεγέντων υπόγειων τεχνικών περασμάτων (ΚΑΛΛΙΣΤΩ**, ΕΓΝΑΤΙΑ ΟΔΟΣ ΑΕ**)

Η δράση αυτή αποτελεί το βασικό προπαρασκευαστικό στάδιο για την υλοποίηση της δράσης C2 (πάντα στο πλαίσιο του ίδιου έργου) και η οποία θα αφορά σε κατάλληλους φυτο-τεχνικούς και άλλους χειρισμούς για την βελτίωση της ελκυστικότητας των υπόγειων περασμάτων για την χρήση τους από την άγρια πανίδα ανταποκρινόμενη σε βασικό στόχο του έργου: την «βελτίωση της συνδεσιμότητας και της κίνησης των υπο-πληθυσμών αρκούδας» σε σχέση με το γραμμικό εμπόδιο του αυτοκινητοδρόμου.

III. Preface:

The construction and operation of large roads causes the fragmentation of natural areas into smaller ones, thus negatively affecting the movements of species and in general the stability of the natural environment (Askins et al. 1987, Andrews 1990, Askins, 1994, Rich et al. 1994, Reed et al. 1996, Forman and Alexander 1998, Alexander and Waters 2000).

Habitat fragmentation is a dynamic process in which large areas of landscapes are subdivided into many smaller ones resulting in the fragmentation of single habitats into smaller and isolated habitats (Andrén 1994, Forman and Alexander 1998). Habitat fragmentation has been recognized internationally as one of the most important issues threatening the conservation of biodiversity

Throughout the world, traffic volumes have increased markedly in the past two decades (United Nations 1992) and the increasing area occupied by recently constructed roads is affecting wildlife populations. For many mammal populations, the main demonstrated impact of roads to date has been in terms of increased disturbance or mortality. Avoidance of otherwise suitable habitats in close proximity to roads has been shown to occur for brown bears *(Ursus arctos)* and wolves (*Canis lupus*) in the U.S.A. (McLellan and Shackleton 1988, Mace et al. 1996, Mech et al. 1988). For some mammal species, roads have been shown to act also as a considerable barrier to dispersal (Mader 1984).

Roads can therefore have a significant effect in fragmenting wildlife populations and eventually lead them to local extinction (Fahrig and Merriam 1994). Increased awareness of environmental problems caused by infrastructure construction has moved engineers, ecologists and policy makers to develop planning concepts to deal with the impacts on nature and landscape. If avoidance of a certain project is not feasible, mitigation measures can be undertaken as a second planning concept.

The maintenance of connectivity zones in relation to this linear "barrier" of a transportation infrastructure is of catalytic importance for maintaining the communication of subpopulations (connectivity) and the functionality of the ecosystem. Fauna free passage zones facilitate dispersal and seasonal migration processes that are critical to the long-term viability of large mammal populations (Weaver et al., 1996).

In order to minimize the geographical and genetic isolation of populations and species of fauna, it is necessary to maintain and / or create linkage areas between existing or potentially isolated parts of the geographical distribution of an animal species.

In the case of the closed highways of Greece that are part of the Trans-European network TENT (such as the Egnatia Odos, the E65, etc.), the geographical cut-off and isolation of habitats and populations is a given, and the "spatial nature" of this phenomenon follows the linear layout of the project in the whole of its occupation zone, but it has a radial effect in the whole sub-populations of the aforementioned species of fauna that live in the wider area.

1. INTRODUCTION

1.1. The LIFE SAFE CROSSING project

The **LIFE SAFE CROSSING Project** with the full title: "**Preventing Animal-Vehicle Collisions – Demonstration of Best Practices targeting priority species in SE Europe**" aims at implementing actions to reduce the impact of roads on some priority species in four European countries:

- Marsican brown bear and wolf in **Italy**,
- Iberian lynx in **Spain**,
- Brown Bear in **Greece** and **Romania**.

The target species are severely threatened by road infrastructures, both by direct mortality as well as by the barrier effect.

The LIFE SAFE CROSSING is based on the experience of LIFE STRADE project (LIFE11BIO/IT/072, www.lifestrade.it) which has developed an innovative tool for the prevention of road kills, and the results of the experimentation in 17 sites have been very promising and wildlife mortality on roads was reduced up to 100% in the intervention areas. It was also seen that one of the main causes of the road kills is the low level of awareness and attention of drivers regarding the risk of collisions with wildlife.

The project therefore aims at the following objectives:

- Demonstration of the use of the innovative Animal-Vehicle Collision (AVC) Prevention tools in new project areas.
- Reduction of the risk of traffic collisions with the target species.
- Improve connectivity and favour movements for the target populations.
- Increase the attention of drivers in the project areas about the risk of collisions with the target species.

The core of the project will be the demonstration of an innovative tool for road kill prevention to new areas. This will be accompanied by best practices to restore wildlife passages in order to favour the movements of animals across roads. These actions will be prepared by an evaluation of the impact and distribution of traffic infrastructures on the target species.

The implementation of communication activities for drivers also strongly contribute to reduce the danger of road kills. Finally, in the scope of a demonstration project, activities are planned to further replicate the implemented activities, mainly the innovative ones.

The duration of the project is 5 years (September 2018 – October 2023) and its implementation is coordinated by the Italian organization AGRISTUDIO in cooperation with in total 13 partners from Italy, Spain, Romania and Greece. Greek partners of the project are:

- EGNATIA ODOS S.A.
- Region of Western Macedonia
- COSMOTE
- NGO Callisto

The project will disseminate an innovative tool for the prevention on road kills, which has been developed in the LIFE STRADE project, to new areas, thus providing a new important management tool. This, together with best practices creation of wildlife passages, will greatly reduce the number of animals killed on roads and enhance connectivity. The concrete conservation actions and the information campaigns for drivers will represent a significant impact not only for the target species but for the overall biodiversity of the project areas. More Specifically, the following results are expected:

- Installation of at least 27 AVC Prevention Systems as demonstration to new areas (6 systems will be installed in Greece: 3 in the Regional Unit of Florina and 3 in the Regional Unit of Kastoria).
- Readaptation of at least 80 wildlife crossing structures (50 in A29 highway in Greece).
- Interventions for road kill prevention on at least 400 km, 35 km in Greece: E 86-E65 National Road Xino Nero- Kleidi - Vevi, (10km); E 86 Old National Road Amyndaio – Kleidi – Vevi (10Km); E65 Old National Road Siatista – Kastoria (from Neapoli I/C to Vogatsiko I/C) (15km).
- Decrease of mortality of target species due to road fatalities with vehicles of at least 50% in the areas of intervention.
- Reduction of speed of at least 30% of vehicles as a reaction to the prevention activities.
- Knowledge of the AVC prevention System to at least 100 decision makers.

As far as Greece is concerned, 50 wildlife passages along A29 Egnatia highway stretch are planned to be upgraded in terms of attractiveness and functionality for wildlife species with emphasis on brown bear (*Ursus arctos*). This will be done in order to facilitate the movements of animals across the road which functions as a linear barrier in the landscape, and thus minimize the risk of population and habitat fragmentation of the targeted species. To achieve these objectives, three specific actions have been designed in the framework of the project, as follows:

Action A4. Analysis and mapping of existing crossing structures for potential wildlife use, roadside verges management and other interventions on the roads.

Action C2. Activities to enhance connectivity between core areas through functional readaptation of underpasses and interventions on road sides.

Action D1. Monitoring the impact of the C Actions.

For the implementation of the above actions on A29 highway (vertical axis Siatista – Krystallopigi of Egnatia highway) in Greece, the cooperation of three project actors has been foreseen, each of them dealing with a specific sub-task under action A4 distributed as follows:

- **CALLISTO NGO**: (a) typology of the 149 underpasses along A29 , (b) installation and monitoring of (45) IR video cameras along (45) underpasses – data screening, entry and processing- overall reporting
- **COSMOTE**: development of an innovative, end-to-end wildlife monitoring solution, in order to monitor the use of underpasses by wildlife, and to effectively assess and classify the collected data - reporting.
- **EOSA**: Screening and identification of wildlife crossing structures for specific upgrade and in order to improve their crossing attractiveness and functionality to wildlife with emphasis on the brown bear (Ursus arctos) – data processing - reporting.

1.2. The action A4

Title of the Action A4: "**Analysis and mapping of existing crossing structures for potential wildlife use, roadside verges management and other interventions on the roads**".

The objective of this action is to identify existing crossing structures along highway A29 that are being used by target species but require particular adaptations (in their structure or in the surroundings) in order to maximize their use by wildlife. Also, potential interventions will be identified such as removal of barriers on roadside verges - such as stone walls, fences, high slopes etc. – or removal of possible attractants near the roads (e.g. fruit trees that attract bears to road sides (Italy), high densities of rabbits that attract Iberian lynx to verges increasing their mortality risk (Spain)). This action will be strictly related and based on the results of Action A3, and on the already existing information, and it will be mainly preparatory for Action C2. The action will be developed mainly with the following tools:

- Identification of potential wildlife passages, barriers to animal movements, vegetation on road verges using telemetry data where they are available (connected with the action A3).
- Analyses of the road stretches with Google Street View.
- Specific field surveys in order to inspect and register the conditions and relevant features of the identified potential fauna passages as well as the barriers to animal movements.
- Installation of camera traps (in Greece specifically designed for the project) near potential crossing structures to assess whether the animals attempt to use them, with what frequency and if there is a type-related preference.

To ensure that appropriate mitigation measures are designed and applied, this action is developed using standards provided on the main existing technical prescriptions on the topic such as the European Handbook 'Wildlife and Traffic' produced as a result of a European COST Action Project, the Spanish technical prescriptions on fauna passages and the first worldwide Handbook of Road Ecology. A specific form is elaborated in order to register common variables of potential wildlife crossing structures and roadside verges, and to evaluate the "Openness Index" of the fauna passages. The features registered are those that have proven some influence on the use and movements of the target species both on transversal structures (dimensions, screening, substrate, presence of barriers close to the entrances, structure of the vegetation at the entrances, etc.) and on roadside verges (vegetation height and density, features of the safety barriers, stone walls etc.).

An analysis of these features allows to determine the activities to be undertaken in Action C2 to reduce road mortality and increase the road permeability.

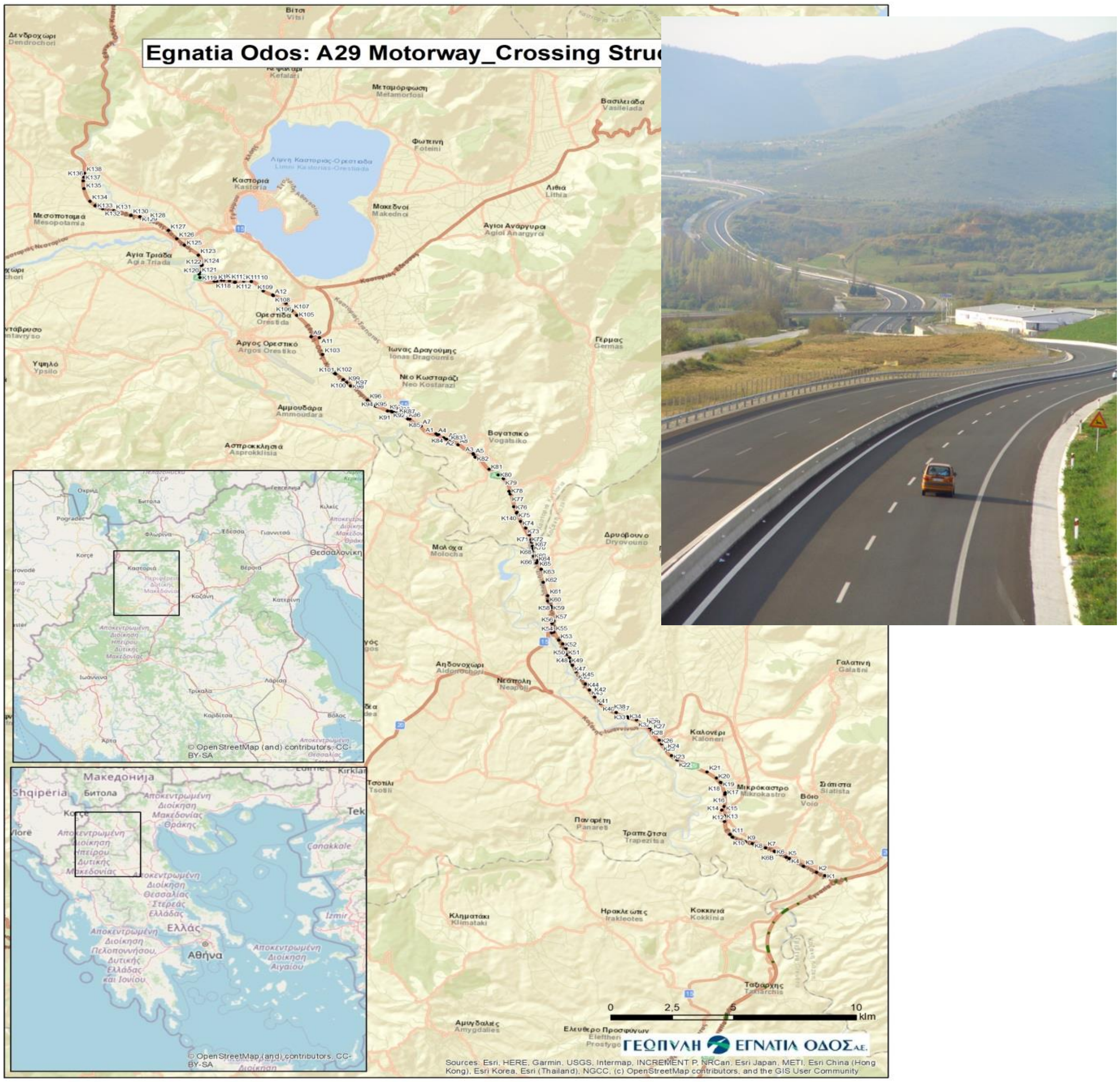
The mitigation measures can include a wide range of actions such as:

i) screening the road over an underpass to provide more quiet entrance diminishing the noise and the disturbances caused by car lights.
ii) to plant corridors of vegetation conducting the animals from the natural areas in the surroundings to the entrance of the crossing structures.
iii) to eliminate barriers (pits, walls) at the entrances and other actions adapted to each situation and considering the preferences of the target species.

It is noticeable that besides the target species these actions will benefit also other endangered species.

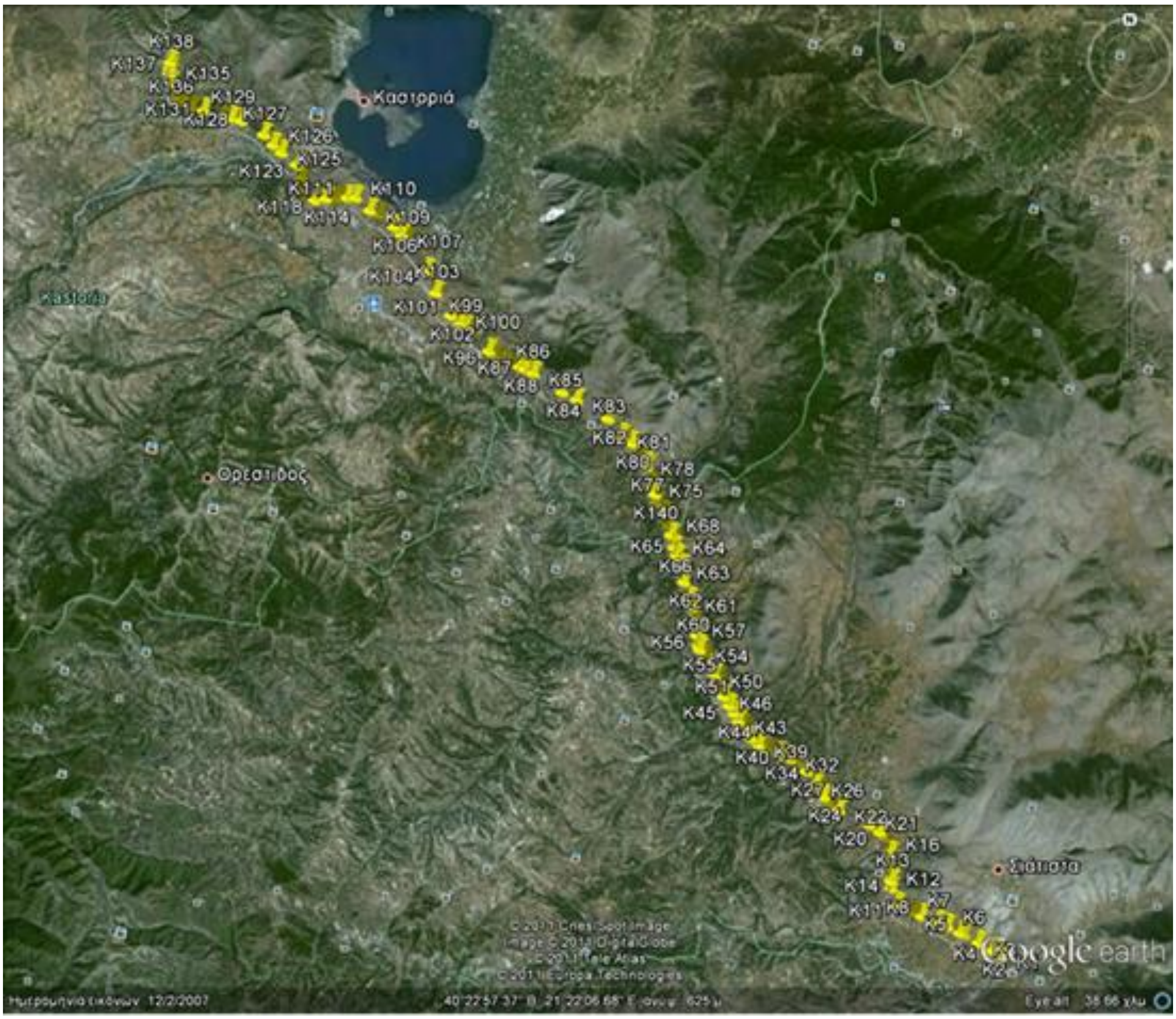
2. STUDY AREA

The study area of the A29 Motorway is located in North-western Greece in the Region of the Western Macedonia. The A29 Highway starts from the area the town of Siatista (I/C Siatista)_ in the Prefectural Unit of Kozani heading northwest through the Prefectural Unit of Kastoria bypassing the city of Kastoria and ending in the Prefectural Unit of Florina at the customs of Krystallopigi on the borders with Albania. The main section of the highway for the implementation of the A4 project activity is the section Siatista – Kastoria with a length of 55 km (Maps & foto 2.1 & 2.2).



Maps & foto 2.1. *The A29 Motorway (Siatista - Kastoria - Krystallopigi) as vertical axes of Egnatia Odos Motorway with its crossing structures*

The corridor in the immediate vicinity of the highway is characterized by a relatively gentle relief of the semi-mountainous zone while the landscape shows strong mosaicism with main characteristics: crops, riparian forests and oak forests. In the wider eastern sector, the main feature of the landscape is the most intense relief of the southern ends of the mountain range of Peristeri (mts Varnoudas-Vernon-Siniatsikon). In the study area the presence and activity of the bear is permanent throughout the annual cycle.



Map 2.2.: *Spatial distribution of the (149) crossing structures of all categories along highway A29. (yellow pins) .*

3. Materials & Methods

3.1. COSMOTE:

3.1.1. The end to end solution: Developed by COSMOTE for the selected underpasses monitoring with IR cameras is composed of the following parts and devices (see Figure 3.2.1).

- 4G (wireless) battery-powered, ultra-low consumption cameras equipped with small but very efficient solar panels for long operation[1]. 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.
- 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.)
  - hosting of a Web portal for snapshots visualization, underpasses information, statistics presentation, etc. (using node.js, javascript, html/css, python, mysql, grafana, etc.)

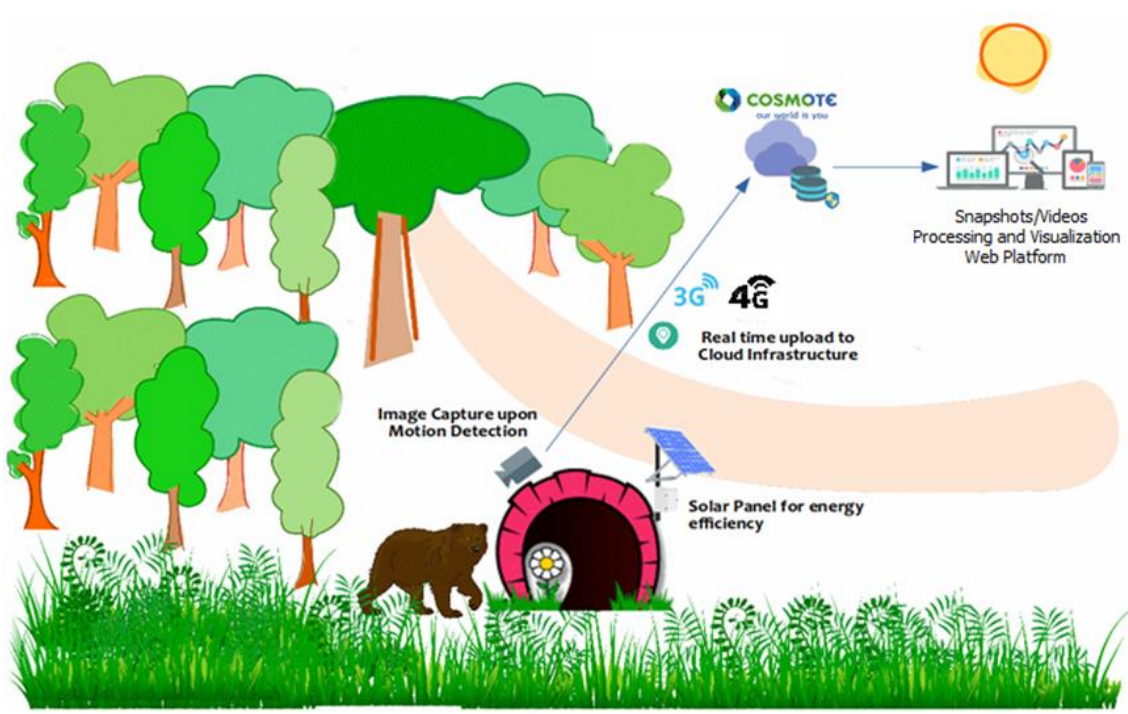


Figure 3.2.1 : The overall, end-to-end, solution architecture developed by COSMOTE.

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

3.1.2. 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.

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 figure 3.2.2):

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.

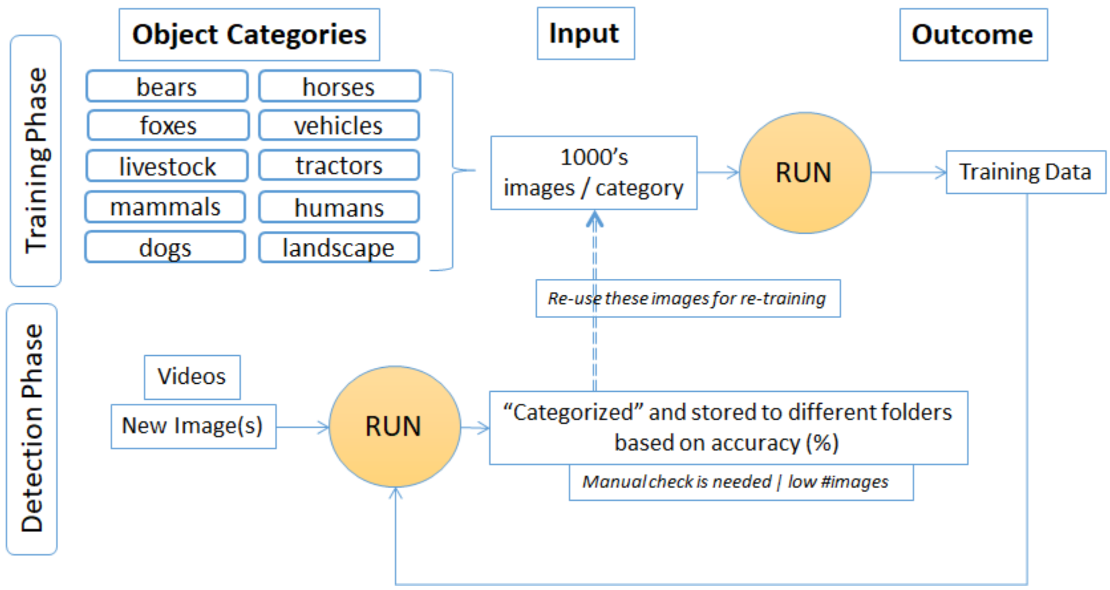
2. Phase B: Training phase. During this phase we’re training the (selected) algorithm to evaluate and remember an image, by creating a model that can then be applied to other (new) images (transferring i.e., the characteristics from one image to another algorithmically).

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).

Fig. 3.2.2. Configuration of the algorithm classification tool. (by COSMOTE)



<u>Species Classification is not an easy task</u>

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.

3.2. CALLISTO: underpasses typology – IR cameras installation, data collection and processing:

The following protocols and steps have been implemented by Callisto's team:

i) Installation of a pilot IR video camera device (as described above) at a representative underpass (K69) for pilot trial and testing of the whole system. Five months monitoring of this camera – data download and entry – data classification and processing.

ii) Intensive fieldwork for the overall typology of all (149) underpass along highway A29 using the standardized field form prepared by "Minuartia". This step was performed by two membered (2) field teams who screened all existing crossing structures along A29. Data entry of the filled in typology forms to the data base template prepared by "Minuartia" was performed by (2) internship students under the supervision of (2) main field team members. Classification and prioritization criteria for the identification of underpasses for monitoring with IR cameras installation was based on: a) previous classification of highway sub-segments crossing risks by brown bears based on statistical analyses using telemetry data and old fence trespassing data (performed under LIFE ARCKAS project – LIFE09NAT/GR/00333), b) bear signs identified and recorded inside the underpasses or at one or both entrances, during the typology procedure in the field and c) expert opinion.

iii) IR cameras installation at (45) pre-selected underpasses performed by a (2) membered field team.

iv) IR cameras status monitoring 24/7 which was performed by one field team member and one internship/volunteer student; using the specific mobile application https://play.google.com/store/apps/details?id=com.mcu.reolink&hl=en_US&gl=US,

v) IR cameras data download and storage (automated for 39 cameras and manually for (6) cameras) over a one year period (from July 2019 to June 2020). Performed by (3) field team members.

vi) Cameras data entry and final screening for re-entry, performed by all field team members with the assistance of internship/volunteer students.

vii) IR data processing: mapping, classification of underpasses use by season and wildlife species with emphasis on the target species *Ursus arctos*.

3.3. EOSA:

3.3.1. Gathering of existing data

In order to prepare the overall activity implementation, during the first two months data, existing information, tools and documents were collected in cooperation of Egnatia Odos S.A. with Callisto, Minuartia and COSMOTE as following:

i) The Crossing Structures Database of the project for Greece (A29 highway) provided by Callisto.
ii) The Guidelines to adapt transversal structures and increase use by large carnivores and other wildlife provided by Minuartia.
iii) The Field form and the instructions for characterization of transversal structures prepared by Minuartia.
iv) Data of the Crossing Structures use by wildlife (camera data) provided by COSMOTE.
v) Photos of the Crossing Structures provided by Callisto.
vi) Position of the Crossing Structures for Google maps use, provided by Callisto.
vii) Data input with the use of a special application, bought in the framework of the LIFE SAFE CROSSING, called "CREATOR (by ArcGIS)", for further facilitation of data input, use and process.
viii) Collection of other information and data about the A29 and wildlife permeability and roadkills.

3.3.2. Preparation of the field visits

In order to implement the field visits, extra pages were added to the field form developing a **Wildlife Permeability Improvement Form** as a kind of CV for each crossing, incorporating all stages from the initial identification to the improvements' description. This Form (presented in ANNEX) includes the following:

i) A first page with photos of entrances of the crossing structures to facilitate their identification.
ii) A page (**Part A**) with a Google map background with the crossing structure and a table with the description of the human activities in the local surroundings in two radii of 100 and 200 m.
iii) A page of data in a form of histogram figure for the use of the crossing by the wildlife species (**Part B**) for crossing structures with available wildlife use data provided by COSMOTE.
iv) The field form and instructions for characterization of transversal structures (**Part C**). This form was completed for all the selected crossing structures for inspection based on the data from the Crossing Structures Database of the project for Greece (A29 highway) provided by Callisto.
v) A special sheet for description of the crossing improvements (Crossing Improvement Sheet) for each of the two entrances of the crossing structures (**Part D**).
vi) An annex of additional detail photos if special arrangements were needed to be described and indicated (**Part E**).

Also, a special mobile phone application (MAPinr) with Google maps background was installed for the detail geographical orientation in the field using the KMZ files for each crossing structure. (see template 3.3.2.1)

LIFE SAFE-CROSSING PREVENTING ANIMAL-VEHICLE COLLISIONS ACTION 4.	
Wildlife Permeability Improvement Forms of Crossing Structures of Highway: A29 (Siatista – Kastoria)	
STRUCTURE CODE: 30_K71	**PK:** ....
A. Local surroundings map **B. Field form and instructions for characterization of transversal structures** **C. Wildlife use data** **D. Crossing Improvement Sheets** **E. Additional photos**	

Photo Entrance 1:SW

Photo Entrance 2: NE

A. Local surroundings map

Human activities and infrastructure:	
In 100 m of NE side:	**In 100 m of SW side:**
☐ Paved Road X Forest road X Agriculture fields ☐ Farm ☐ House ☐ Factory/Industry ☐ Other: .... ☐ Other:	X Paved Road ☐Forest road X Agriculture fields ☐ Farm X House ☐ Factory/Industry ☐ Other: .... ☐ Other: ....
In 200 m of NE side:	**In 200 m of SW side:**
☐ Paved Road X Forest road X Agriculture fields ☐ Farm ☐ House ☐ Factory/Industry ☐ Other: .... ☐ Other:	X Paved Road ☐ Forest road X Agriculture fields ☐ Farm ☐ House ☐ Factory/Industry ☐ Other: .... ☐ Other: ....
Comments:	

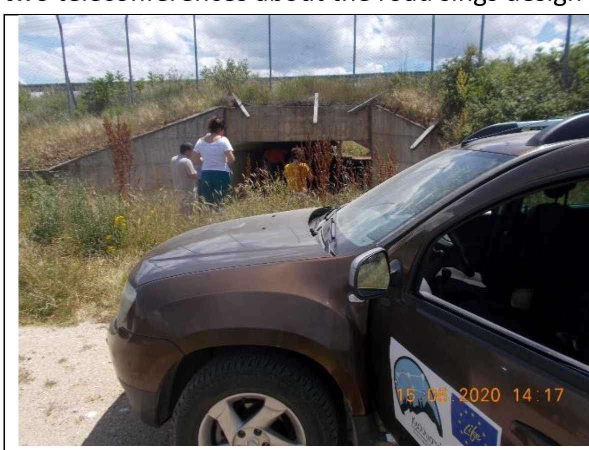
3.3.3. Organization of technical meetings and collective field visits.

In order to finalize the total number of the crossing structures for improvement, two technical meetings took place in Egnatia Odos S.A. headquarters on 5th and 10th of June, while a special technical meeting was organized on 15th of June 2020 in Kastoria with Callisto project technical team and Egnatia Odos S.A. staff involved with the programme (see foto 3.3.3.1) followed by a field visit (see fotos 3.3.3.2-4). During the first two meetings technical aspects for the final selection of crossing structures and their improvement were discussed in order to facilitate the final decision according to the best practical and effective approach. During the second meeting a special discussion took place about the development of a special application, "CREATOR (by ArcGIS)", used during monitoring and for further facilitation of input of data and improvement proposals, as well as for the use and process of all acquired data, which was completed with an additional online teleconference. During the third meeting, further evaluation of the criteria for the final choice of the crossing structures was discussed, as well as the technical aspects of the improvements, e.g. the plants species which will be used.

The re-evaluation of the cameras data was decided using the additional available data of the second semester of 2020 until 30th of June, especially those from the use of crossing structures by the bears. Additionally, extra field visits were organized in order to add more candidate crossing structures.

Also, general or more technical issues were discussed during other technical meetings, organized by the Region of Western Macedonia, that took place during the first semester of 2020:

- the kick off meeting of the project in Florina on 25th of February, Region Unit of Florina, and
- two teleconferences about the road sings design on 15th and 21st of May.



Fotos 3.3.3/2-3:collective field visit of underpasses in June 2020 by all involved project partners

3.3.4. Adopting the appropriate criteria for selection of the crossing structures

Basic part of the preparation was the selection of the crossing structures using three categories of criteria as they have been provided by the "*Guidelines to adapt transversal structures and increase use by large carnivores and other wildlife*" prepared by Minuartia:

I. The location and the attributes related to landscape and road section. In this category, three factors were taken into account:
   a. The available data of roadkills
   b. The available telemetry data about the presence and use of the area by the bears
   c. The proximity of human settlements, facilities and activities
II. The intense of the use of the structures by the bears according the following approaches:
   a. Structures with the high level of use (more than 100 passes) were not selected for improvement assumed as effective, as discussed and proposed by the project partners (Minuartia)
   b. Limited use by the bears but estimated as critical for the connectivity
   c. Possible use without confirmation by the cameras' data and based on the experience and field data
III. The dimensions of the structures using the Openness Index as a key factor. The priority was given mainly for the structures with large Openness Index with some exceptions and in combination with the cases of IIb (Limited use by the bears but estimated as critical for the connectivity).

In order to use mortality and telemetry data for brown bear on the A29 highway special technical reports and references were used as following:

Mastrogianni A., 2012. Evaluation of the status of crossing structures for the wildlife at the vertical axes of Egnatia motorway Siatista – Krystallopigi with emphasis on the brown bear. Practice thesis. Department of Biology, School of Positive Science, Aristotle University of Thessaloniki. (In Greek)

Mertzanis Y. 2011. Confrontation of roadkills with brown bears at the vertical axes of Egnatia motorway "Siatista – Krystallopigi, KA45" – Section Siatista – Koromilia. Determination of high danger sections for the installation of reinforced fence. Technical Report. Callisto NGO, Project LIFE "Arctos Kastoria". (In Greek)

Karamanlidis A.A., (cord.) 2011. The status of the brown bear (*Ursus arctos*) at the area of the vertical axes of Egnatia motorway Siatista – Krystallopigi. Final report of research action with the support of Vodafone (July 2010 – July 2011). ARCTUROS. Thessaloniki, October 2011. 1-80. (In Greek)

ARCTUROS, 2011. Technical report for the confrontation of roadkills with brown bears (*Ursus arctos*) at the vertical axes of Egnatia motorway "Siatista – Krystallopigi, KA45". Determination of high danger sections for the installation of reinforced fence. Thessaloniki, December 2011. 1-54. (In Greek)

Georgiadis L., (cord). 2009. Vertical axes of Egnatia motorway: Siatista – Krystallopigi. Proposals for improvements for the safe traffic of vehicles and the prevention of the isolation of wildlife populations. NGO ARCTUROS, CALLISTO. Thessaloniki. p22. (In Greek)

The selection of the crossing structures included all different uses and types of structures. Considering the Openness Index (O.I.) as a key criterium, the selection of the structures was prioritized accordingly.

4. RESULTS

4.1. COSMOTE

4.1.1. The end to end solution:

During operation in the field for for the monitoring stage of crossing structures, the system exhibited a long list of innovative features, most of which are not available in the market. A non-exhaustive list follows:

- 24x7 (wildlife) monitoring of underpasses. This is safeguarded by the use of ultra-low consumption battery (and solar) powered wireless 4G cameras (see 4.1.1)

- **Fig. 4.1.1.:** The 4G wireless Camera incl. Solar Panel (Reolink Go 4G)

- 24x7 access to cameras' configuration such as, PIR on/off, PIR schedule, PIR sensitivity, video recording, audio recording, IR lights, etc. (4.1.2)

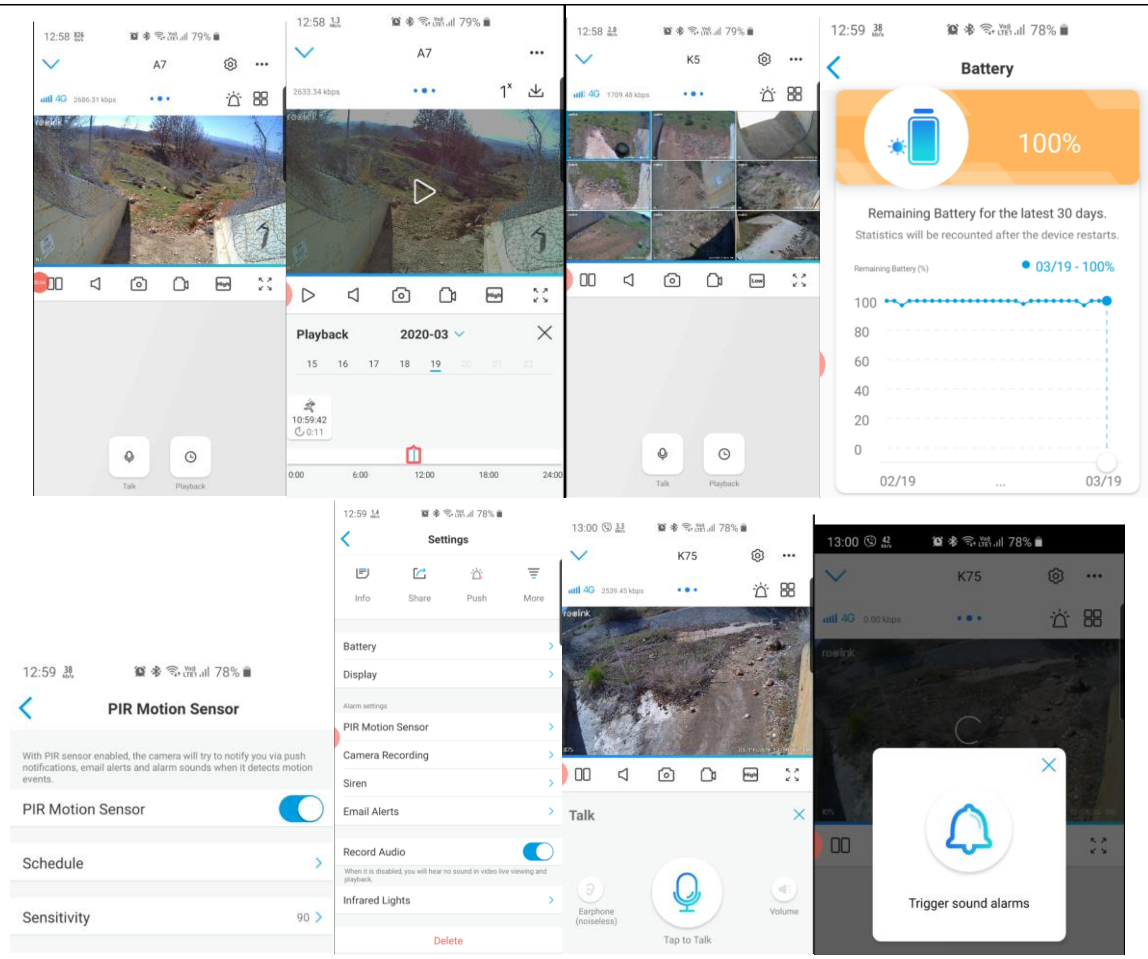


Figure 4.1.2: 24x7 Access to Cameras' Content/Features & Remote Configuration (live streaming from one camera, live streaming from multiple cameras concurrently, remote playback, camera configuration, battery charge %, 2-way audio communication, siren, etc.)

- 24x7 access to cameras' features such as, real-time video/audio streaming from a single camera, real-time video/audio streaming from multiple cameras concurrently, video/audio playback, battery usage and remaining battery percentage (%), two-way audio communication, (local) siren upon alert, etc. (see.4.1.2.)
- Automated procedures for snapshots' uploading via COSMOTE's 3G/4G network and snapshots' storage at COSMOTE's cloud infrastructure
- Real-time alerting upon movement detection to smartphones (via push notifications) and/or e-mail, incl. snapshot(s) (see fig. 4.1.3.)

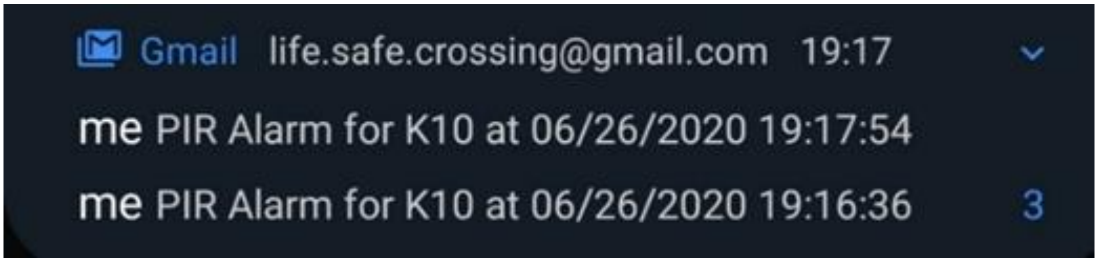
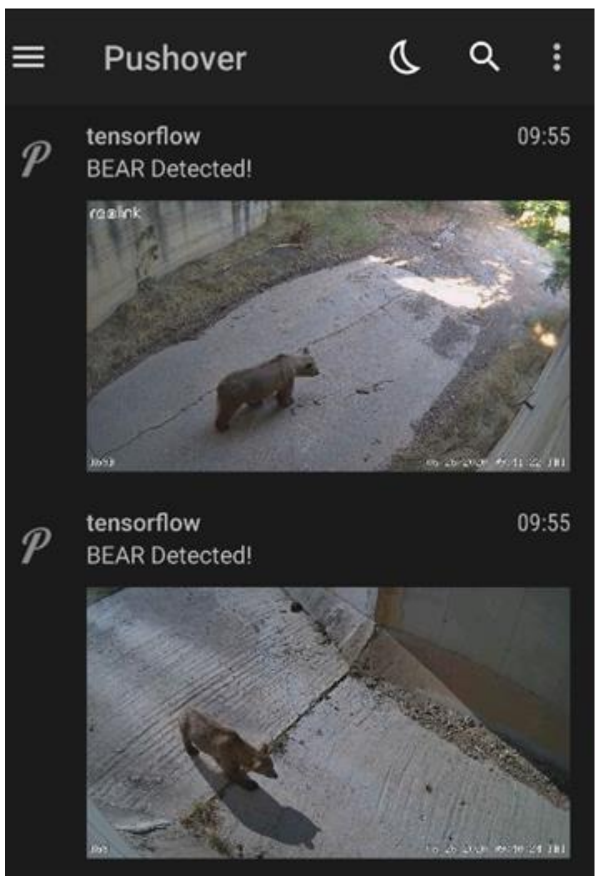


Figure 4.1.3..: Near real-time alerting @smartphone when a movement is "detected" *(this implies that a snapshot (and a short video) has been taken, stored locally @camera's SD card and uploaded automatically to COSMOTE's cloud infrastructure)*

- Near-real time custom (presence) alerts upon detection of specific species (e.g., bears) via push notifications @smartphones incl. snapshot (see Figure 4.1.4)

Figure 4.1.4: Near real-time alerting @smartphone when a bear is "detected"



- Innovative tools for automated detection of objects/species passing through (both in near-real time and offline) and automated categorization/storage (of snapshots) based on species category (e.g., bears, foxes, dogs, sheep) and/or other "objects" such as vehicles, humans (see Annex A)

- Snapshots' visualization through an intuitive, user-friendly web portal (incl. underpass info, snapshots/underpass, search capability, etc.) | http://193.218.97.145:8081/ (see Figure 4.1.5., Figure 4.1.6 and Figure 4.1.7.)

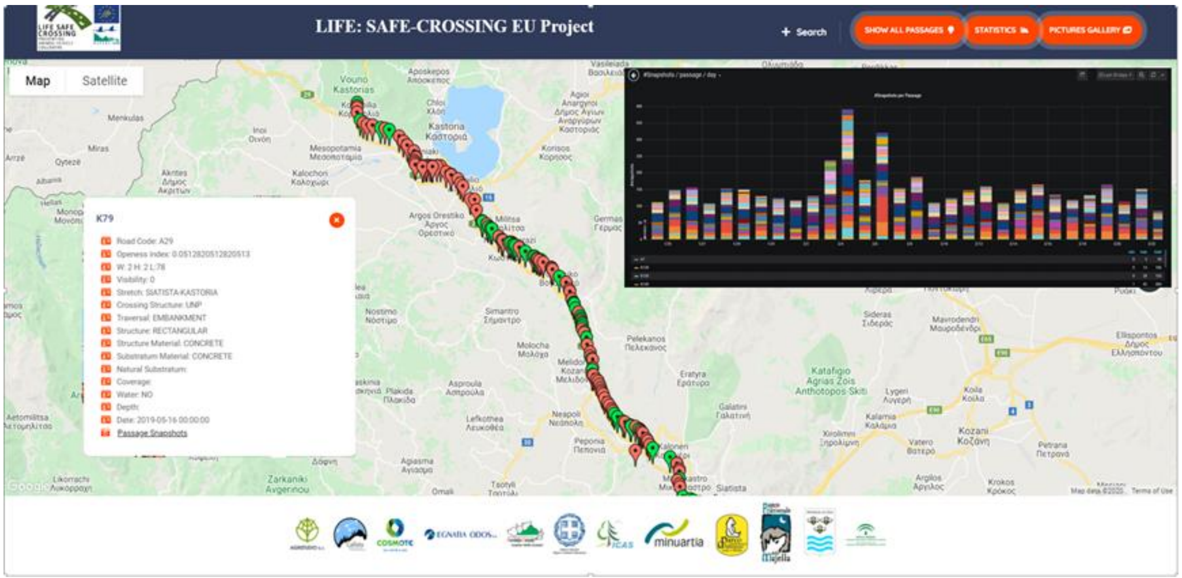


Figure **4.1.5**.: The (Greek) Underpasses Portal: http://193.218.97.145:8081/ (info per underpass with search capability, snapshots per underpass, snapshots from all underpasses, statistics / underpass, etc.)

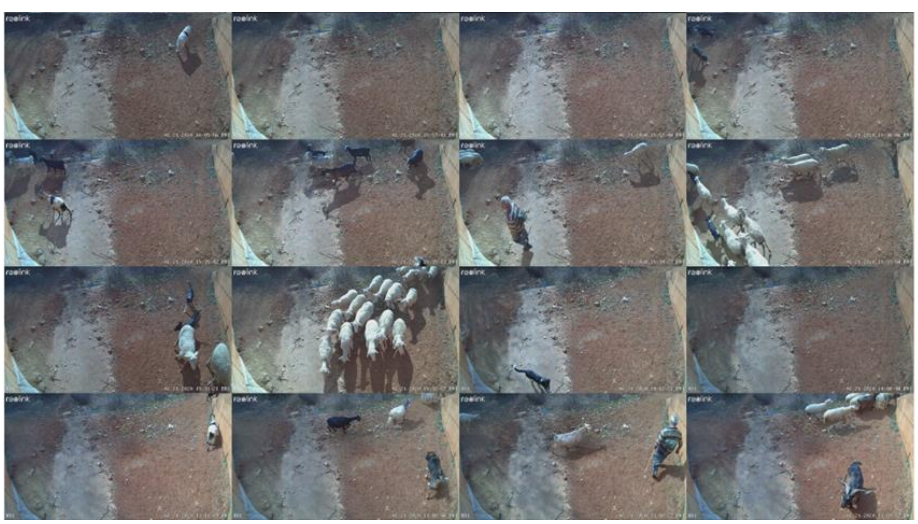


Figure 4.1.6: Visualization of snapshots for a specific underpass

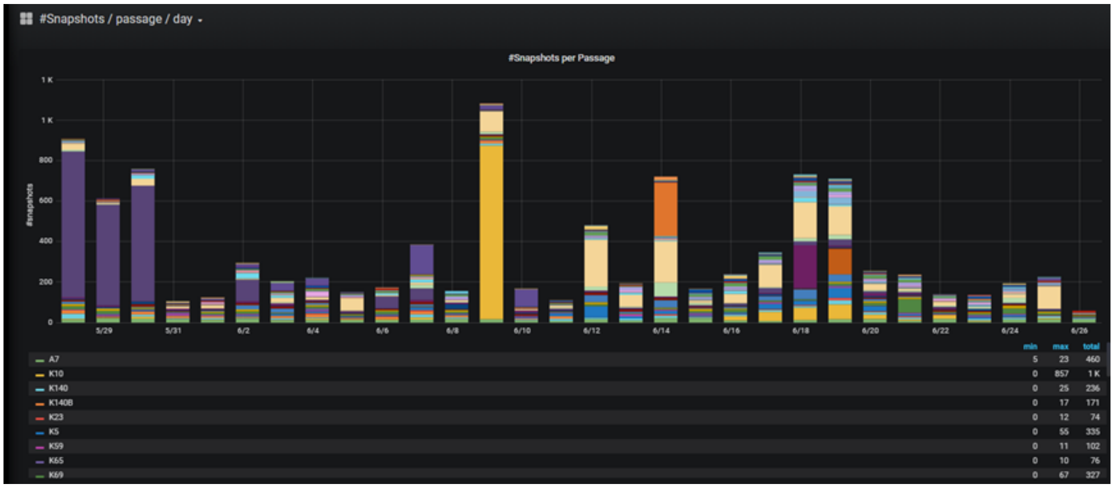
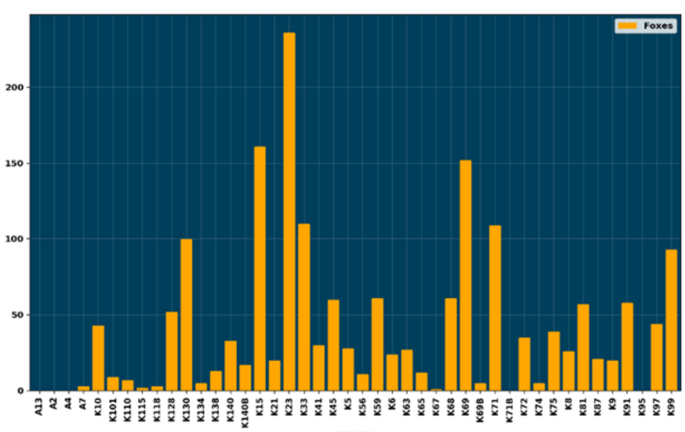
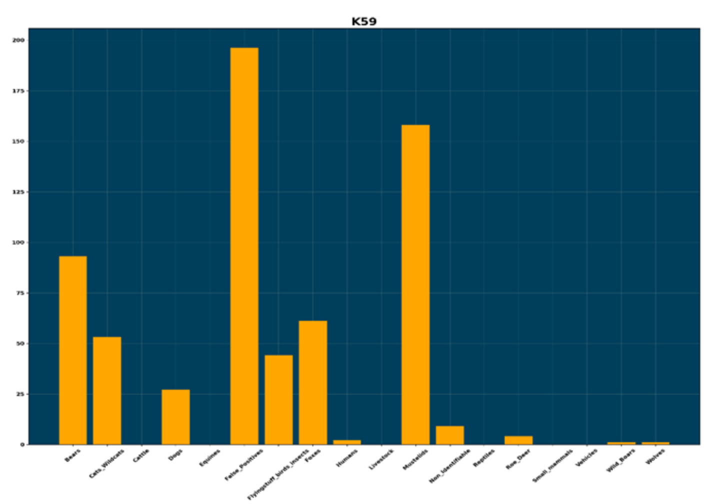


Figure 4.1.7. : Zero-touch statistics: Snapshots / day / underpass (http://193.218.97.145:3000/d/KtvYcU9mz/snapshots-passage-day?orgId=1)

- Innovative tools for zero touch statistics. Extraction of graphs such as: #snapshots/day/week/…/underpass, #appearances of spices per underpass, #appearances of a specific species per underpass, without user intervention | http://193.218.97.145:8081/plots/ (see Figures **4.1.8 & 4.1.9**).
-

Figures 4.1.8 & 4.1.9: Zero-touch statistics: Frequency of use of a specific species per underpass (for all underpasses and species) *(Indicative charts for bears and foxes)* (http://193.218.97.145:8081/plots/Species-Objects%20distribution%20per%20underpass/ Zero-touch statistics: Frequency of use by species/objects passed through a specific underpass (for all underpasses and species) *(Indicative charts for K59 and K69 underpasses)*





(http://193.218.97.145:8081/plots/Species-Objects%20per%20underpass/)

4.1.2. End to End solution benefits:

The solution exhibits a long list of benefits esp. for the environment, but also for the human resources required for the manual processing of the huge number of the collected snapshots/videos. More specifically, the solution:

1. Eliminates the need for on-site visits to cameras' installations for material collection (from the SD card), due to the utilization of wireless 4G cameras with very high autonomy enhanced by small photovoltaic panels along with the introduction of automated procedures for the uploading (and storage) of the cameras' material to COSMOTE's cloud infrastructure.
2. Supports automated procedures for (near-real time) detection and classification/categorization of passing animals / objects as well as the exporting of statistics / usage graphs, which is a painstaking and time-consuming work due to the huge amount of material to be processed; done manually so far. Note that these "object recognition tools" can be also utilized for offline detection and classification of species by processing snapshots/videos that have been gathered by cameras that have been installed in the rest countries of the project.
3. It combines low cost with ease of installation but most importantly, it is an expandable and reusable, (even) in other countries, solution, as all you need is a wireless 4G camera with a SIM card and a photovoltaic panel.

As such, it is expected:

- An 80% reduction of the time required to process (and categorize into species/objects) of cameras' content (more than 60.000 photos)
- An 80% reduction of the time required to export of statistical data / charts due to the automated procedures supported by the solution
- An 95% reduction of the on-site visits at the installation locations of the cameras for material gathering, with consequent economic and environmental benefits.

4.1.3. Species Classification / Achievements

The results of this process can be summarized as follows:

- **Bears: >80%** | can be further improved by adding more images in the dataset
- **Dogs: >90%**
- **Sheep: >95%**
- Foxes: 70% | can be further improved by adding more images in the dataset
- Skunks and small mammals: 60% | model trained with relatively low #snapshots, night shots, etc.
- **Human/Persons: ~100%**
- **Cars: ~100%**
- **Tractors: ~100%**
- **Landscape (no wildlife presence): >80%** | no wildlife detected
- Non-Identifiable | not detected/recognized by the model

As noted above, we have collected more than 60.000 images. These images shall be "categorized" on a per species/object and on per underpass basis, in order to extract information regarding not only the frequency of species passing through an underpass but also the use of the underpasses by a specific species, that is which underpasses used e.g. by bears, by foxes, etc.

To reduce the huge overhead required for the above process to complete to the absolute minimum, we have developed a tool which not only generates the required statistics/graphs with a click of a button but also enables their visualization through the web portal in an automated way.

The relevant statistics are shown below (fig. 4.1.10).

http://193.218.97.145:8081/plots/Species-Objects%20distribution%20per%20underpass/

http://193.218.97.145:8081/plots/Species-Objects%20per%20underpass/

Fig. 4.1.10 Graphs from the generated required statistics produced by the classification tool algorithm. (species/objects by Crossing Structure).

4.2. CALLISTO

4.2.1 Underpasses typology outcome:

Callisto’s project partner field team screened in the field all (149) structures along A29. All data on features, characteristics, use by wildlife species etc, of the crossing structures have been recorded using the template data base field form (v.2) prepared by Minuartia (fig.4.2.1.1 template field form extract)

Identification and location of the structure	STRUCTURE CODE:
Road code:	PK:
Road stretch:	Coordinates (X,Y):

Main structural features

Type of non-wildlife crossing structures (With NO particular adaptations for wildlife)	Type of Wildlife crossing (Specific for wildlife or adapted to allow fauna use)
☐ Tunnel (TUN) ☐ Overpass (OVP) ☐ Viaduct (VIA) ☐ Underpass (UNP) ☐ Culvert / drainage (CUV) ☐ Other:	☐ Ecoduct (ECO) ☐ Wildlife Overpass (WOP) ☐ Multi-use Overpass (MOP) ☐ Wildlife Underpass (WUP) ☐ Multi-use Underpass (MUP) ☐ Modified culvert (WCU) ☐ Amphibian tunnel (ATP)

Road transversal section:
☐ Flat ☐ Embankment ☐ Cutting ☐ Slopes combination

Structure section:	Composition of the structure:
☐ Circular ☐ Rectangular ☐ Vault ☐ Other:	☐ Simple ☐ Double ☐ Triple ☐ Other:

Visibility of opposite entrance: ☐ 0% ☐ 25% ☐ 50% ☐ 100%

Dimensions (m):
Height (H): Width (W): Length (L): Openness Index (Section/L):

Multicellular
Height (H): Width (W=W1+W2): Length (L): Openness Index (Section/L):

Construction material:
Structure ☐ Concrete ☐ Corrugated steel ☐ Other:
Substratum material ☐ Concrete ☐ Corrugated steel ☐ Natural substratum (%): ☐ Other:

Presence of water:
☐ No ☐ Yes, permanent ☐ Yes, temporal Water layer depth (cm): Surface covered by water (%):

Dry ledges:
☐ One side Material: Width (m):
☐ Both sides Material: $Width_1$ (m): $Width_2$ (m):

Uses of the passages:
☐ Cattle trail ☐ Pedestrian trail ☐ Forestry road (unpaved) ☐ Paved road
☐ Water channel ☐ Stream crossing ☐ Other:

Other features:

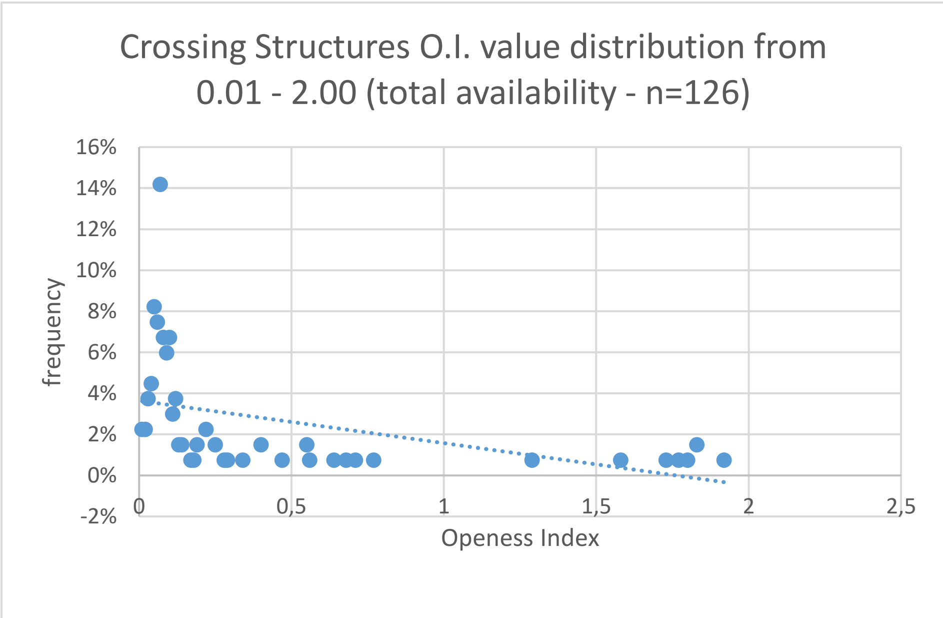
Inspected by:	Date inspection:

minuartia LIFE SAFE CROSSING - LIFE17 NAT/IT/000464 – Transversal structures inspection

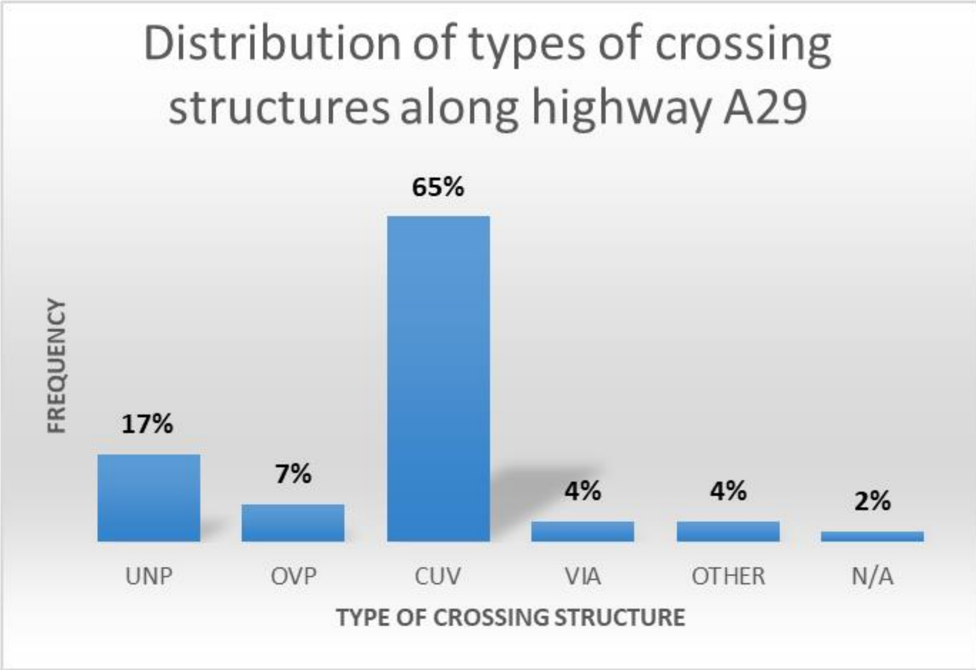
The typology of the crossing structures was performed in the field by a (4) membered field team over 2 weeks. For each crossing structure a detailed fact sheet was elaborated and containing photos of both entrances, surrounding vegetation and micro-environment features (see fotos 4.2.1.2 – 7).

Fotos 4.2.1.2-7: field team members from Callisto during fieldwork for crossing structures typology.

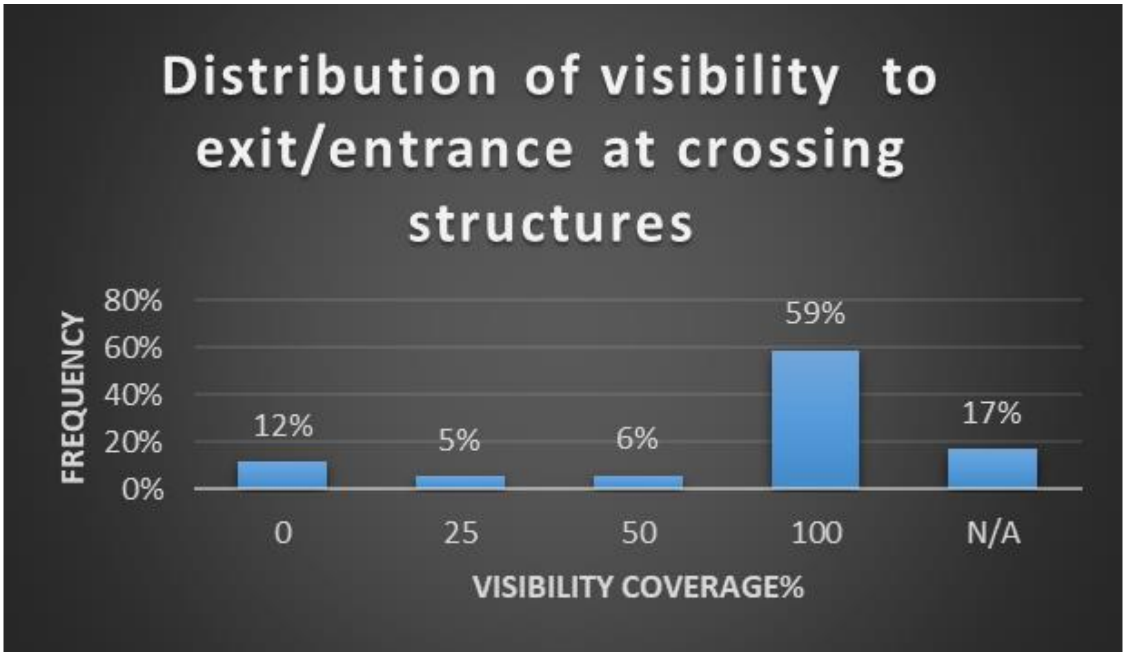
Following data entry, a first data processing was performed based on the set of the different components and parameters characterizing the crossing structures and included in the aforementioned standardized field form. This processing resulted in the production of graphics in order to better illustrate the profile and functionality (in terms of use by wildlife) of the investigated structures. To start, the Openess Index)O.I.) of the different types of crossing structures is illustrated in the following graph (also presented in sub-chapter 4.3. (EOSA Results) after being processed by Callisto's project partner team. Graph (4.2.1.2) shows the overall distribution of the O.I. values (from 0.01-2.0) for the total number of crossing structures.

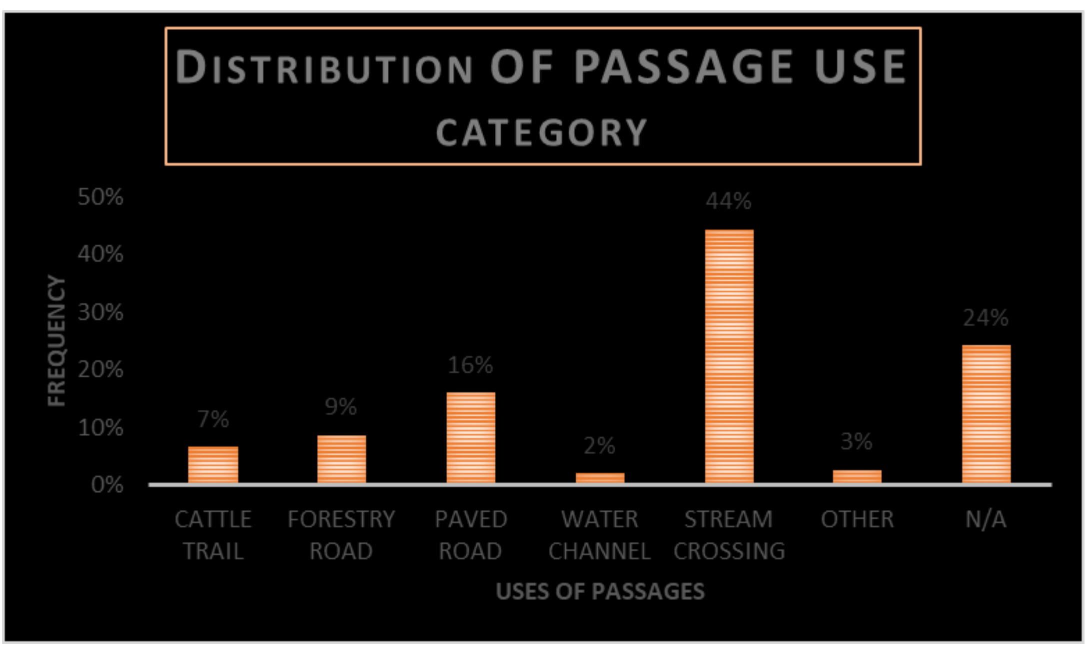


The total distribution (availability) of the different types of crossing structures is illustrated on graph (4.2.1.3).

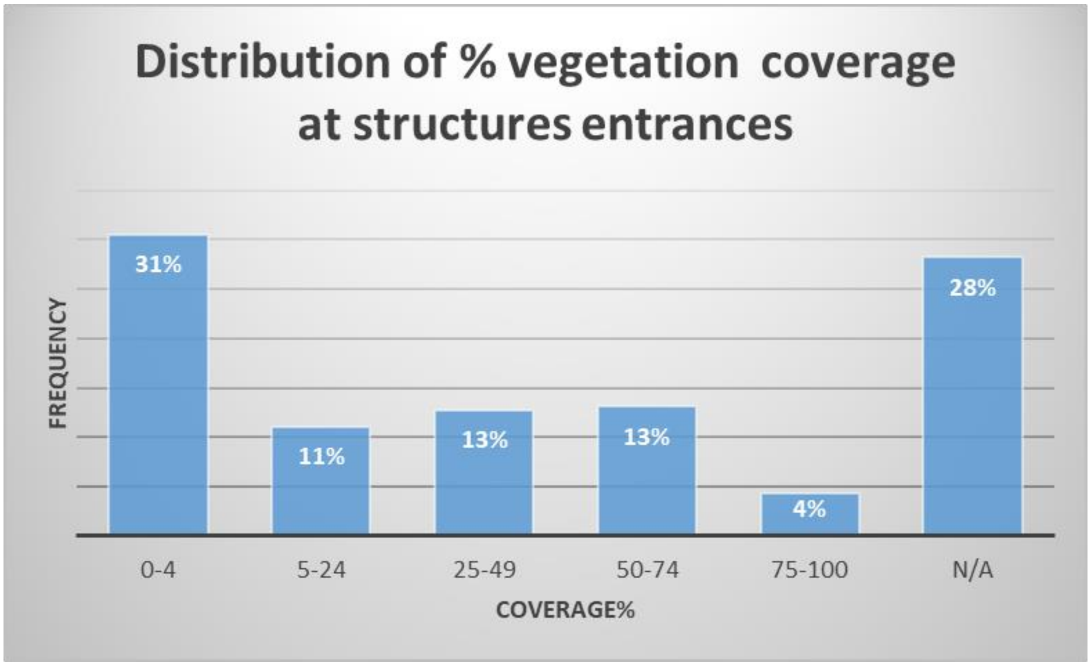


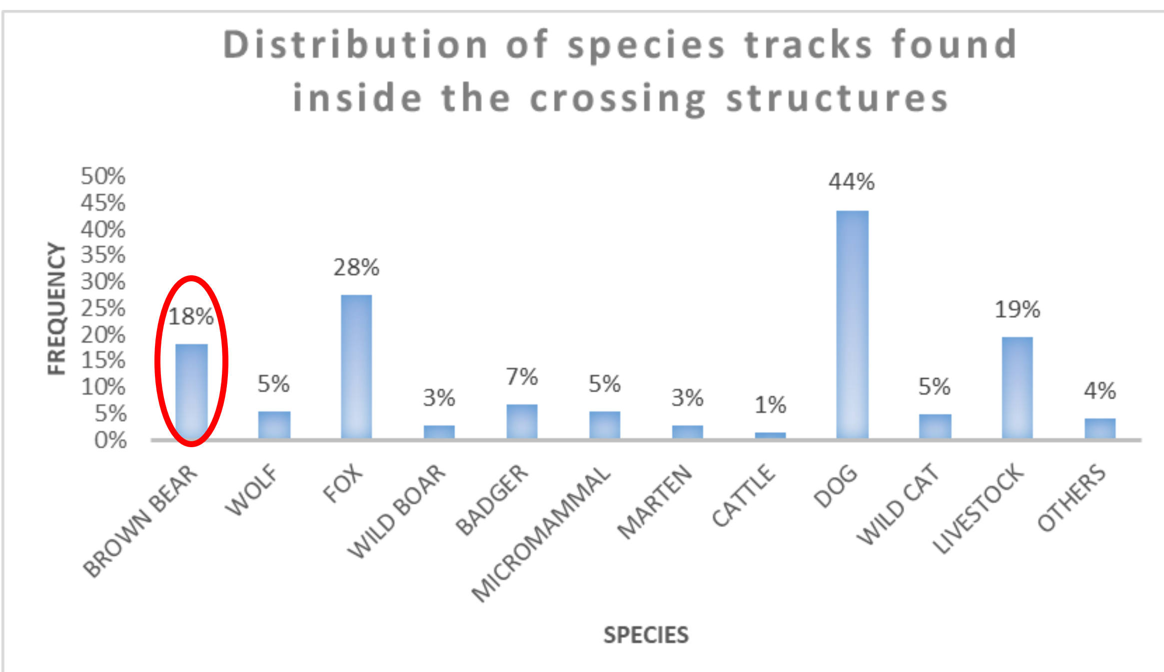
The visibility related to the opposite exit/entrance which is also related to coverage around each crossing structure as well as the use category of crossing structures/passages are presented on graphs (4.2.1.4, and 4.2.1.5) respectively.



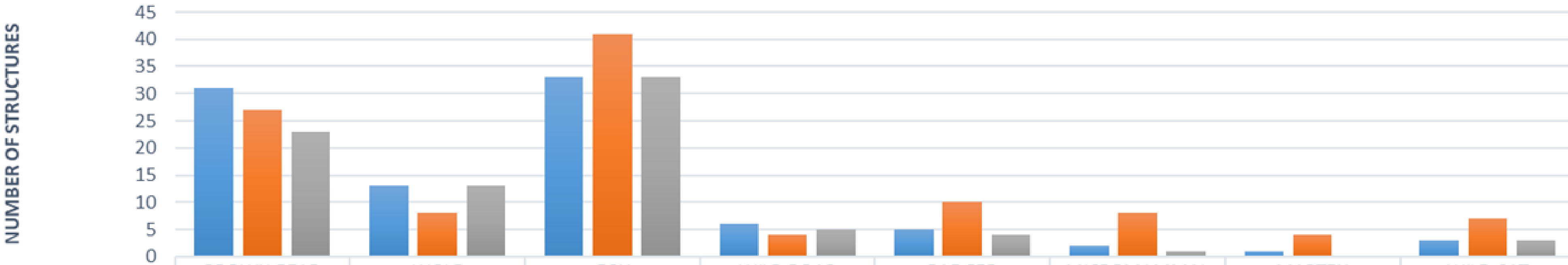


The distribution of the % of vegetation coverage at all investigated crossing structures as well as frequency of occurrence of different wildlife species detected inside but also outside (but at a close distance from the passages during fieldwork typology are presented on graphs 4.2.1.6, 4.2.1.7 & 4.2.1.8.





DISTRIBUTION OF WILDLIFE SPECIES FOUND INSIDE AND OUTSIDE PASSAGES



	BROWN BEAR	WOLF	FOX	WILD BOAR	BADGER	MICROMAMMAL	MARTEN	WILD CAT
ENTRANCE 1	31	13	33	6	5	2	1	3
INSIDE PASSAGE	27	8	41	4	10	8	4	7
ENTRANCE 2	23	13	33	5	4	1	0	3

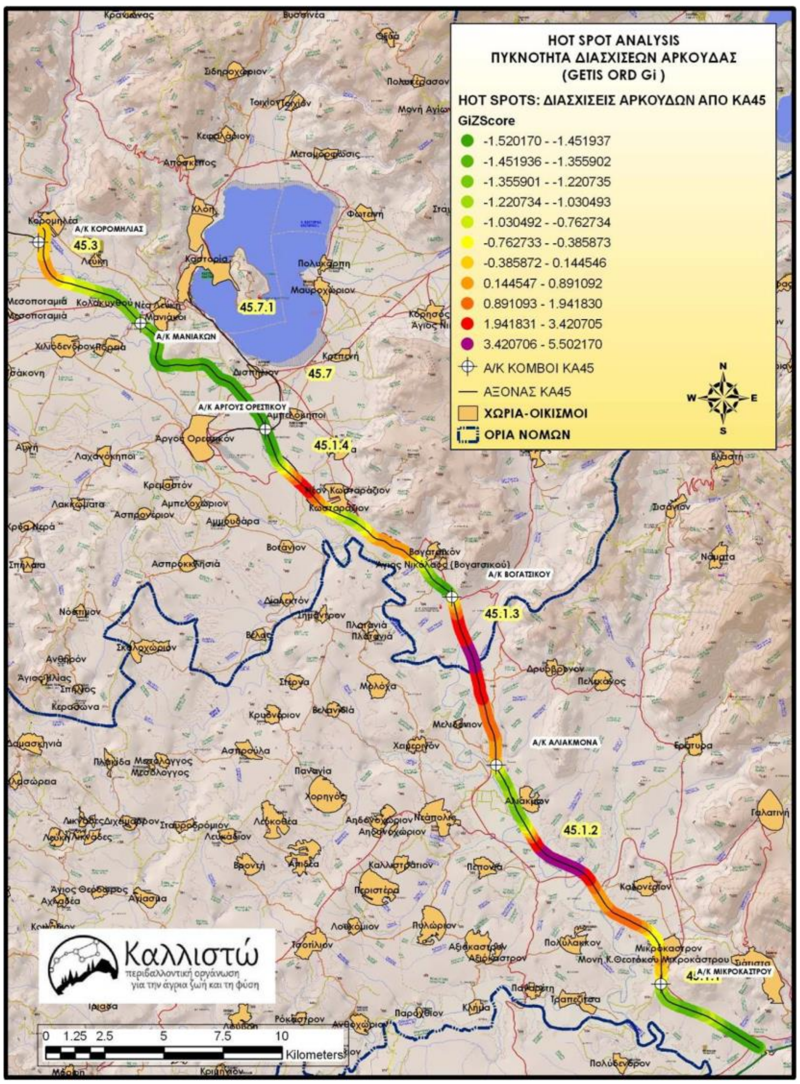
WILDLIFE SPECIES

ENTRANCE 1 INSIDE PASSAGE ENTRANCE 2

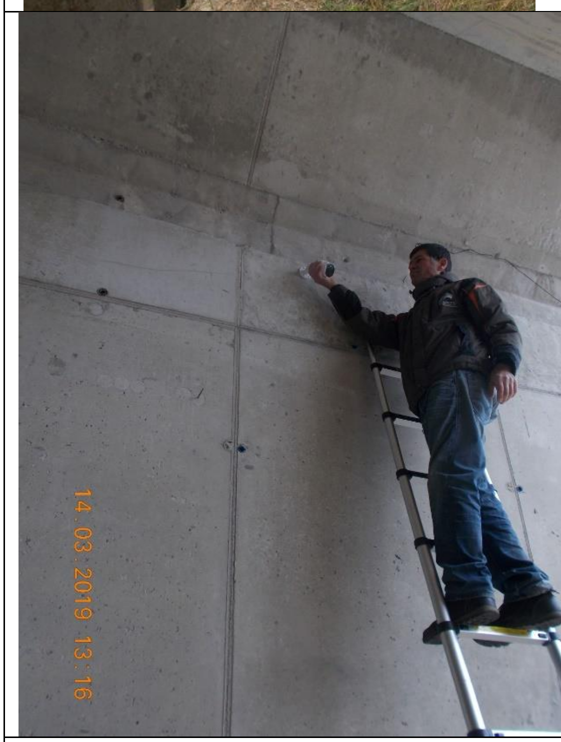
4.2.2. Choice of crossing structures – installation of IR video cameras

The choice of the crossing structures for cameras installation and monitoring was based, as mentioned before on (4) main criteria as follows:

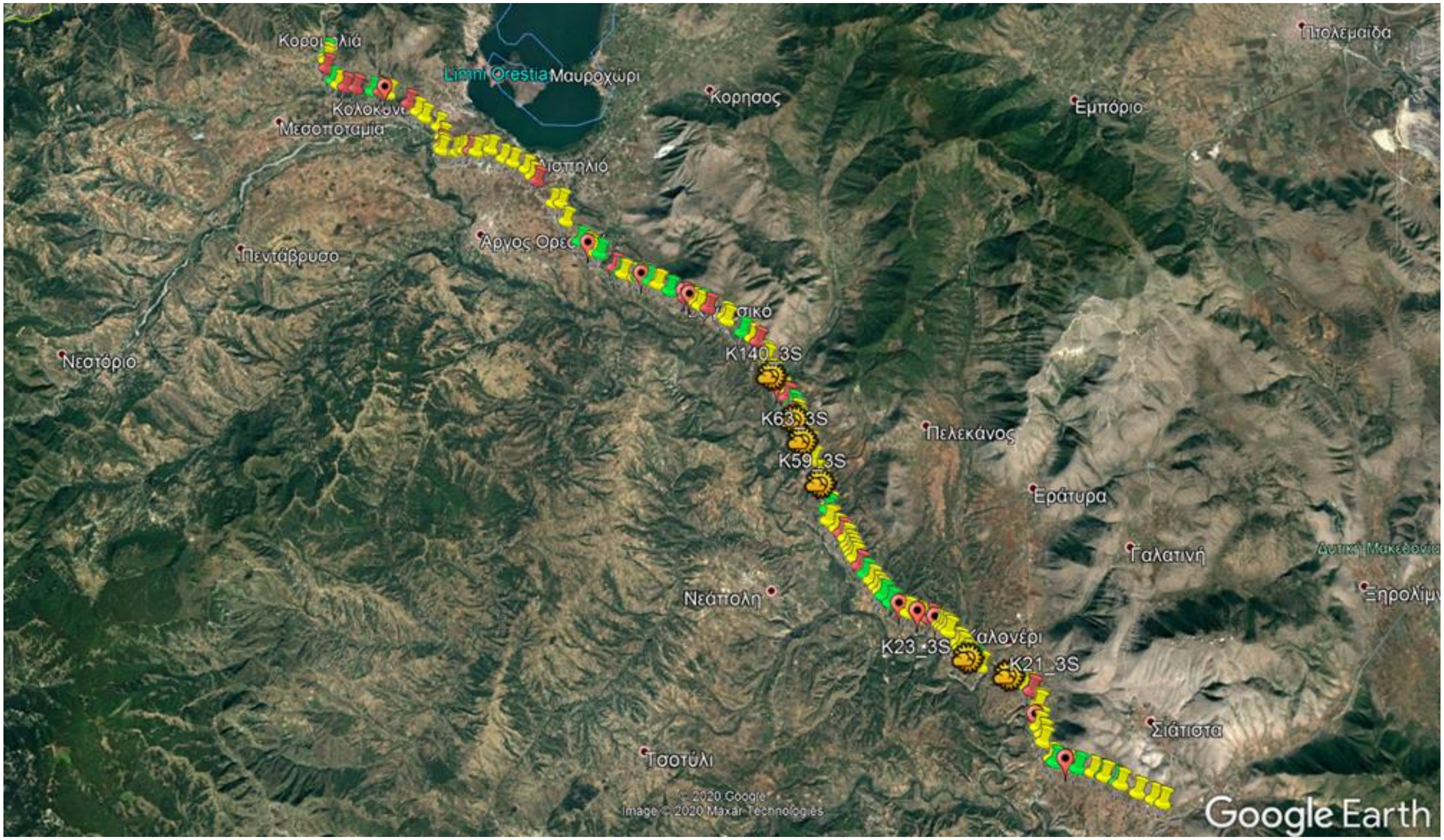
1) Classification of highway A29 sub-segments according to intersections with bear crossing routes evidenced by (a) telemetry data of a sample of (11) radio-tagged bears in 2011-12 **(n= 20.863 radiolocations)** under project LIFE09NAT/GR/00333 (LIFE "ArcKas"), (b) traffic fatalities incidents from a sample of (21) bear car collisions along A29, (c) old fence trespassing points by bears (n=383) (see map 4.2.2.1).
2) Findings of bear signs and tracks inside or at the entrances of the crossing structures during th in situ typology process
3) Expert opinion
4) Mobile telephony coverage in order for the cameras to be able to store and transmit audio-visual data and other applications functions on COSMOTE's cloud.



The installation of forty five (45) IR video cameras was performed by the (4) membered Callisto's field team in summer 2019 over a period of 4-5 weeks (see fotos 4.2.2.2 – 5). Monitoring of cameras status and performance was implemented both by COSMOTE crew and by one member from Callisto project partner. The locations of the monitored crossing structures are presented on map 4.2.2.6.



Fotos 4.2.2.2.-5: IR cameras installation by Callisto field team.

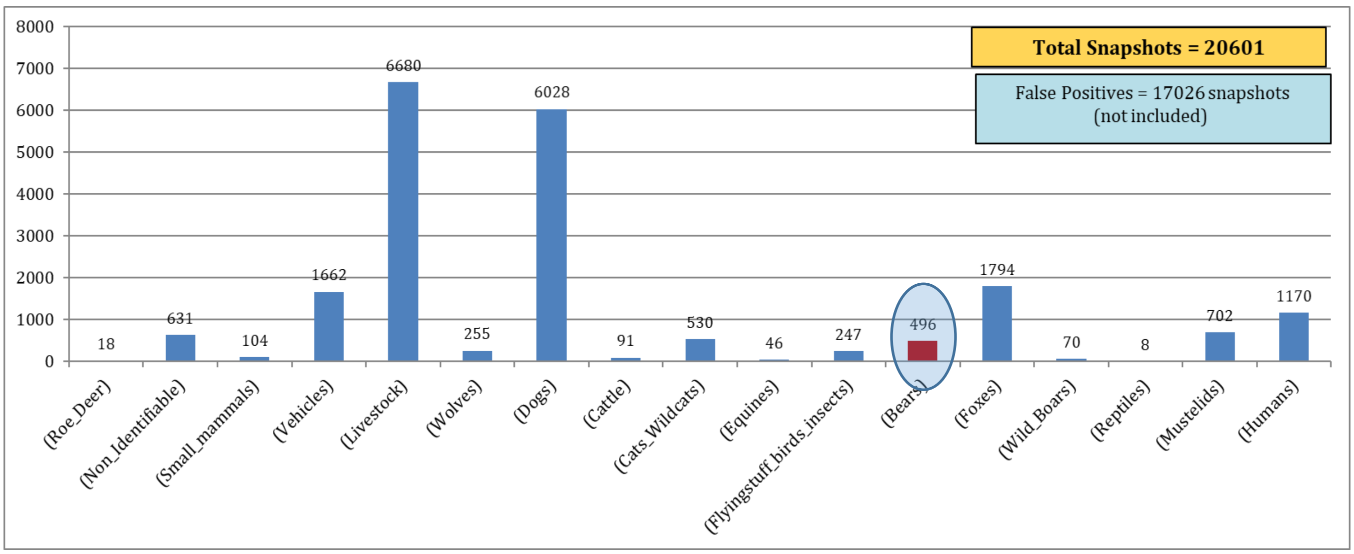


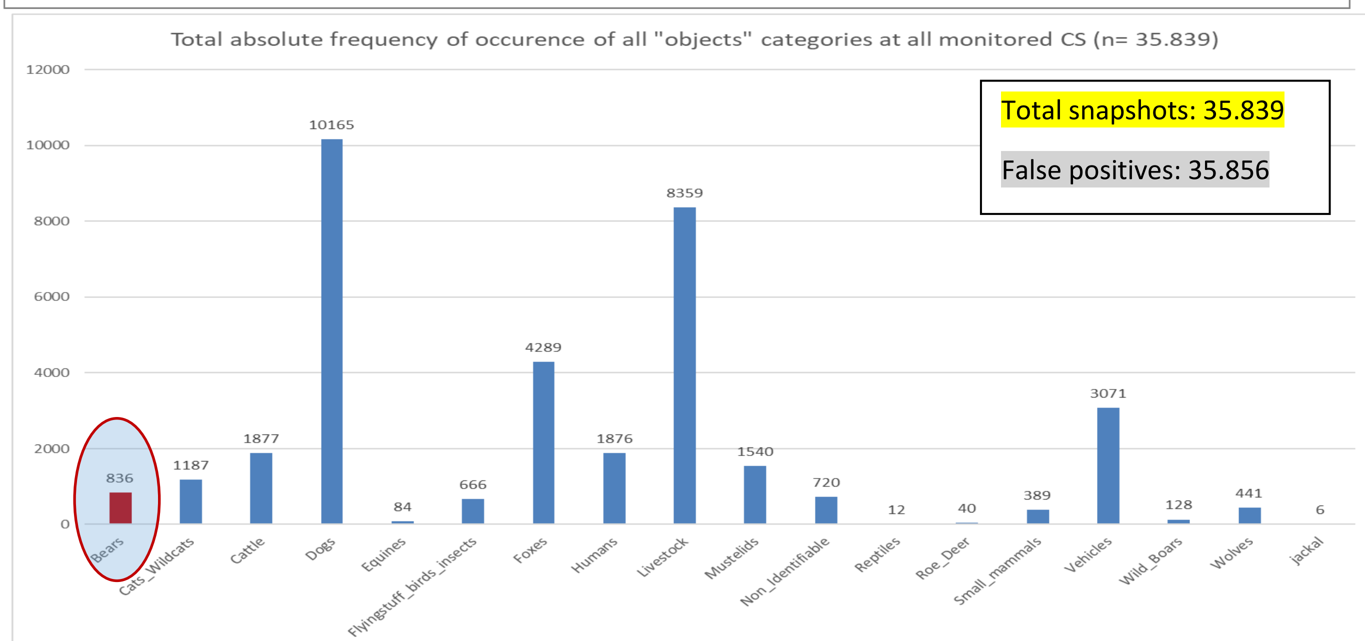
Map 4.2.2.6: distribution of all the crossing structures along highway A29. The different symbols (pins) interpretation is as follows: (**a) yellow pins**: distribution of all (149) inspected crossing structures along highway A29– **(b) green pins**: distribution of IR cameras monitored crossing structures – **(c) red pins**: distribution of additional crossing structures candidate for upgrading (Callisto field team proposed during underpasses typology process) before the in situ inspection by EOSA team member- (d) “sun” pins: underpasses used by bears during all (4) seasons of the year (monitoring period).

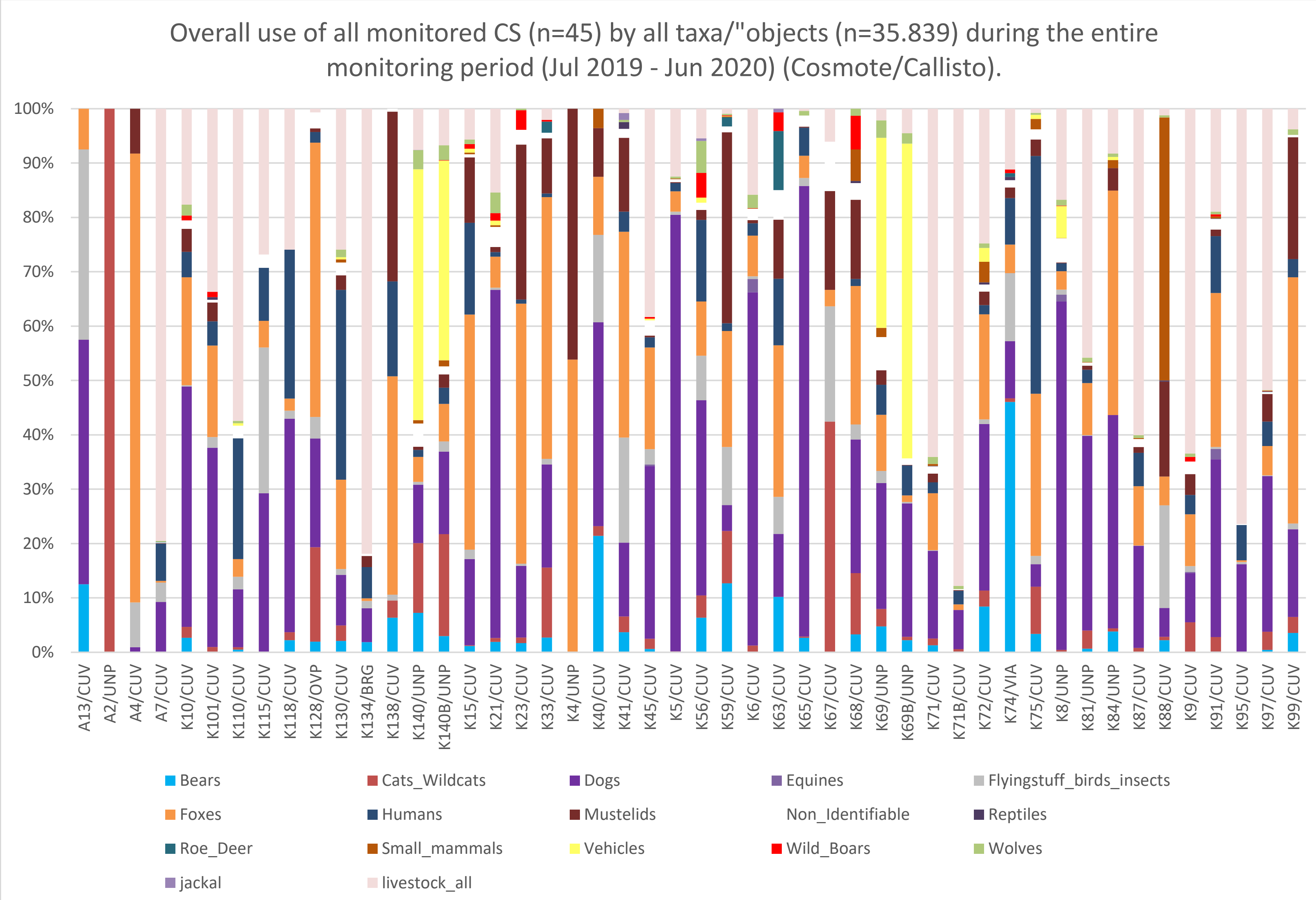
4.2.3. IR Cameras operation, outcome and data processing (COSMOTE/Callisto):

The IR cameras operated over a period of ~ (12) months from **July 2019** to June **2020.** They generated a total of circa **71.695** snapshots and videos. The recording period was divided into two sub-periods in order for the teams from Callisto and COSMOTE to better process the massive outcome as follows: (a) first recording period **July 2019 – January 2020** and (b) second recording period **February 2020 – June 2020**. The IR cameras outcome was processed following the (2) sub-periods after reclassification of all species ("objects") species recorded with the assistance of the classification tool developed by COSMOTE and described. The overall results for "objects" (taxa) having used all the monitored CS from the first sampling period (July 2019 – January 2020) with (**496**) cases of brown bear use and from the total period with a total of (**836**) cases of brown bear use are presented in the following graphs 4.2.3.1 – 3):

Fig. 4.2.3.1,2 & 3: First period (Jul 19-Jan20) and total period (**Jul 2019- Jan 2020)** taxa/"objects" use frequency of all 45 monitored CS and respective brown bears comparative use frequency.

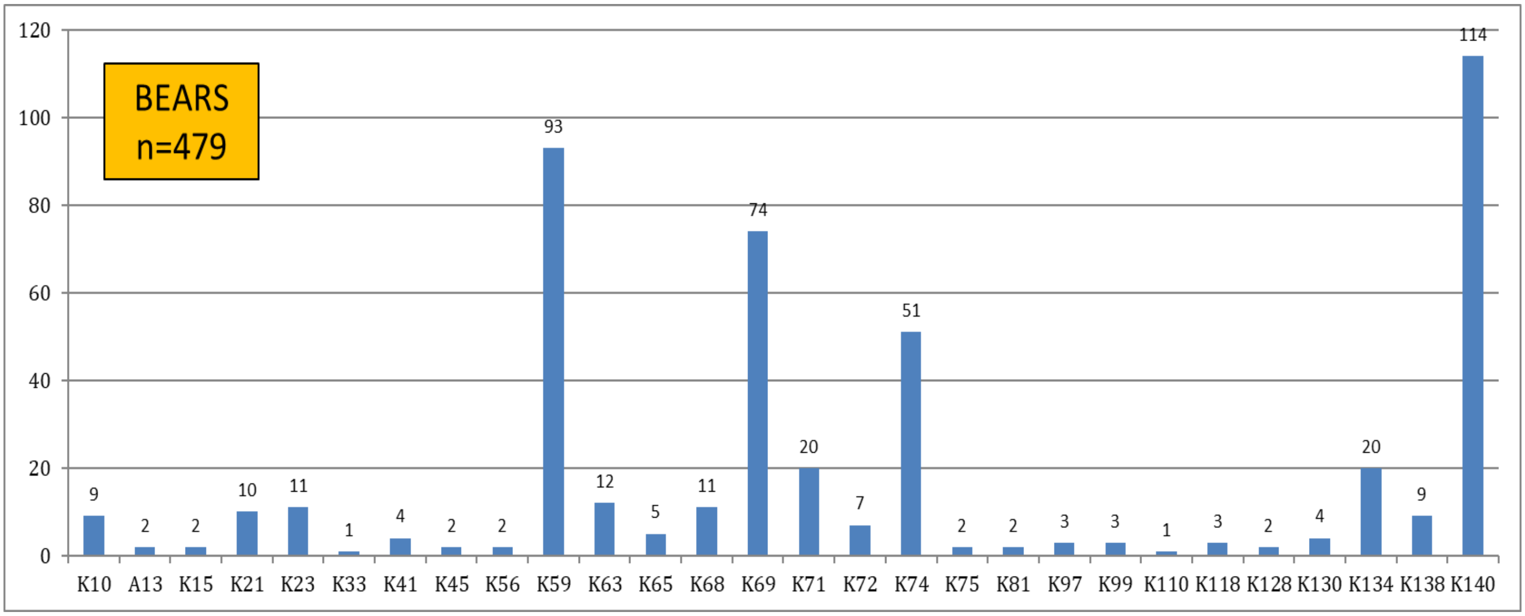


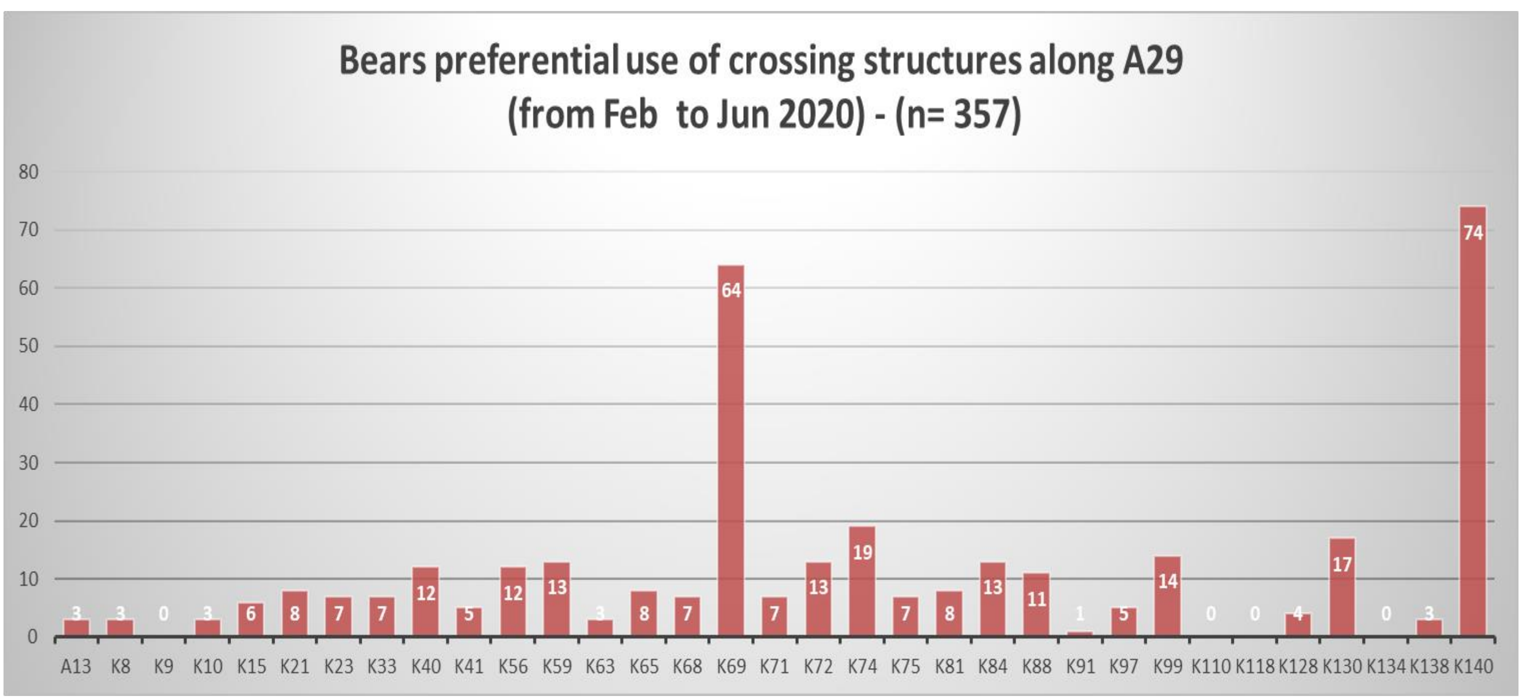



Overall use of all monitored CS (n=45) by all taxa/"objects (n=35.839) during the entire monitoring period (Jul 2019 - Jun 2020) (Cosmote/Callisto).
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
A13/CUV A2/UNP A4/CUV A7/CUV K10/CUV K101/CUV K110/CUV K115/CUV K118/CUV K128/OVP K130/CUV K134/BRG K138/CUV K140/UNP K140B/UNP K15/CUV K21/CUV K23/CUV K33/CUV K4/UNP K40/CUV K41/CUV K45/CUV K5/CUV K56/CUV K59/CUV K6/CUV K63/CUV K65/CUV K67/CUV K68/CUV K69/UNP K69B/UNP K71/CUV K71B/CUV K72/CUV K74/VIA K75/CUV K8/UNP K81/UNP K84/UNP K87/CUV K88/CUV K9/CUV K91/CUV K95/CUV K97/CUV K99/CUV
Bears
Cats_Wildcats
Dogs
Equines
Flyingstuff_birds_insects
Foxes
Humans
Mustelids
Non_Identifiable
Reptiles
Roe_Deer
Small_mammals
Vehicles
Wild_Boars
Wolves
jackal
livestock_all

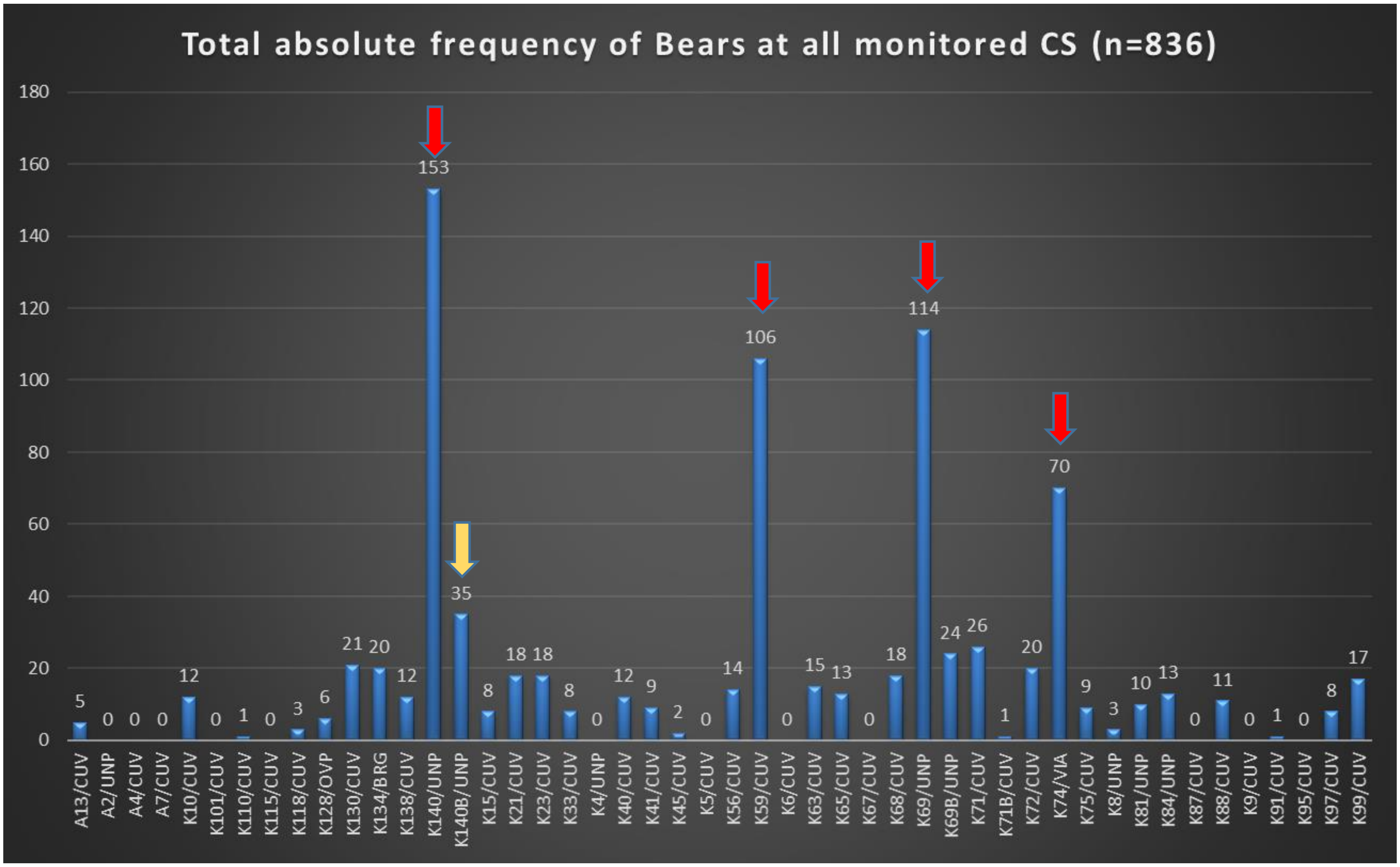
Regarding the preferential use of CS by bears during the first **(Jul 2019 – Jan 2020**) (**n=479**) and second (**Feb 2020 – Jun 2020**) (**n=357**) monitoring periods s along A29 as well as the overall use by bears (n=916) over the entire monitoring period **(Jul 2019 to Jun 2020**) are illustrated in the following graphics 4.2.3.3 - 5.

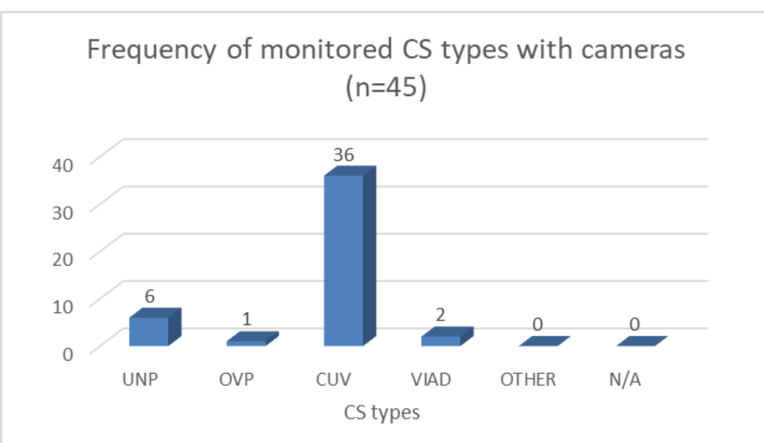
Fig. 4.2.3.(3 -5): Bears preferential use of monitored crossing structures over the 1st and 2nd monitoring periods (Jul 2019-Jan 2020) and (Feb 2020- Jun 2020) and over the total monitoring period (Jul 2019 to Jun 2020).

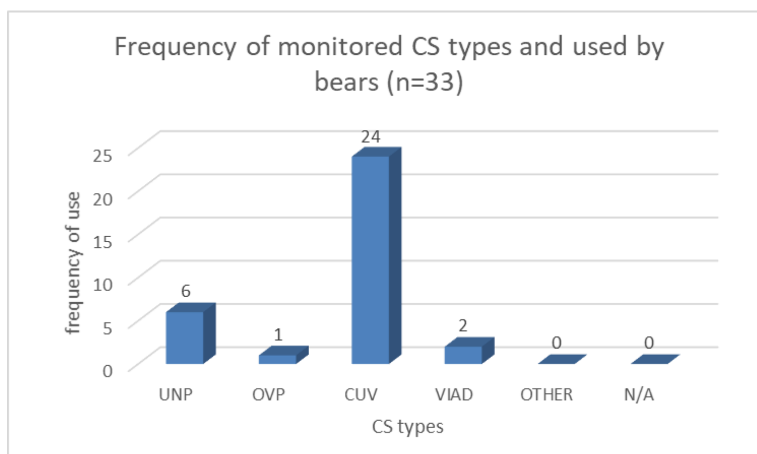




The distribution of the different types of the monitored CS as well as the distribution of their use by bears is presented in the following graphs (4.2.3, 6-7).







From the above graphics we can draw the following remarks:

1) Over a total of 45 IR monitoring cameras (7) (A4, K13, K31, K38, K40, K84 & K88) were placed at crossing structures without mobile telephony coverage and therefore these were checked manually by a Callisto's field team member on a regular time basis.

2) The separation of the two monitoring periods was also based on the bio-ecological criterium of bears mobility rate according to the hypophagia and hyperphagia periods in the year cycle, the former occurring in late winter and spring season whereas the latter occurs in late summer – fall period. These two periods may affect the spatio-temporal mobility of bears and thus the use of certain crossing structures.

3) During the first monitoring period (Jul 2019 – Jan 2020) we had (**479**) individual bear crossing cases and use of (31) out of (45) = **69%** of the IR camera monitored crossing structures along A29.

4) During the second monitoring period (Feb 2020 – Jun 2020) we had (**357**) individual bear crossing cases and use of (28) out of (45) = **62%** of the IR camera monitored crossing structures along A29.

5) During the overall monitoring period (Jul 2019 – Jun 2020) we had a total of (**836**) individual bear crossing cases and use of (36) out of (45) = **80%** of the selected and IR camera monitored crossing structures along highway A29. This overall rate of use by bears of the selected crossing structures shows a satisfactory level of representativity regarding the selected sample (n=45) of crossing structures to be monitored over a total number of (149) crossing structures.

6) By comparing the preferential use of the monitored structures over the two monitoring periods we observe that (24) out of (45) = **53.3%** are used by bears in both monitoring periods.

7) A markedly preferential use by bears for specific crossing structures has been observed and namely for (4) crossing structures which present common features regarding either (1) comfortable openness index (2) surrounding micro-environment which given the presence of natural vegetation and/or water provides a simulation of naturalness to the crossing structure. (see fotos 4.2.3 (5 , 6) and also photos of use by bears 4.2.3 (8,9, 10 & 11).

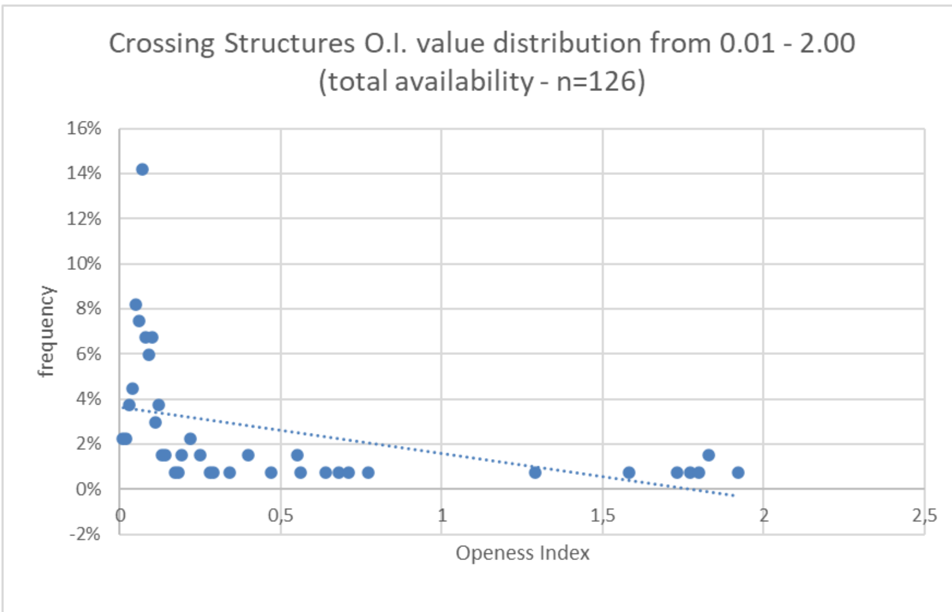
Fotos 4.2.3 (5&6) Configuration of two preferential crossing structures for bears along A29.

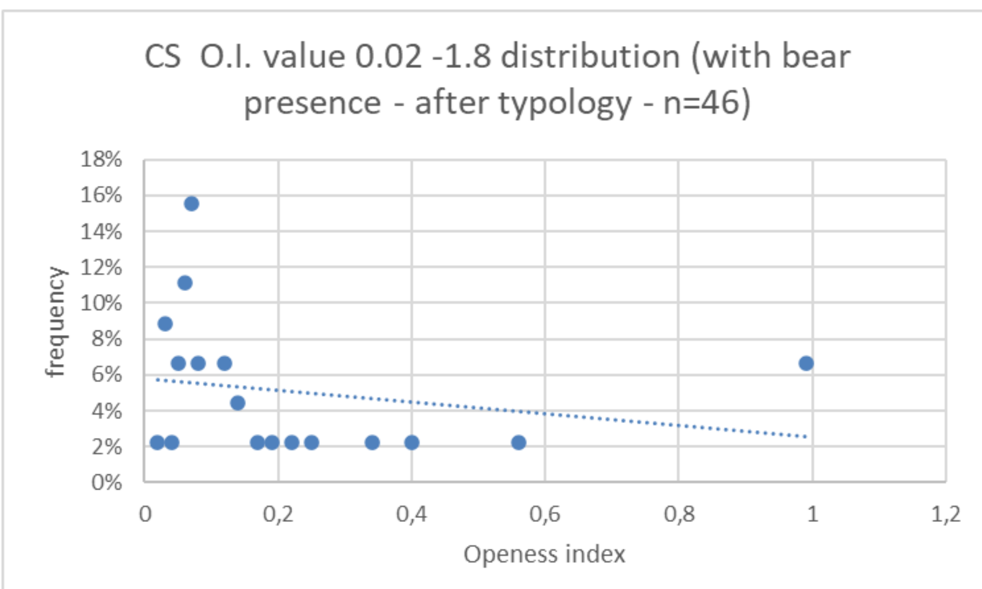
Fotos 4.2.3 (8-11): different bear individuals and females with cubs using the most preferential monitored crossing structures along highway A29.

All data produced at this first stage of action A4 implementation from the (45) IR cameras monitoring sessions, were sent to EOSA project partner, after the necessary processing, in order to be valorized at the next stage (of action A4) involving the final selection of crossing structures to be upgraded.

4.2.4. Further data processing – Statistics:

In several case studies through literature regarding CS characteristics analyses versus use by wildlife, it becomes increasingly evident that certain specific features of the CS's play a more important role for their functionality and their attractiveness to wildlife species. One of these key parameters/features of the CS's is the "Openness Index" (O.I.) a composite metric feature that makes the CS "appear" more "spacy" and thus more attractive for crossing by wildlife species. The overall availability of different classes of O.I. values of the investigated CS's along the studied A29 as well as the distribution of the CS's O.I. values used by bears (during the typology phase) are presented in the following figures 4.2.4 (1-2).





Other key variables such as micro-environment composition i.e. presence of water/streams, vegetation coverage at CS's entrances, as well as the passage use type (trail, forest road etc.) appear to also a play decisive role in their choice by wildlife species and more specifically by the targeted species Ursus arctos. In the following figures we illustrate the results of testing the role of the aforementioned parameters and variables using non-parametric statistics, as the Shapiro-Wilk normality test data, showed that our data were not normally distributed (W = 0.50067, p-value = 3.65e-11 p<<0.05).

According to the above results we used three types of non-parametric tests: (a) "Pearson-Spearman's" correlation index for the continuous variables, (b) "Kruskal-Wallis" test and (c) Mann-Whitney test for the categoric variables. We tested the bear crossing events (as the dependent variable) versus the following independent variables (based on the CS's typology): (a) "Openness Index", (b) presence of water, (c) Vegetation coverage at entrances, (d) CS passage use category and (e) CS type. We also tested the hypothesis of differential use of CS across the (2) monitoring periods.The results are presented in the following figures 4.2.4 (1-6):

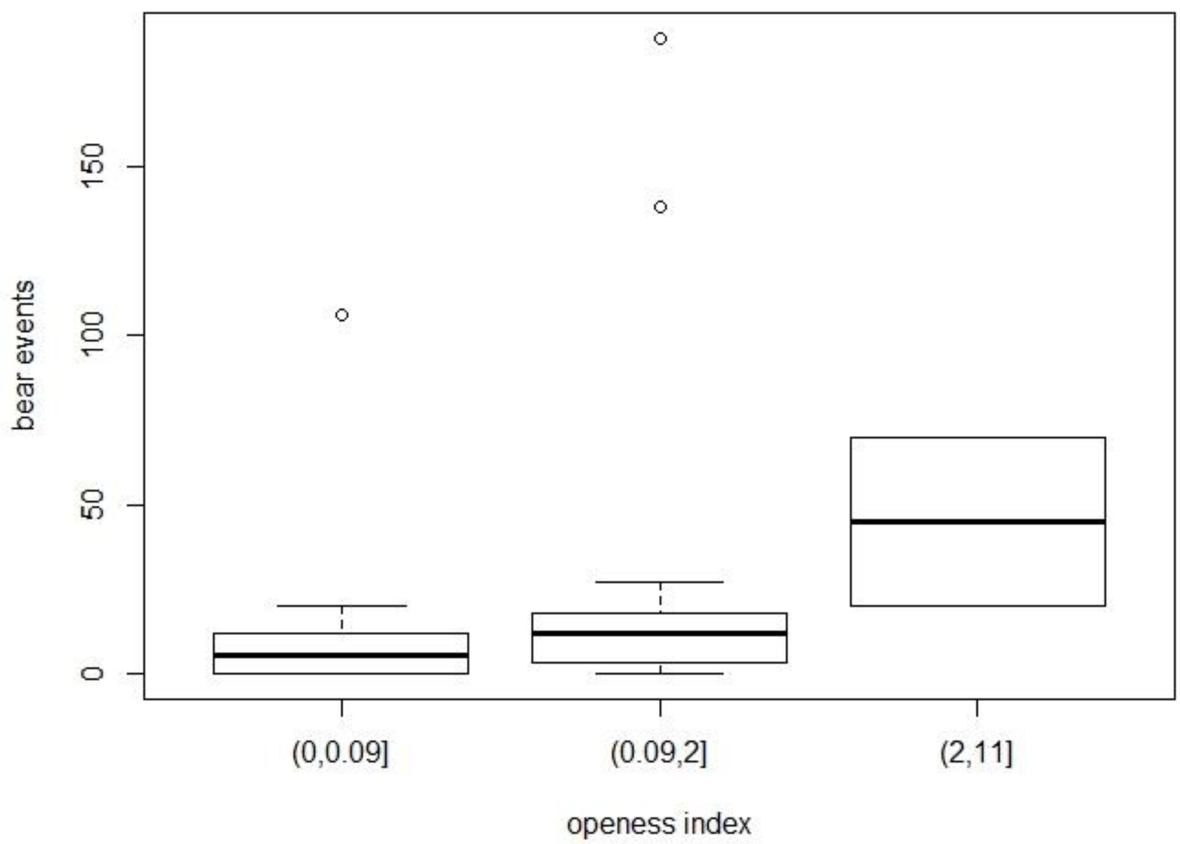


Fig. 4.2.4 (1) : Bears statistically significant preferential use of CS's with higher O.I. - Kruskal-Wallis chi-squared = 6.5658, df = 2, p-value = 0.03752

Fig. 4.2.4(2): Bears statistically significant preferential use of CS's with presence of water (streams with permanent or intermittent water) - Mann-Whitney test - Wilcoxon rank sum test with continuity correction data: W = 98.5, p-value = 0.01027.

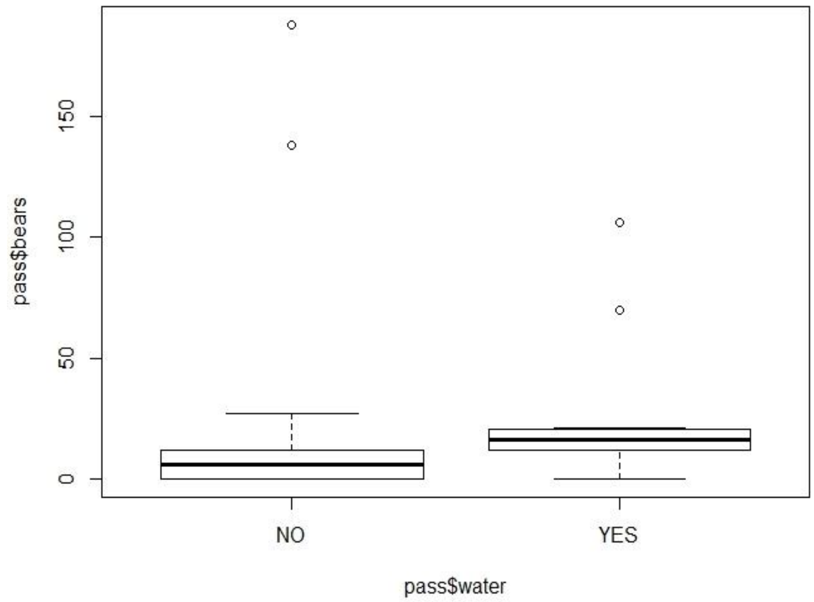


Fig. 4.2.4(3): Bears statistically significant preferential use of CS's with presence of vegetation coverage at the entrances – (Spearman's rank correlation rho=**0.3486788** - S = 9887.1, p-value = 0.01891). N.B. The corr index is lower than threshold values (0.50) as mentioned in relevant literature (Cervinka et al. 2015)

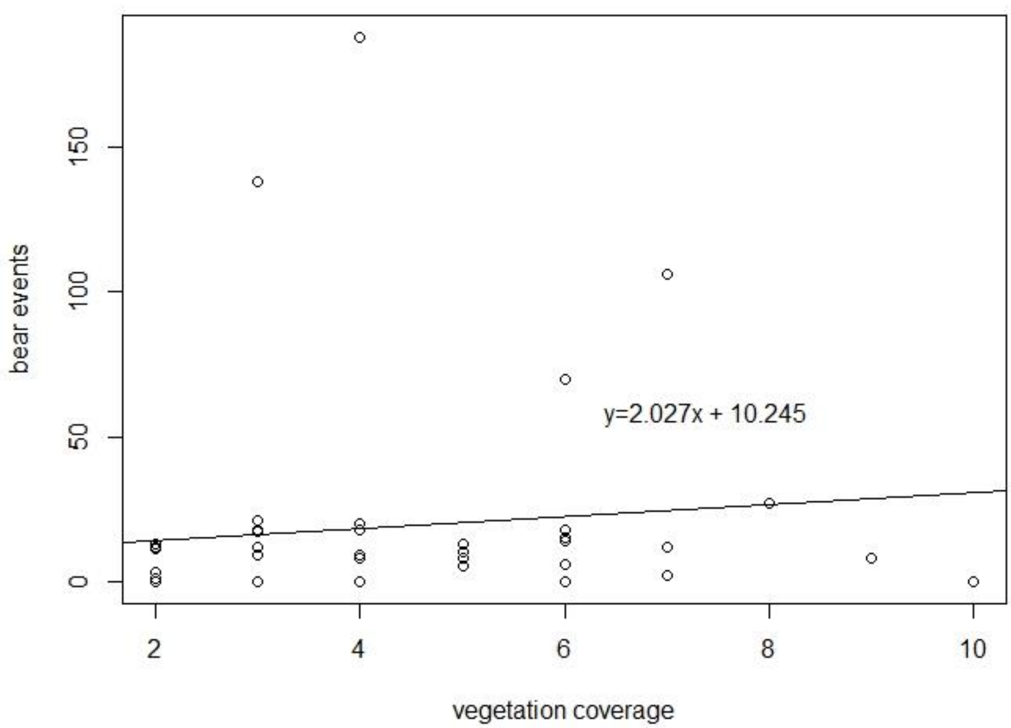
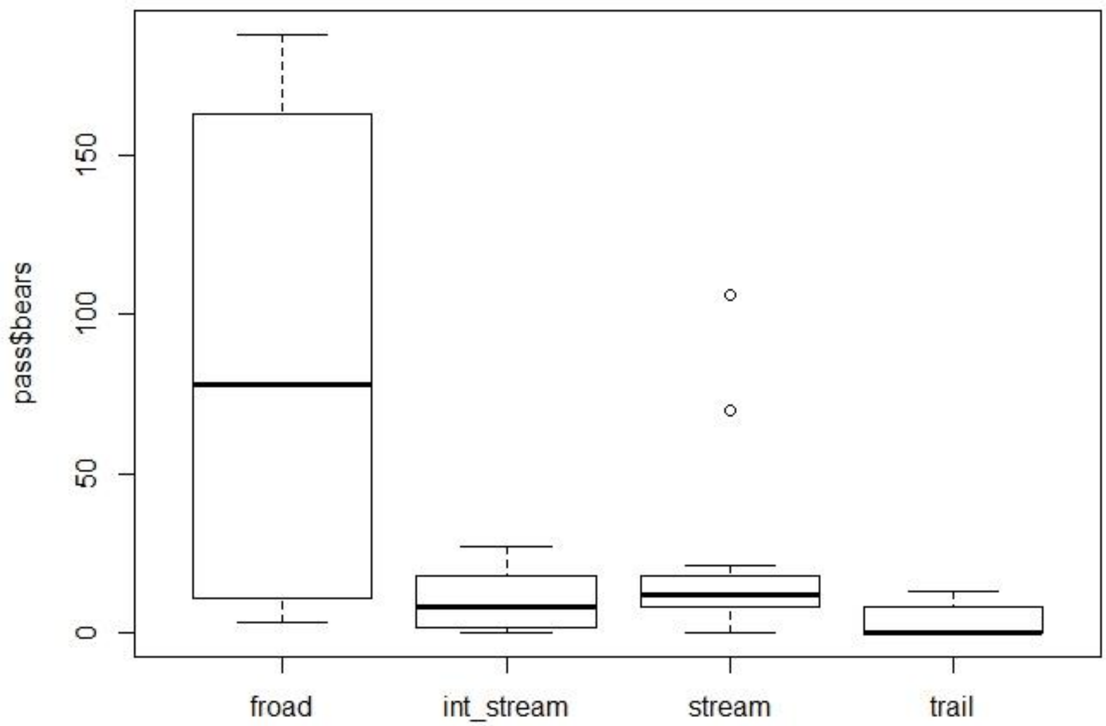
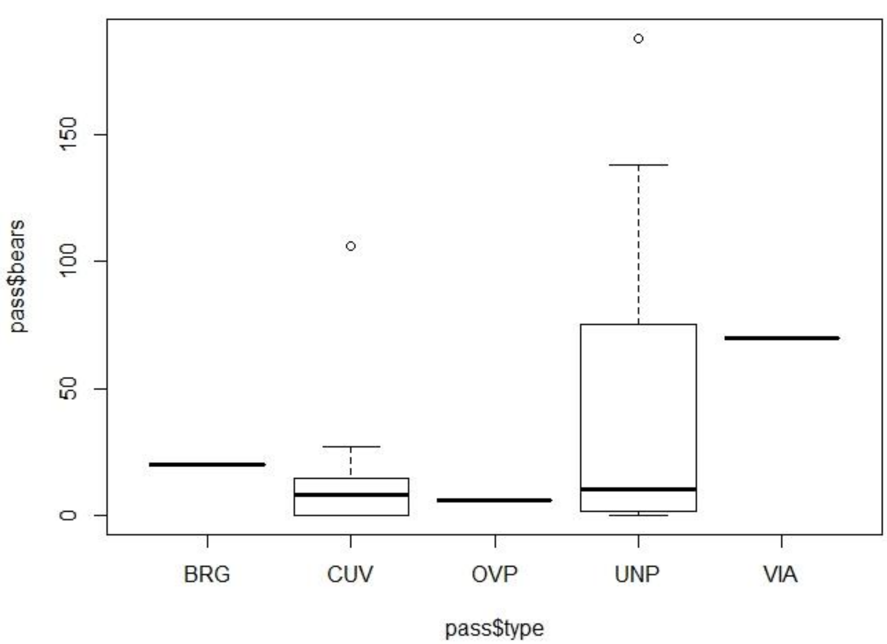
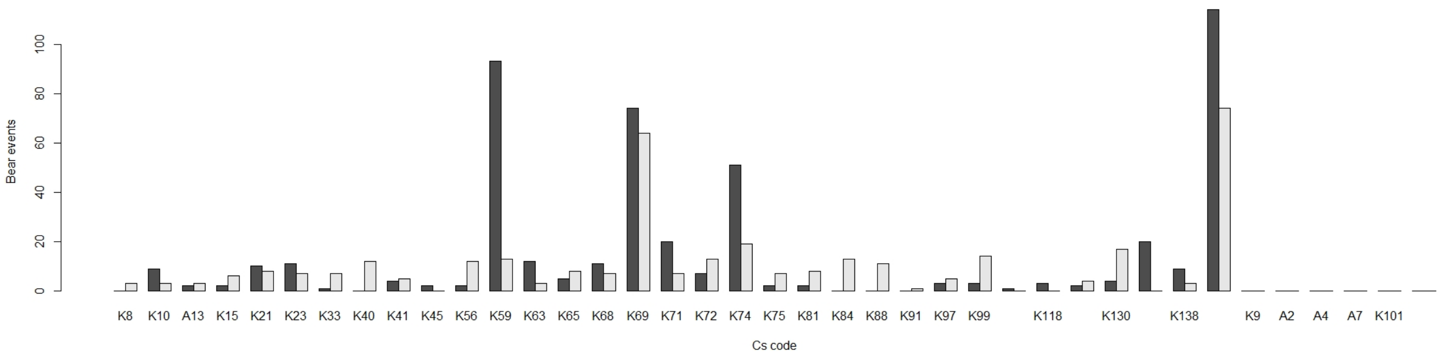


fig. 4.2.4. (4): Bears statistically significant preferential use of CS's with forest roads - Kruskal-Wallis chi-squared = 10.952, df = 2, p-value = 0.004187**. Fig 4.2.4.(5)**: Bears preferential use of CS type "UNDP" = "underpasses" - Kruskal-Wallis chi-squared = 4.1137, df = 4, p-value = 0.3908 (non significant).





Finally we did not detect any seasonal differences in overall CS structures use by bears. A hypothesis that could have been expected to be related to hypophagia and hyperphagia periods as bears might follow different routes and thus use different CS's with different intensity. (V = 285, p-value = 0.943 , paired Mann-Whitney (Wilcoxon) rank test with continuity correction) **Fig 4.2.4 (6).**



4.3. EOSA:

4.3.1. Timeline of the field activities/inspections

The implementation of the field visits took place on the following 8 days (in parenthesis the crossing structures with their code):

20th March: 8 crossing structures (K1, K2, K5, K6, K6b, K8, K10, K11)

9th April: 7 crossing structures (K17, K18, K19, K21, K23, K25, K32)

10th April: 9 crossing structures (K40, K41, K43, K44, L45, K46, K47, K50, K52)

14th April: 17 crossing structures (K54, K55, K56, K59, K65, K69, K71, K72, K73, K74, K75, K140, K79, K81, A5, A8, A13)

15th April: 22 crossing structures (A4, K84, A1, A1-A7, A7, K85, K87, K91, K95, K96, K97, K101, K102, K103, K105, K107, K106, A12, K108, A10, K112, K113)

29th April: 15 crossing structures (K121, K122, K124, K123, K125, K127, K129, K130, K131, K132, K134, K135, K136, K137, K138)

14th July: 8 crossing structures were inspected for the first time (K9, K15, K33, K67, K68, K114, K115, K118) while 4 crossing structures were inspected for second time (A13, K87, K129, K135)

24th July: 4 crossing structures were inspected for the first time (K63, K88, K99, K128b) while 2 crossing structures were inspected for second time (K68, K87) and one for third time (A13).

The first day on 20th of March was used as a pilot implementation of the overall Wildlife Permeability Improvement Form which was finalized and used for all the next inspections after small improvements.

4.3.2. Number and type of crossing structures characterized and monitored by cameras

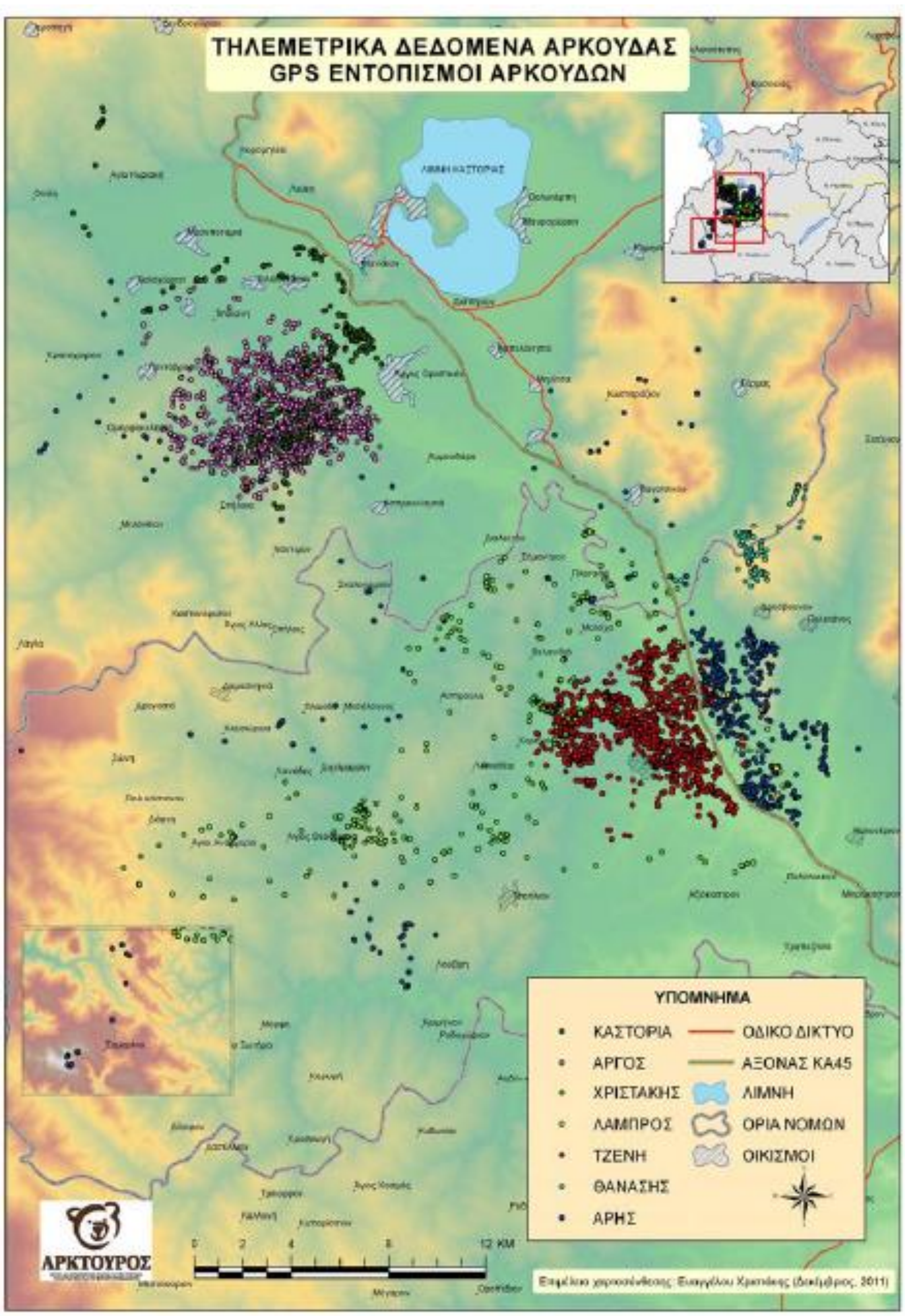
The total inspected crossing structures are (**90**). Finally, (**56**) were selected for improvement of which (39) are evidenced with IR camera's monitoring data. Numbers per crossing type are presented in the Table 4.1.

Table 4.1. *Crossing per type that inspected, selected for improvement and monitored by cameras*

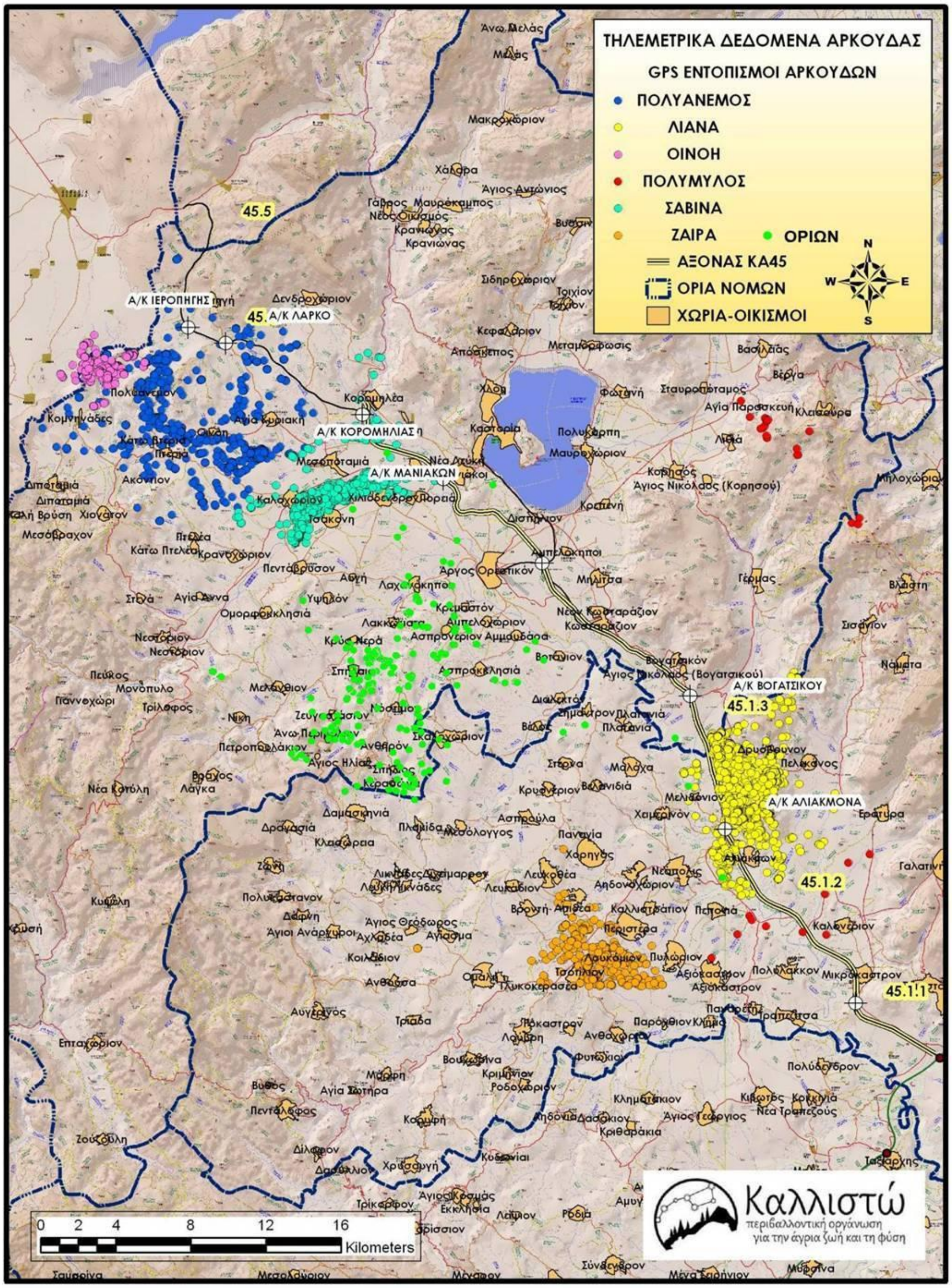
	Type of Crossing	**Inspected 90 Crossing structures**	**Final 56 crossing structures for improvement**	**45 Camera monitored crossing structures**	**39 Selected crossing structures monitored by cameras**
I	Culverts (CUV)	**60**	**47**	**36**	**33**
II	Underpasses (UNP)	**22**	**6**	**6**	**4**
IIa	*Forest Roads*	*(10)*	(2)	(3)	(1)
IIb	*Paved Roads*	*(7)*	-	-	-
IIc	*Wildlife Underpasses*	*(5)*	(4)	(3)	(3)
III	Overpasses (OVP)	**1**	**-**	**1**	**-**
IV	Viaducts (VIA)	**6**	**2**	**1**	**1**
V	Bridges (BRIDGE)	**1**	**1**	**1**	**1**

4.3.3. Location of the crossing structures

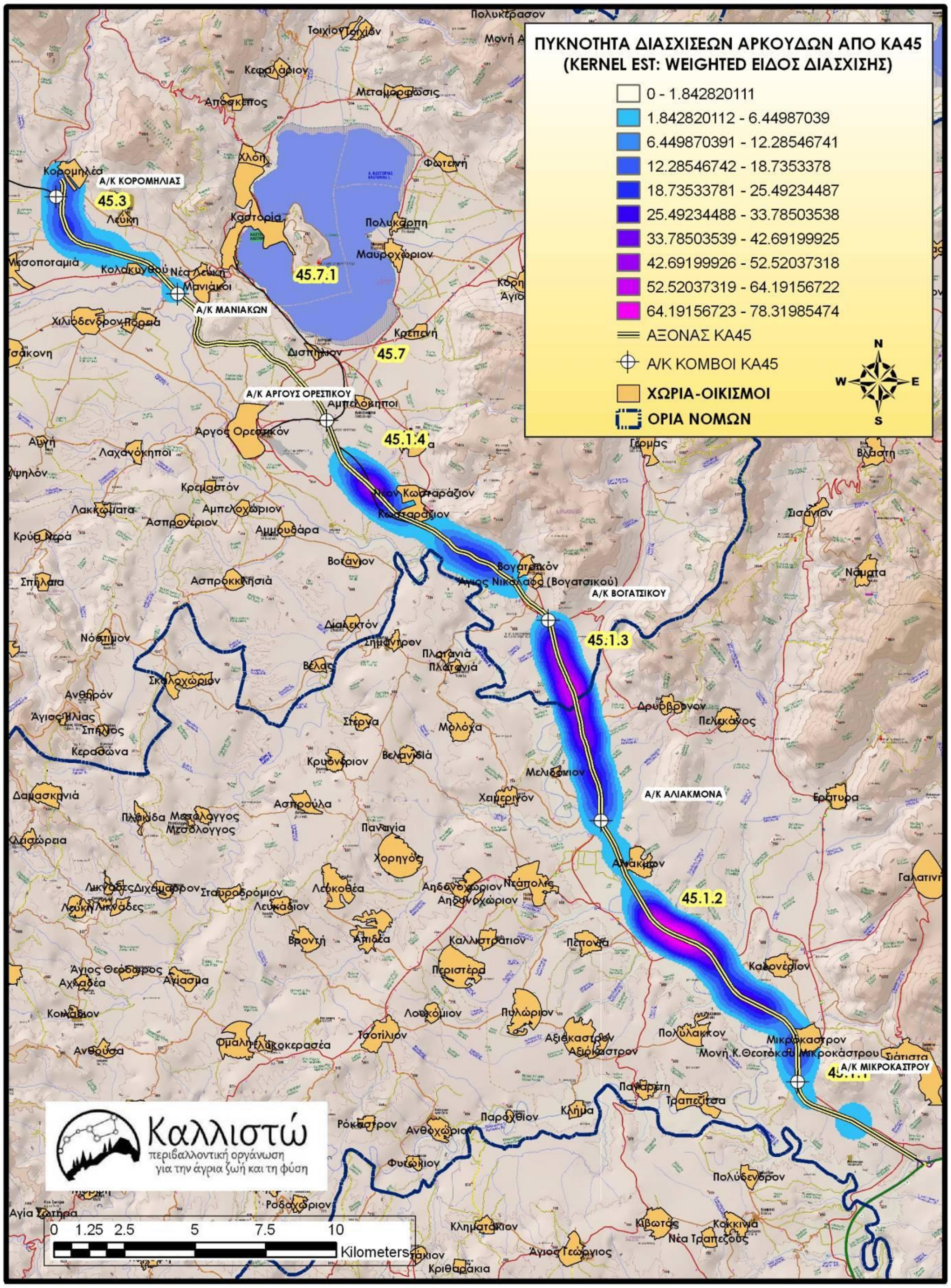
In order to select the most appropriate distribution of the crossing structures for improvement, previous information was used related with road kills and the use of the A29 area and its particular sections by bears. These data are based on telemetry and field data as results from previous projects implemented during the last 10 years (referred in chapter 3B) as included in the following maps:



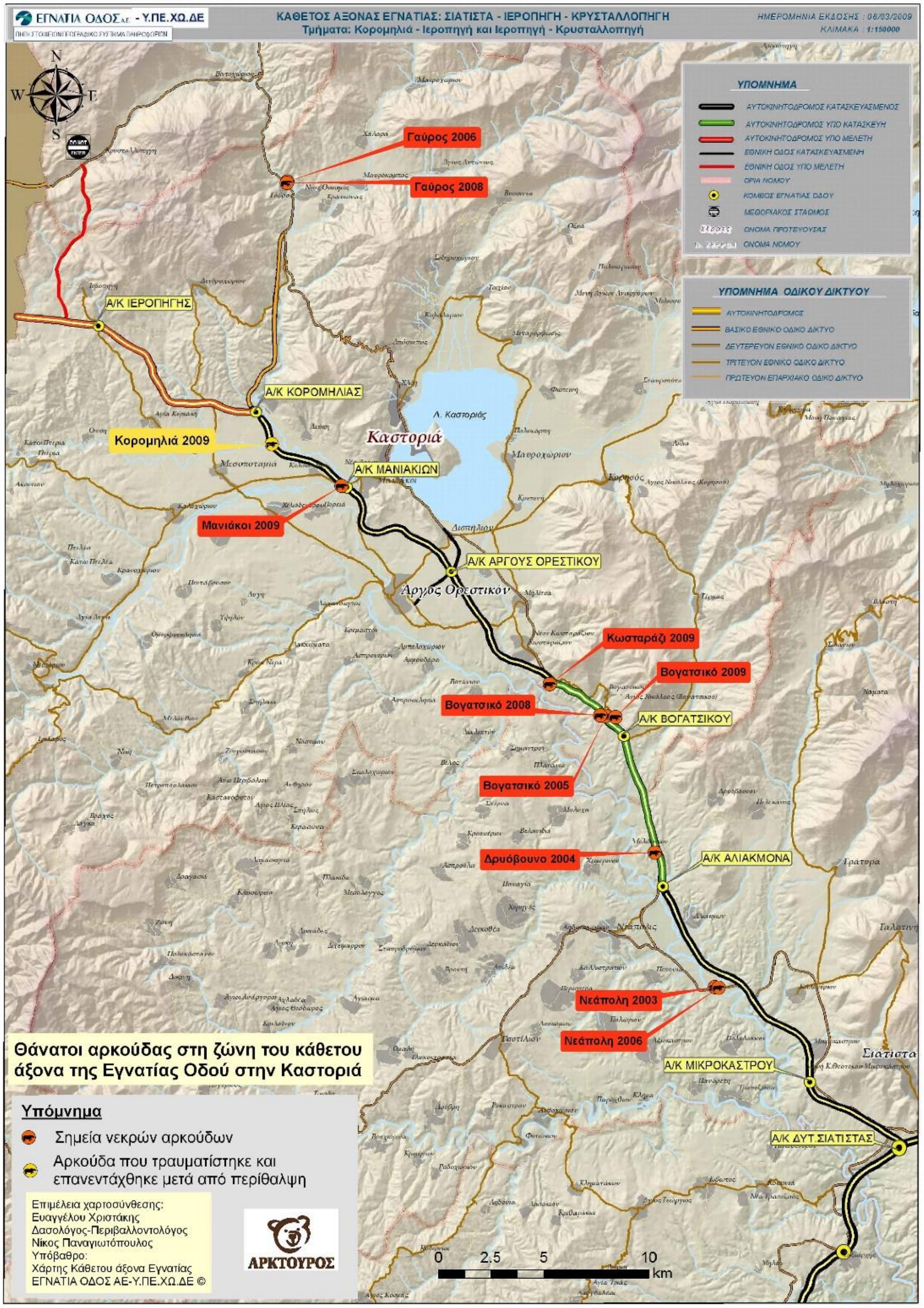
Map 4.3.1. *Telemetry data of 7 bears in A29 area (ARCTUROS, 2011)*



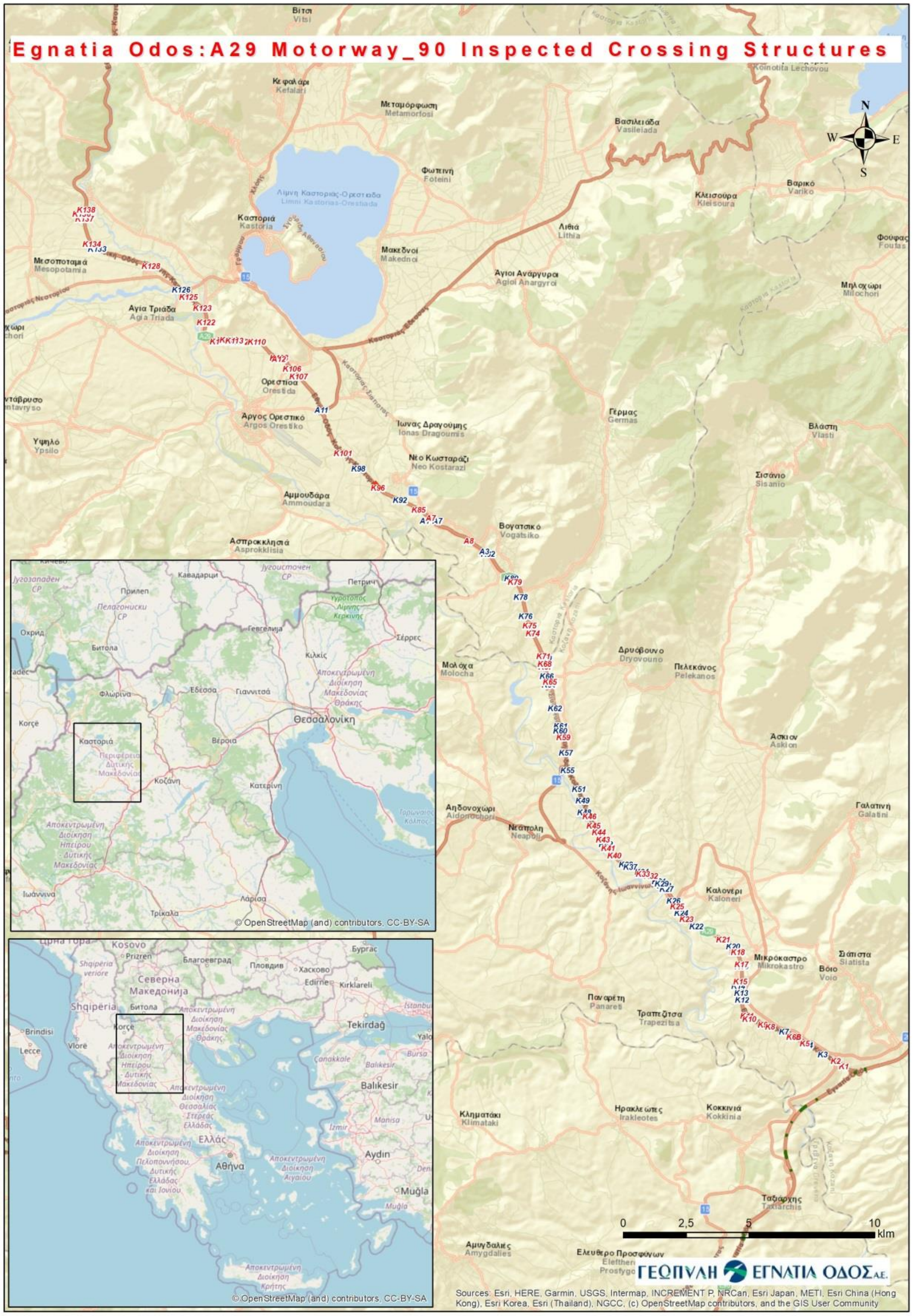
Map 4.3.2. *Telemetry data of 7 Bears in A29 area (Callisto, 2011)*



Map 4.3.3. *Density of bear crossing on A29 (KA45) (Kernel method, Callisto, 2011)*



Map 4.3.4. *Bear road kills on A29 for the period 2004-2009 (Γεωργιάδης κα 2009)*



Map 4.3. 5. *Distribution of the 90 selected crossing structures for inspection*

4.3.4. Characteristics of the crossing structures

Towards presenting the overview of the characteristics of the total number of 149 crossing structures an analysis of their dimensions per height, width and length has been made by Callisto based on the A29 crossing structures database. The first level of analysis gave the results in the following relative figures:

1) Distribution of the structure height (**figure 4.3.4.1**)
2) Distribution of the structure height frequency (**figure 4.3.4.2**)
3) Distribution of the structure width (**figure 4.3.4.3**)
4) Distribution of the structure width frequency (**figure 4.3.4.4**)
5) Distribution of the structure length (**figure 4.3.4.5**)
6) Distribution of the structure width frequency (**figure 4.3.4.6**)

Height and width were grouped in 6 classes (in meters):

1) 0-1.99
2) 2-3,99
3) 4-5,99
4) 6-10
5) >10
6) N/A

Length was grouped in 8 classes (in meters):

1) 10-24
2) 25-39
3) 40-54
4) 55-69
5) 70-84
6) 85-100
7) >100
8) N/A)

Additional analysis was made, as presented in **figures 4.3.4.7** and **4.3.4.8** with the distribution of Openness Index of the structures in 10 classes:

1) < 0,04
2) 0,05-0,07
3) 0,08-0,09
4) 0,10-0,49
5) 0,50-0,74
6) 0,75-1,49
7) 1,50-2,49
8) 2,50-4,99
9) >5
10) N/A

Fig. 4.3.4.1. Distribution of structure height of the A29 crossings

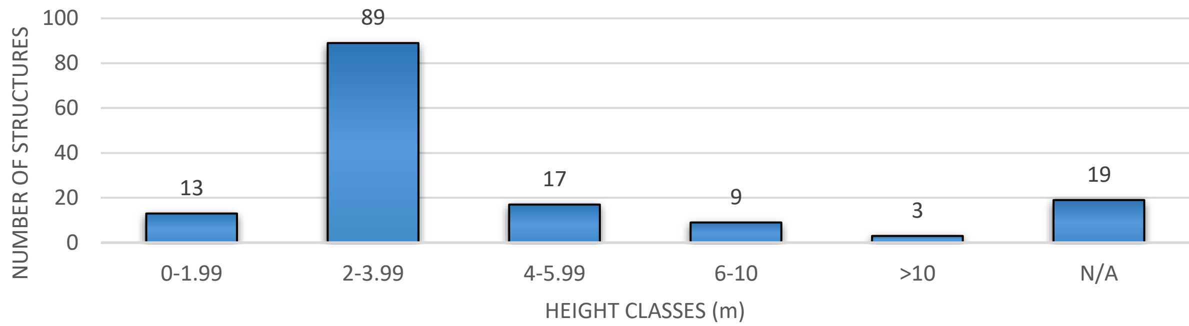


Fig. 4.3.4.2. Distribution of structure height frequency of the A29 crossings

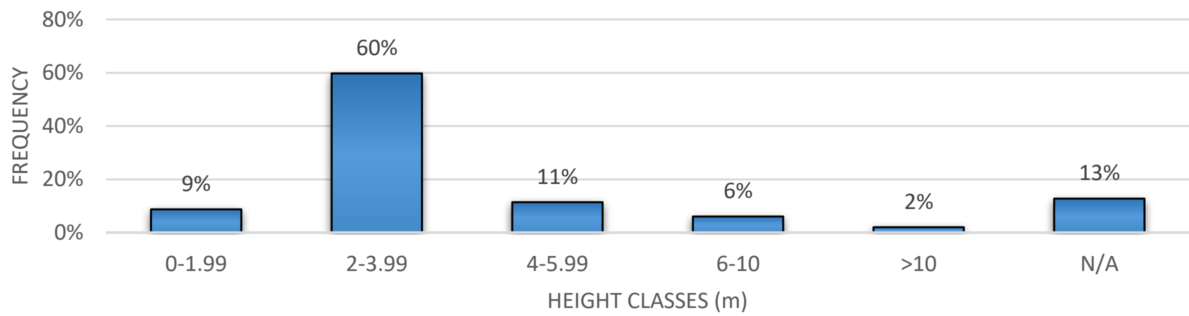


Fig. 4.3.4.3. Distribution of structure width of the A29 crossings

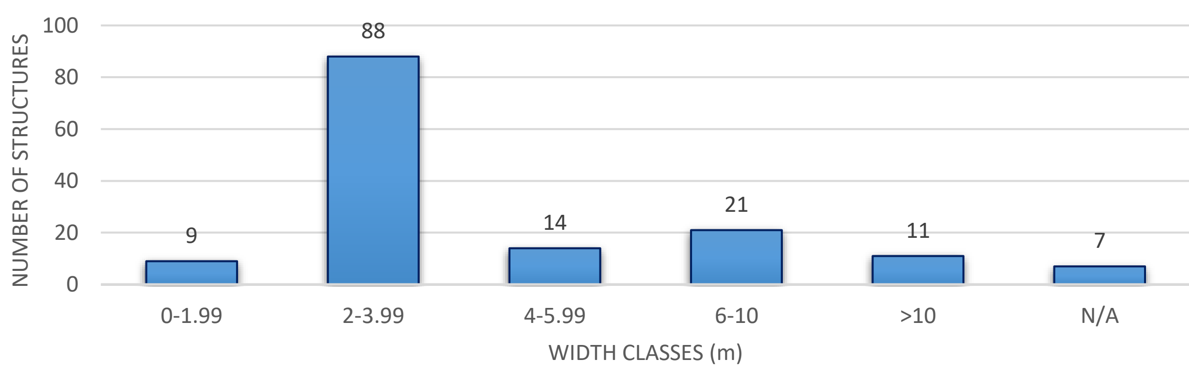


Fig. 4.3.4.4. Distribution of structure width frequency of the A29 crossings

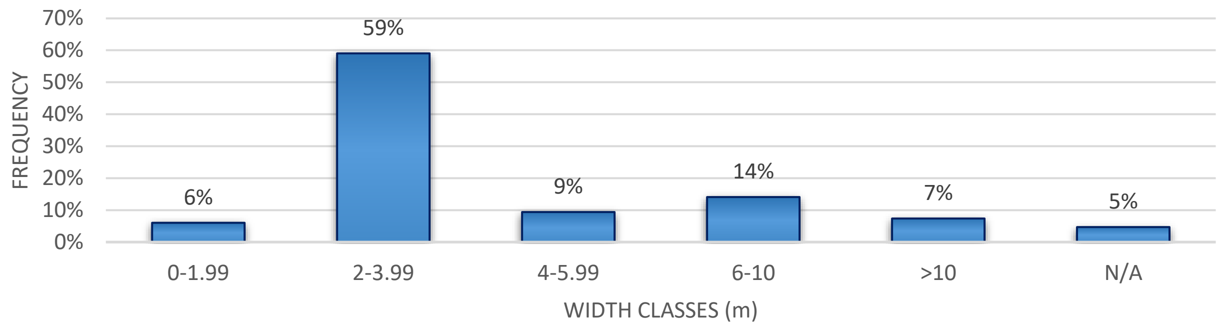


Fig. 4.3.4.5. Distribution of structure length of the A29 crossings

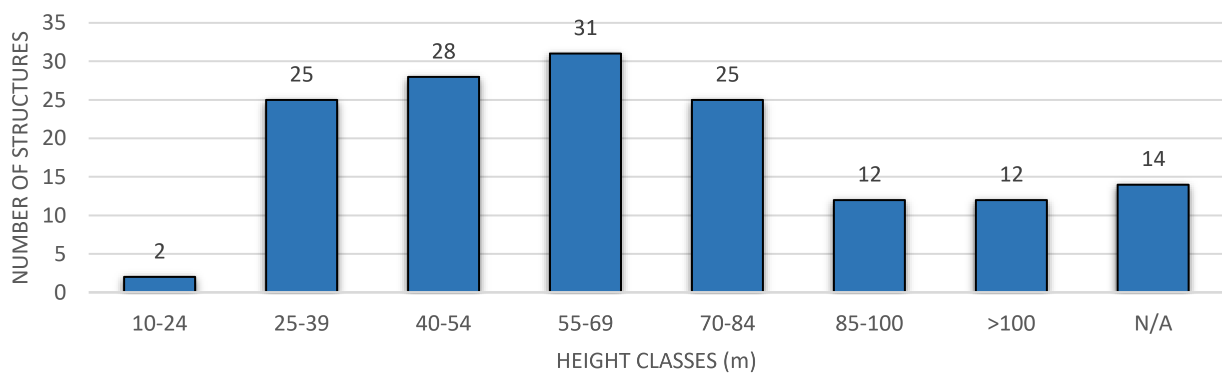
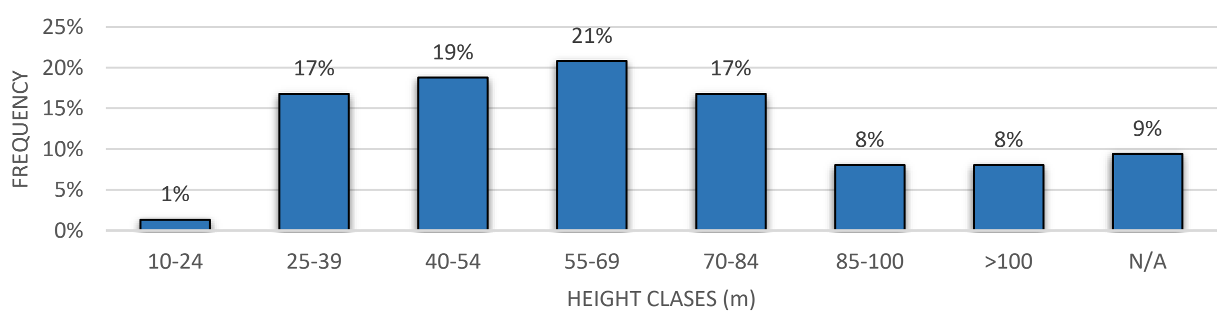
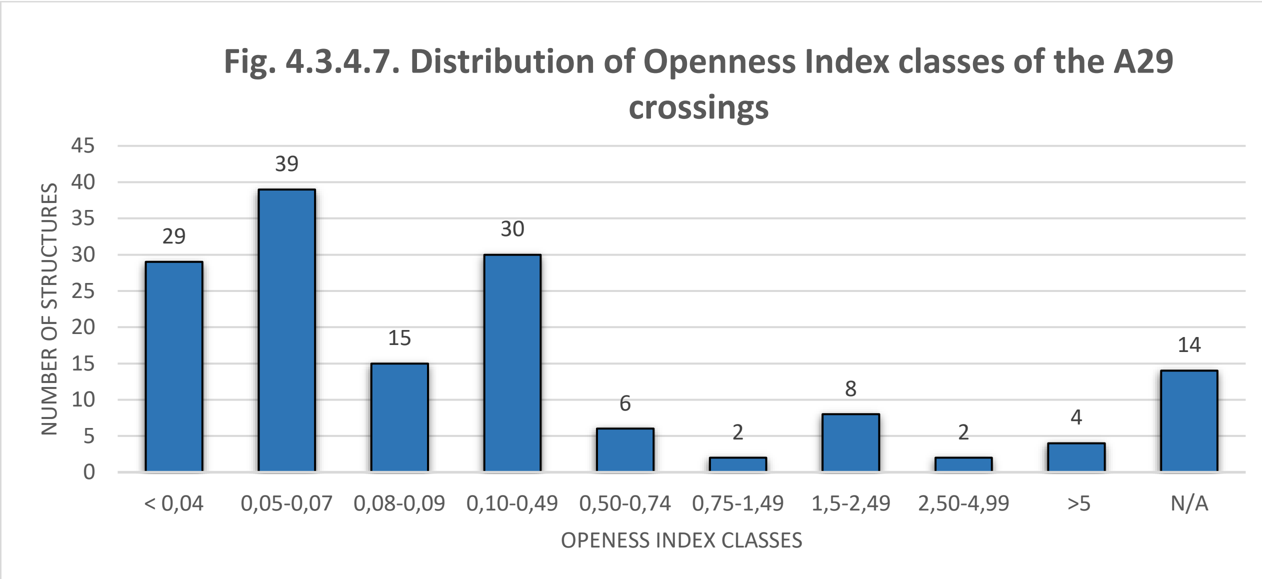
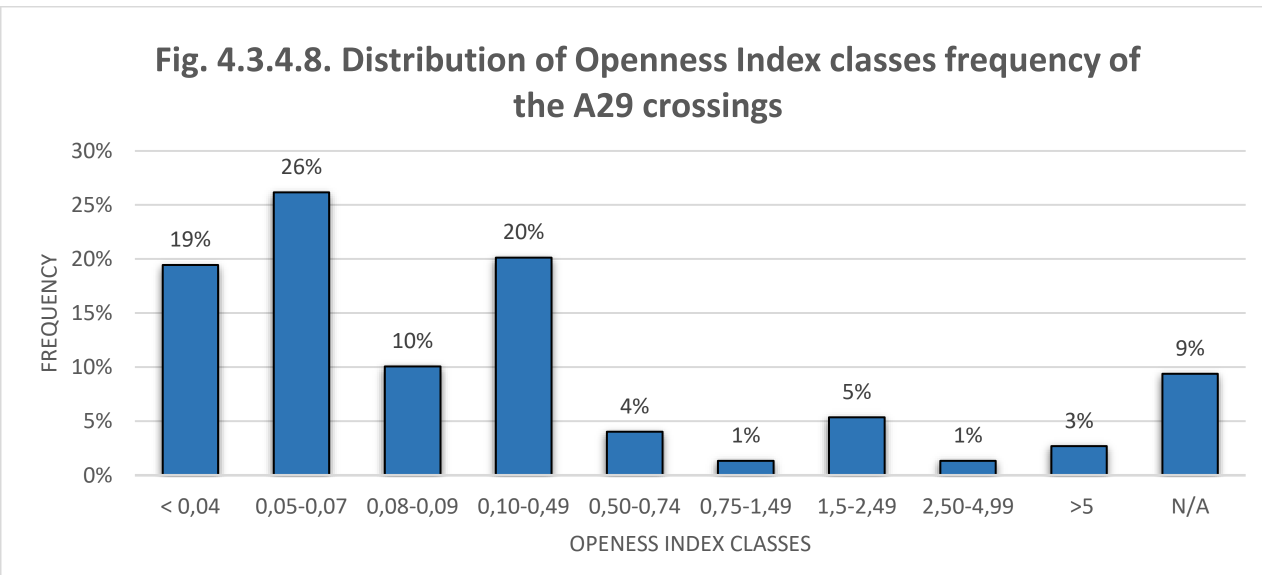


Fig. 4.3.4.6. Distribution of structure length frequency of the A29 crossings







As the **figures 4.3.4.7 and 4.3.4.8** show the majority (79%) of the crossing structures have Openness Index smaller than 0.75[2], only 1% have between 0.75 and 1.5, while from the rest 21% the largest class (5%) is in the range 1,50 – 2,49 considering 9% as not defined (N/A).

[2] The Openness Index (OI) of 0.75 is critical as it is recommended as minimum for large size animals as bears according to the Guidelines to adapt transversal structures and increase their use by large carnivores and other wildlife (LIFE SAFE-CROSSING, Minuartia 2020). In Vaclav et al 2019 the OI of 0.75 is recommended as minimal for medium sized mammals (roe deer, wild boar) while for large mammals as red deer and large carnivores the recommended minimal OI is 1,5.

4.4. Number and typology of crossing structures monitored with camera traps

The total number of monitored crossing structures by cameras was **45** and as is described in **table 4.1** they include **37 culverts**, **6 underpasses** (3 forest roads and 3 wildlife underpasses), **1 viaduct** and **1 bridge**. In order to achieve the most effective monitoring of the overall task of the technical improvements of the crossing structures there was a special focus on selection of monitored crossing structures with camera traps. As the **table 4.1** shows, from the final 56 selected crossing structures for improvement **39** (**69,54%**) are monitored by cameras. From the 39 monitored crossing structures with cameras selected for improvement, **33** are **culverts**, **4** are **underpasses** (1 forest road and 3 wildlife underpasses), **1** is **viaduct** and **1** is **bridge**. Monitored crossing structures that haven't been selected have large use level (more than 100 animal passes such as K59: 105 passes, K69: 228 passes, K140: 200 passes) or very small Openness Index.

4.5. Results of the monitoring activity with camera traps (from the beginning of the project to 31/05/2020)

Towards evaluating the monitoring activity for the 45 crossing structures monitored by cameras, according to the collected data by COSMOTE and in cooperation with Callisto, an overall matrix of species and their use of the crossing structures was created and is presented in **table 4.2**. The big number of false (**17.170**) is due to the species auto-recognition system of COSMOTE which is expected while its effectiveness is constantly in improvement process. The data of the table include the information of all the species for the first period of monitoring (Jun 2019-Feb 2020) with additional data for the bears for the second monitoring period (Mar 2020 – Jun 2020). Totally **37.860** passes were recorded through all the crossing structures, while only 3 were used less than 10 times and one 28 times. Most of the crossing structures have more then 150-200 passes while 14 crossing structures have more than 1.000 passes. Except for livestock (**6.573**), dogs (**6.018**), vehicles (**1.661**) and humans (**1.170**) fox is the species with the largest number of passes (**1.793**). For the rest of the wildlife species the most interesting numbers are related with the following species:

- The bear: **953** passes using **35** crossing structures
- The wildcat: **529** passes using **37** crossing structures
- The wolf: **255** passes using **28** crossing structures
- The wild boar: **70** passes using **10** crossing structures
- The roe deer: **18** passes using **2** crossing structures

Based on these data there is a clear difference in the use of crossing structures between carnivores and ungulates which highlights the differences between the two taxa on behavioural ecology aspects and their requirements on permeability conditions of the crossing structures. On the other hand, it is clear that bears and wolves can also use crossing structures with smaller openness index. This result points out the need for passing in combination with the absence of fear on individual and not on population base. Ecological permeability should be assessed by including both large carnivores and ungulates and choosing larger O.I., can be the most important factor in order to support effective ecological connectivity for all the species following a more general ecosystem and biodiversity approach (Reck et al 2018).

Table 4.2. *The overall view of the use of crossing structures (brown cells: bear, blue: wildcat, green: Roe deer, pink: wild boar, grey: wolf) based on the cameras' monitoring data including the final 56 crossing structures for improvement.*

A/A	Passage	Type	OI	Bears (Jul19-Feb20)	Bears (Mar20-Jun20)	Bears (Jul19-Jun20)	Cats-Wildcats	Cattle	Dogs	Equines	False - Positives	Flying stuff (birds, insects)	Foxes	Humans	Livestock	Mustelids	Non-Identifiable	Reptiles	Roe deers	Small mammals	Vehicles	Wild boars	Wolves	T
1	K138	CUV	0,12	9	2	11	1	0	0	0	32	0	13	16	0	42	0	0	0	0	0	0	0	115
2	K135	CUV	0,07																					
3	K134	BRIDGE	2,4	21	0	21	0	2	56	0	44	3	5	15	864	22	3	0	0	0	0	0	0	1.035
4	K132	CUV	0,06																					
5	K131	CUV	0,09																					
6	K130	CUV	0,14	4	14	18	5	0	59	0	1.929	2	100	308	258	10	23	0	0	1	4	0	2	2.719
7	K129	CUV	0,13																					
8	K128b	CUV	0,07	2	3	5	14	0	44	0	98	6	52	6	0	1	9	0	0	0	0	0	0	235
9	K121	CUV	0,09																					
10	K118	CUV	0,07	3	0	3	2	35	53	0	130	2	3	37	0	0	0	0	0	0	0	0	0	265
11	K115	CUV	0,07	0	0	0	0	11	12	0	112	11	2	4	0	0	1	0	0	0	0	0	0	153
12	K114	CUV	0,07																					
13	K113	CUV	0,18																					
14	K110	CUV	0,1	1	0	1	1	43	23	0	4.692	5	7	48	81	0	5	0	0	0	1	0	1	4.908
15	K105	CUV	0,1																					
16	K101	CUV	0,12	0	0	0	2	0	34	0	45	4	9	5	0	2	1	1	0	0	0	2	0	105
17	K99	CUV	0,03	3	14	17	6	0	40	0	103	2	93	12	4	15	1	0	0	0	0	0	2	295
18	K97	CUV	0,12	3	5	8	25	0	383	0	140	0	44	70	591	1	5	0	0	0	0	0	2	1.269
19	K96	VIA	NA																					
20	K95	CUV	0,4	0	0	0	0	0	83	0	840	1	0	44	516	0	2	0	0	0	0	0	0	1.486

A/A	Passage	Type	OI	Bears (Jul19-Feb20)	Bears (Mar20-Jun20)	Bears (Jul19-Jun20)	Cats-Wildcats	Cattle	Dogs	Equines	False - Positives	Flying stuff (birds, insects)	Foxes	Humans	Livestock	Mustelids	Non-Identifiable	Reptiles	Roe deers	Small mammals	Vehicles	Wild boars	Wolves	T
21	K91	CUV	0,09	0	1	1	12	0	159	9	264	1	58	44	88	3	16	0	0	3	0	0	4	662
22	K88	CUV	0,02																					
23	K87	CUV	0,01	0	0	0	4	0	63	0	116	1	21	21	266	2	14	0	0	1	0	0	3	512
24	A7	CUV	0,08	0	0	0	1	0	89	0	137	25	3	90	415	0	3	0	0	0	0	0	3	766
25	A1	CUV	0,02																					
26	K84	UNP(W)	0,68																					
27	A4	UNP(W)	0,09	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	A2	CUV	0,02	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3
28	A13	CUV	0,1	2	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	6
29	A8	CUV	0,09																					
30	K81	UNP(W)	0,22	1	4	5	38	0	274	0	208	1	57	15	347	4	8	0	0	1	0	0	6	964
31	K79	UNP(W)	0,05																					
	K140	UNP	0,25	116	84	200	112	0	92	1	413	6	33	22	129	5	57	0	0	6	603	0	41	1.720
	K140B	UNP ?	0,25	14	18	32	63	0	65	0	357	3	17	32	57	1	11	0	0	6	191	0	7	842
32	K75	CUV	0,08	2	3	5	7	0	7	0	141	3	39	1	0	5	5	0	0	5	0	0	1	219
33	K74	VIA	10,5	51	16	67	1	0	8	0	315	11	5	0	9	1	2	1	0	0	0	1	0	421
34	K73	CUV	0,12																					
35	K72	CUV	0,08	7	7	14	3	0	39	0	405	1	35	3	47	5	3	1	0	9	5	0	1	571
36a	K71	CUV	0,19	20	7	27	13	0	277	0	652	1	109	37	1.285	14	26	0	0	4	0	0	23	2.468
36b	K71B	CUV	0,19	2	1	3	1	0	29	0	32	0	0	16	598	0	1	0	0	0	0	0	4	684
	K69	UNP	0,55	148	80	228	57	0	322	0	645	32	152	124	51	34	144	0	0	31	499	0	60	2.379
	K69B	UNP	0,55	20	13	33	4	0	100	0	58	1	5	46	49	0	12	0	0	0	268	0	15	591

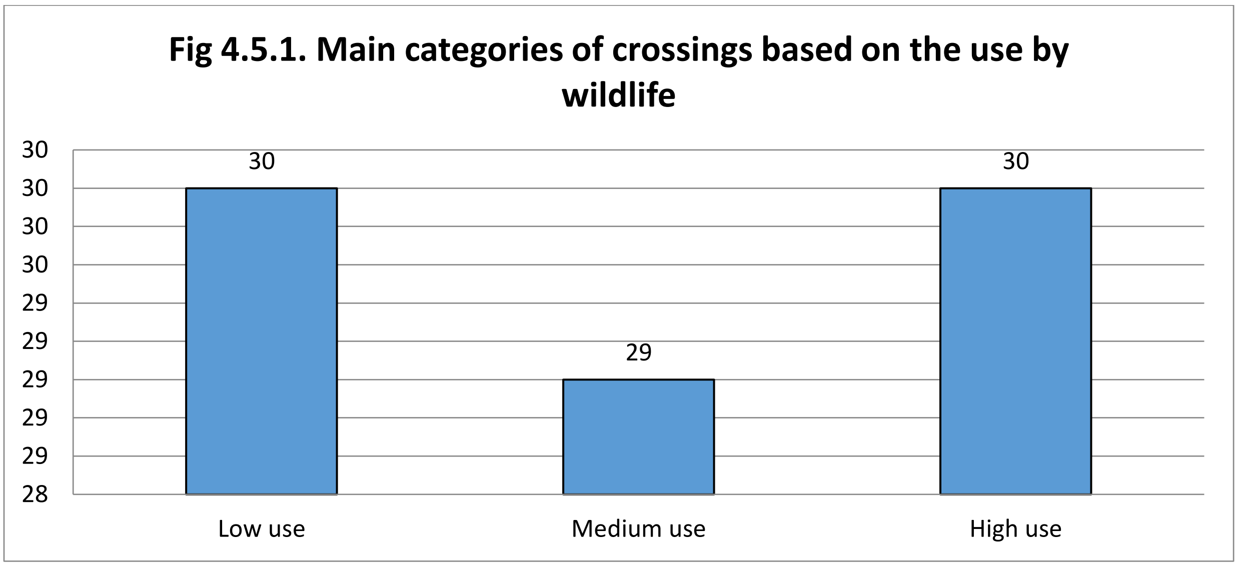
A/A	Passage	Type	OI	Bears (Jul19-Feb20)	Bears (Mar20-Jun20)	Bears (Jul19-Jun20)	Cats-Wildcats	Cattle	Dogs	Equines	False - Positives	Flying stuff (birds, insects)	Foxes	Humans	Livestock	Mustelids	Non-Identifiable	Reptiles	Roe deers	Small mammals	Vehicles	Wild boars	Wolves	T
37	K68	CUV	0,07	11	5	16	37	0	64	0	196	13	61	2	0	50	17	2	0	31	0	11	1	501
	K67	CUV	0,06	0	0	0	2	0	0	0	15	4	1	0	0	3	3	0	0	0	0	0	0	28
38	K65	CUV	0,14	4	8	12	0	0	252	0	377	3	12	20	0	0	9	0	0	0	0	0	1	686
39	K63	CUV	0,03	12	2	14	0	0	10	0	529	8	27	8	0	6	8	0	14	0	0	5	0	629
	K59	CUV	0,07	93	12	105	53	0	27	0	196	44	61	2	0	158	9	0	4	0	0	1	1	661
40	K56	CUV	NA	2	10	12	6	0	14	0	106	7	11	14	10	1	3	0	0	0	0	3	6	193
41	K52	CUV	0,08																					
42	K46	UNP(FR)																						
43	K45	CUV	0,1	1	0	1	6	0	102	1	268	9	60	6	123	1	9	0	0	0	1	1	0	588
44	K41	CUV	0,08	4	4	8	5	0	19	0	370	3	30	0	0	14	4	3	0	0	0	0	1	457
45	K40	CUV	NA	6	0	6																		
46	K33	CUV	0,04	1	6	7	7	0	4	0	47	0	110	0	0	9	3	0	0	0	0	0	0	187
47	K32	CUV	0,08																					
48	K23	CUV	0,11	11	7	18	7	0	20	0	462	1	236	6	0	247	28	0	0	0	0	36	1	1.062
49	K21	CUV	0,56	10	6	16	2	0	526	0	244	4	20	2	146	2	28	0	0	3	2	4	25	1.024
50	K18	CUV	0,17																					
51	K15	CUV	0,04	2	3	5	1	0	35	0	99	3	161	16	8	7	4	0	0	0	0	6	0	345
52	K10	CUV	0,08	9	3	12	7	0	90	0	342	1	43	11	27	16	7	0	0	0	0	0	6	562
53	K9	CUV	0,06	0	1	1	10	0	35	0	417	1	20	16	14	9	11	0	0	0	0	0	1	535
54	K8	UNP(FR)	0,4	0	2	2	2	0	1.255	12	939	16	26	17	249	1	103	0	0	0	87	0	23	2.732
55	K6	CUV	0,09	0	0	**0**	10	0	503	23	242	5	24	22	184	3	22	0	0	1	0	0	14	1.053
56	K5	CUV	0,22	0	0	**0**	1	0	751	0	253	3	28	12	157	3	7	0	0	2	0	0	0	1.217

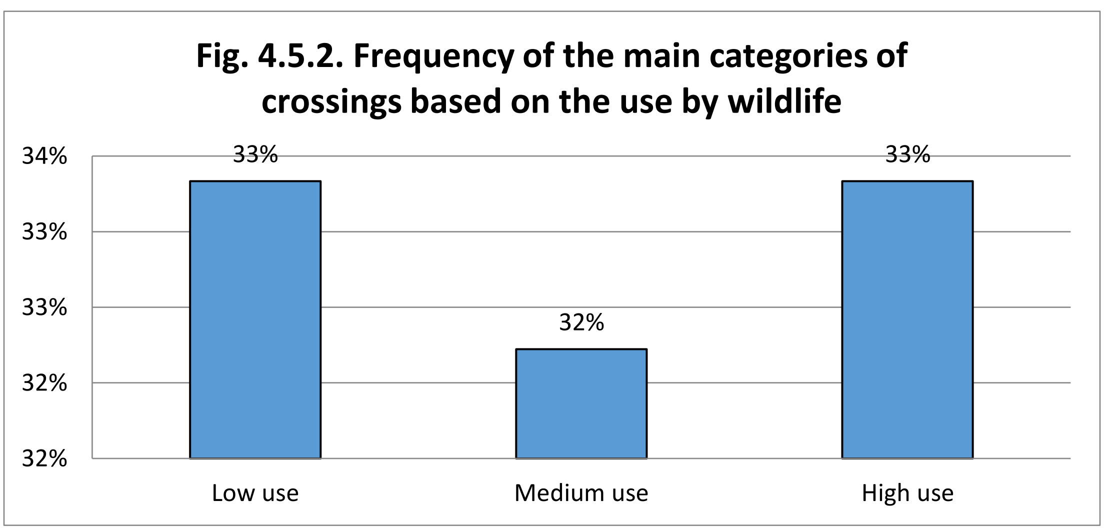
A/A	Passage	Type	OI	Bears (Jul19-Feb20)	Bears (Mar20-Jun20)	Bears (Jul19-Jun20)	Cats-Wildcats	Cattle	Dogs	Equines	False - Positives	Flying stuff (birds, insects)	Foxes	Humans	Livestock	Mustelids	Non-Identifiable	Reptiles	Roe deers	Small mammals	Vehicles	Wild boars	Wolves	T
Total uses:				595	341	936	529	91	6.018	46	17.017	247	1.793	1.170	6.573	697	627	8	18	104	1.66	70	255	37.860

Considering the findings of animal presence by tracks and signs that were recorded during the field inspections of the 90 crossing structures using a general "qualitative indicator", three categories of crossing structures can be summarized as follows, taking into account that the data recorded during July were in a very dry condition, therefore with limited possibilities to find tracks:

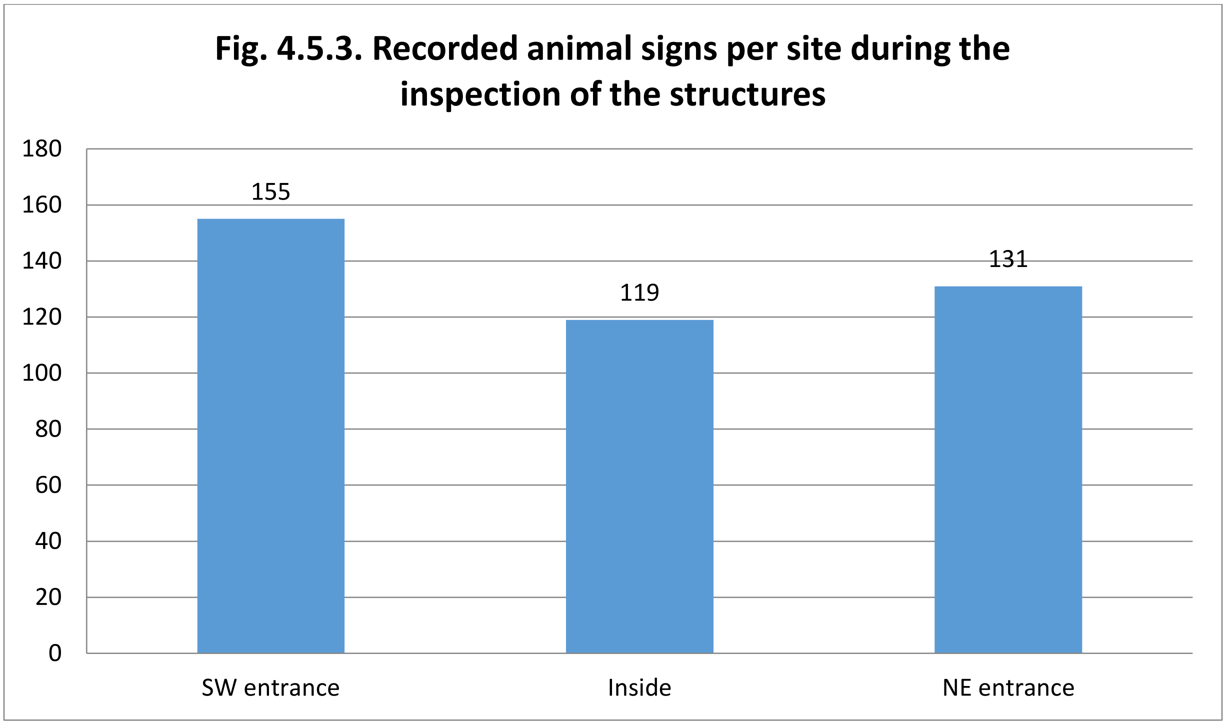
- Low use: the structure is almost inaccessible, no tracks were recorded
- Medium use: some tracks of wildlife, but the use of the structure doesn't seem regular
- High use: a lot of tracks recorded; it seems that the structure is constantly used by the wildlife.

The **figures 4.5.1.** and **4.5.2.** describe these three categories of the crossing structures based on the use by wildlife and their frequency correspondingly.





Totally 405 signs were recorded during the structure inspections from which **155 (38%)** were at southwestern entrance, **119 (29%)** inside and **132 (32%)** at the north-eastern entrance (**figures 4.5.3. and 4.5.4.**). Additionally, the **figure 4.5.5** presents the overall view of the crossing structures related with the species presence at the entrances and inside the crossing structures.



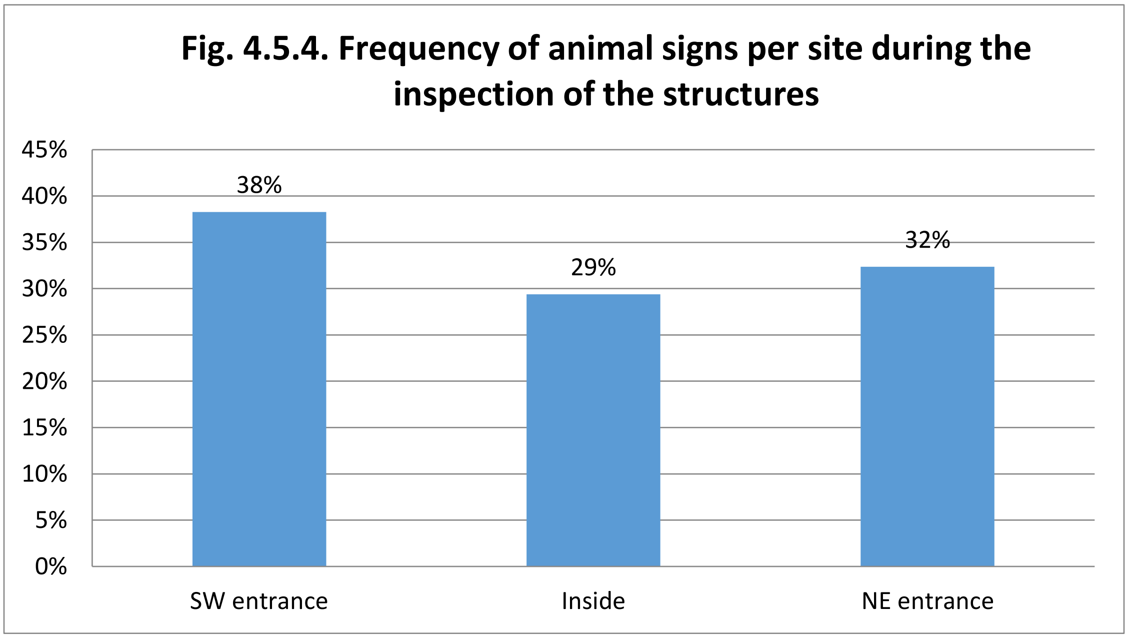


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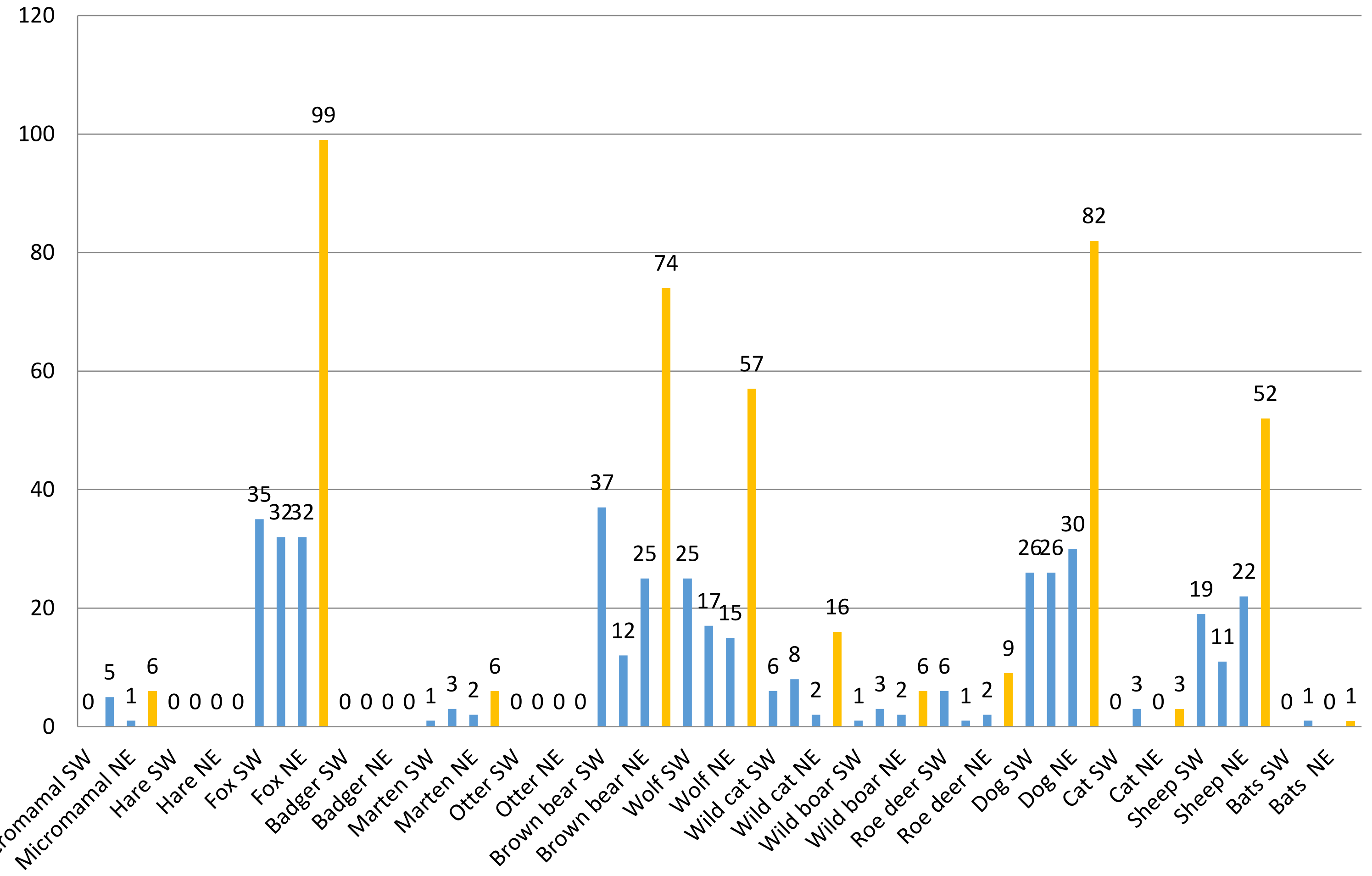
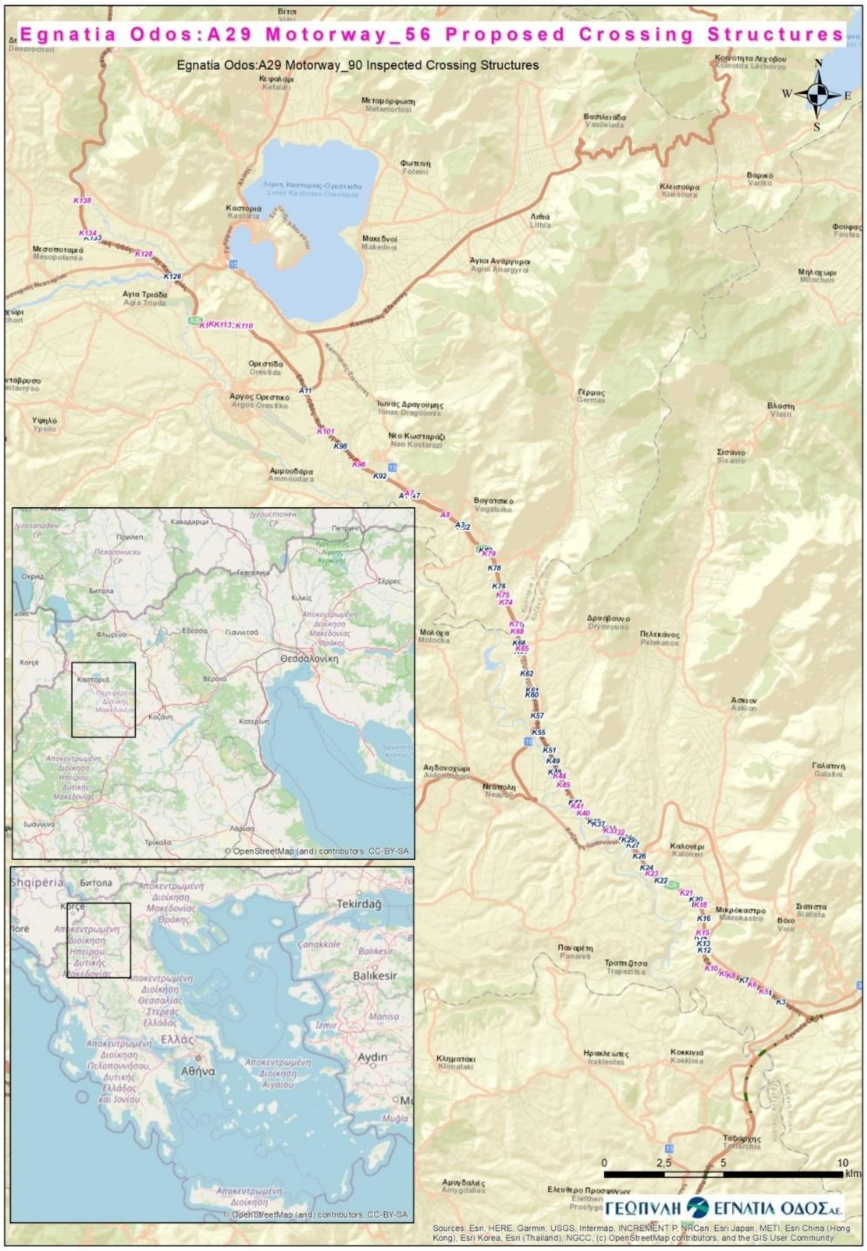
Fig. 4.5.5. Animal tracks in crossing structures of A29 Highway: SW Entrance, Inside, NE Entrance (blue collumns) and Total (yellow collumns)



4.6. Selection of the underpasses to be readapted

As has been described in chapter 4.B (Table 4.1) from the total 149 crossing structures the total inspected crossing structures are (**90**), while the final selected structures for improvement are (**56)**. The 90 inspected crossing structures with their 3 first pages of their Wildlife Permeability Improvement Form (WPIF) are presented in the **Annex I**. The final (**56**) crossing structures with their Wildlife Permeability Improvement Form fully developed with their improvement interventions are presented in the **Annex II**. The distribution of the 56 selected crossing structures for improvement is presented in **map 4.6.1.** below.



Map 4.6.1 *Distribution of the 56 selected crossing structures for improvements*

The composition of the selected **56** crossing structures per structure type is the following:

1) **47 culverts**
2) **6 underpasses**
    - *2 forest roads*
    - *4 wildlife underpasses*
3) **1 viaduct** and
4) **1 bridge**

The composition of the 90 inspected crossing structures per structure type is the following:

1) **60 culverts**
2) **22 underpasses**
    - *10 forest roads*
    - *7 paved roads*
    - *5 wildlife underpasses*
3) **1 overpass**
4) **6 viaducts** and
5) **1 bridge**

The distribution of the 90 selected crossing structures for inspection is already presented in **map 4.6.1.**

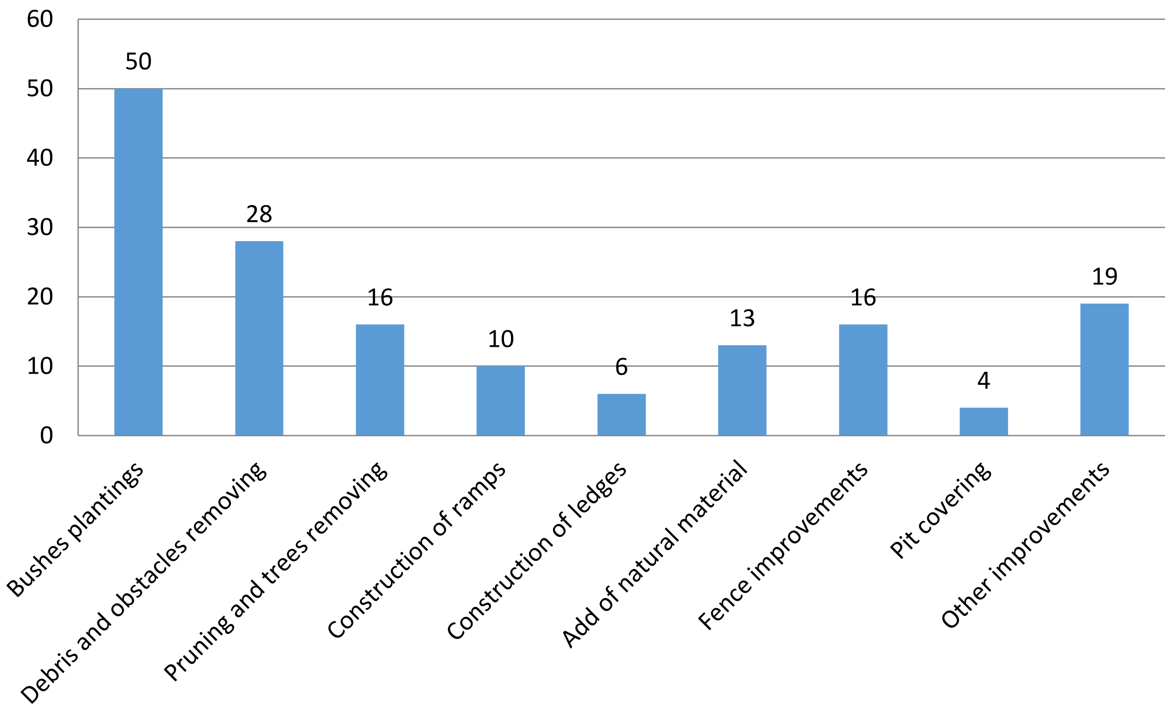
The final choice of the 56 crossing structures is a result of fulfilling the criteria described in the chapter 3 and in general their distribution is presented in **map 4.6**.**1** In comparison with the maps that have been produced in previous projects in the A29 area (**maps 4.3.1, 4.3.2, 4.3.3 and 4.3.4**) it's clear that the final choice follows the need of connectivity for the local brown bear population based on the existing telemetry data of totally 14 individuals of the species, the road kill data of the period 2004-2009 and in general it follows the critical zones of bear crossing structures as they were presented using the Kernel method in **map 4.3.3**.

The spectrum of proposed improvements covers the following categories of tasks as described in **figure 4.6.2.**:

1) Bush planting
2) Debris and obstacles removing
3) Pruning and tree removing
4) Construction of ramps
5) Construction of ledges
6) Addition of natural material
7) Fence improvements
8) Pit covering
9) Other improvements

In the “Other improvements” several other interventions are included, such as the installation of light/noise screens (especially when vegetation doesn’t cover an open space above a crossing), planting of trees (in cases that the entrances are not close to the fence) and fixing erosion problems, further details being provided for each of the main interventions where required.

Fig. 4.6.2. Categories of improvements of the 56 selected crossing structures in A29 highway



In respect to differences related with improvements foreseen in the project proposal, 6 more crossing structures were selected for improvement, whereas the initial proposed number was 50. On the other hand, additional categories of technical tasks assumed as very important and have been included, such as, the removing and pruning of bushes and trees, the construction of ramps and ledges, the addition of natural materials on the entrance sides, fence improvements, the covering of pits and other interventions as already have been described.

In combination with the selection of the technical improvements, special criteria were used in order to select the proper plant species for “greening” the crossing entrances as following:

1. Use native species
2. Use species with resistance in both dry and frost seasons
3. Use bushes and not trees close to the fence
4. Use trees only when crossing entrances are not close to the fence, with species that are not tall with fragile branches such as poplars
5. The height of the bush species should not exceed the height of the fence (2-3 m)

6. Use species that attract mammals to the structure entrance, but not birds, in order to avoid roadkills
7. Use species that are not eatable by the livestock
8. Plant dense enough, when plantings are on the top of the crossing entrance, in order to support light and noise isolation
9. Availability in the market and the vendor's stocks.

Using the above criteria and after a market investigation for their availability, the final species selection included two species for bushes (*Spartium junceum* and *Cotinus coggygria*) and one for tree planting (*Salix sp.*). For the determination of both the additional technical improvements and the planting criteria, several additional bibliographical sources were studied and used (Hlaváč et al 2019, Carey et al 20016, Rose et al 2016, Μπούσμπουρας 2005).

The photos in the following pages represent the main types of crossing structures with short description of the interventions that are planned for their improvements.

Photo *1.* *K05, SW entrance. Main intervention: Plantings.*

Photo 2. *K40 SW entrance. Main intervention: Debris removal and tree pruning.*

Photo 3. *K32, NE entrance. Main intervention: Debris removal and plantings.*

Photo 4. *K46 NE entrance. Main intervention: Correction of the fence ending on the sides and plantings.*

Photo 5a. *K74 SW entrance. Main intervention: Creation of dry ledges*

Photo 5b. *K74 NE entrance. Main intervention: Continue dry ledges to the SW entrance (**ph.5a**).*

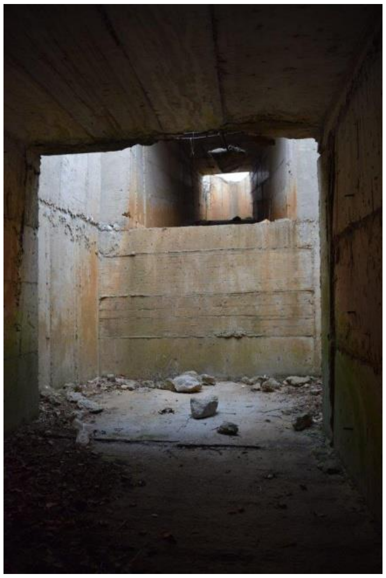


Photo 6. *K73 NE entrance. Main intervention: Creation of two ramps.*

Photo 7. *K113 NE entrance. Main intervention: Plantings and removing the obstacles and the debris.*

Photo 8. *K114 SW entrance. Main intervention: Plantings and removing the obstacles and the debris.*

Photo *9.* *K128b NE entrance. Main intervention: Removing the debris and the vegetation.*

Photo 10. *K138 NE entrance. Main intervention: Creating a ramp and install a light/noise screen.*

5. CONCLUSIONS

I. Regarding COSMOTE end to end device:

The wildlife monitoring solution developed by COSMOTE's R&D Department in the context of the LIFE SAFE-CROSSING project is **a very innovative solution**, **it is not available in the market, developed from scratch specifically for the project needs**, guided by the challenges identified during the project activities. **As such, it must be considered as a prototype.**

We stall stress also that, it's not a "simple" wildlife monitoring solution, since it exhibits **a long list of innovative, add-on features**, such as:

- Real-time alerting upon movement detection to smartphones (via push notifications) and/or e-mail, incl. snapshot(s)
- Near-real time custom (presence) alerts upon detection of specific species (e.g., bears) (via push notifications @smartphones incl. snapshot)
- Innovative tools for automated detection of objects/species passing through (both in near-real time and offline) and automated categorization/storage (of snapshots) based on species category (e.g., bears, foxes, dogs, sheep) and/or other "objects" such as vehicles, humans.
- Innovative tools for zero touch statistics. Extraction of graphs such as: #snapshots/day/week/…/underpass, #appearances of spices per underpass, #appearances of a specific species per underpass, without user intervention | http://193.218.97.145:8081/plots/
- Snapshots' visualization through an intuitive, user-friendly web portal (incl. underpass info, snapshots/underpass, search capability, etc.) | http://193.218.97.145:8081/

The solution exhibits a long list of benefits esp. for the environment, but also for the human resources required for the manual processing of the huge number of the collected snapshots/videos. More specifically, the solution:

4. Eliminates the need for on-site visits to cameras' installations for material collection (from the SD card), due to the utilization of wireless 4G cameras with very high autonomy enhanced by small photovoltaic panels along with the introduction of automated procedures for the uploading (and storage) of the cameras' material to COSMOTE's cloud infrastructure.
5. Supports automated procedures for (near-real time) detection and classification/categorization of passing animals / objects as well as the exporting of statistics / usage graphs, which is a painstaking and time-consuming work due to the huge amount of material to be processed; done manually so far. Note that these "object recognition tools" can be also utilized for offline detection and classification of species by processing snapshots/videos that have been gathered by cameras that have been installed in the rest countries of the project.
6. It combines low cost with ease of installation but most importantly, it is an expandable and reusable, (even) in other countries, solution, as all you need is a wireless 4G camera with a SIM card and a photovoltaic panel.

As such, it is expected:

- An 80% reduction of the time required to process (and categorize into species/objects) of cameras' content (more than 60.000 photos)

- An 80% reduction of the time required to export of statistical data / charts due to the automated procedures supported by the solution
- An 95% reduction of the on-site visits at the installation locations of the cameras for material gathering, with consequent economic and environmental benefits.

All the above functionalities were not foreseen by the Description of Action (DoA) [see Part B - technical summary and overall context of the project] **and were offered free-of-charge by COSMOTE** to facilitate the time-consuming activities (such as the manual species categorization and per passage), but also to increase the reliability of the project outcomes and contribute to their sustainability beyond the project end. More details about the intelligence introduced in the solution regarding the species classification and statistics extraction processes can be found in the Annex A.

Finally, on top of the above, COSMOTE has provided for free 45 SIM cards (one per camera/passage), without charging the connectivity related costs (see data transfer between the 45 cameras and COSMOTE's cloud infrastructure).

II. Regarding CALLISTO & EOSA data processing, analyses and valorization:

Considering the analysis of the results of the action A4 and evaluating the existing crossing structures for potential wildlife use and as the **table 4.2** shows, the wildlife species use the majority of the 45 structures monitored with cameras.

The repetitive and preferential use by bears of specific crossing structures (among the 45 monitored) as shown above and which remain the same throughout the two monitoring periods is probably related to two facts:

- Bears do travel in the landscape following defined routes to which there is a high degree of fidelity. There is a spatial coincidence between the travelling routes and the crossing structures with the most appropriate configuration.
- The configuration of the crossing structures increases their attractiveness and bears diverge from their usual traditional travel routes in order to use safer and more attractive crossing routes and structures.

There is a quantitative difference in use intensity of crossing structures in terms of number of crossing structures usedf between the two monitoring periods: the first period (late summer - fall hyperphagia) shows a more focused use of the most attractive crossing structures a tendency that could be attributed to the fact that bears are seeking specific food targets and thus follow straight forward the safest itineraries. As for the second period (den emergence, FWCY and hypophagia) bears exhibit a more diffuse spatial behavior, thus using a higher number of crossing structures.

Concerning the 90 inspected structures and based on recorded animal sings during their inspection, there is an equal frequency of the use of structures between **low (30%), medium (29%)** and **high use (30%)** (**fig. 4.5.1 and 4.5.2.**). Also, remarkable is that in both cameras and inspection data records it is a common conclusion that animals are trying to use structures with small Openness Index. This fact can be evaluated not based on the convenience of the structures for animal crossing, but mainly as the expression of two behavioural ecology factors:

1) The need and the natural press for the animals to pass to the other side of the highway;
2) The use of crossing structures mainly on individual and not on population base and estimating the absence of fear especially of the young carnivores during the expression of the dispersal behaviour.

Additionally, critical factor for the overall evaluation is that the structures were not constructed for animal use and especially for bears, but mainly for hydraulic purposes. This is a crucial parameter that has to be taken into account, as during the design of the A29 highway and the implementation of the relevant EIA (1998) bear presence was sporadic in the area and therefore at this period there was no need for special measures for the species. However the construction period came much later and in the in between time bear population chorology dynamics made of this area a permanent habitat. At the same time, the improvement of the population status of the bears in the broader Region of Western Macedonia and the extension of its distribution shows the importance to estimate the dynamic status of the species population (Georgiadis and Voumvoulaki 2017).

On the other hand, the comparison of the use of the structures between carnivores and ungulates shows that there is a significant species-oriented difference. While bears, wildcats and wolves have **953, 529** and **255** passes respectively using **35, 37** and **28** out of **45** structures correspondingly, wild boars have **70** passes using **10** structures while roe deers have **18** passes using just **2** structures. In order to support effective ecological connectivity for all the species following a more general ecosystem and biodiversity approach (Reck et al 2018), this difference highlights the importance of aiming at the improvements on crossing structures with larger possible Openness Index than just focusing on structures used by bears. In a parallel approach working on structural connectivity and taking a measure on physical features and arrangements has to aim the securing of the effective functional connectivity for all species (Hilty 2020). Following this approach and having in mind that:

A. The Openness Index as described in **fig. 4.3.4.8** is:
    - **lower than 0.75** in **79%** of the structures
    - in the critical range **between 0.75 and 1.5** in **1%** of the structures
    - **between 1.5-2.49** in **5**% of the structures
    - **between 2.5-4.49** in **1**% of the structures
    - **higher than 5** in **3%** of the structures;
B. Almost all the underpasses and viaducts have been used for construction of local paved roads which decrease their ecological permeability;

the 9% of the structures with Openness Index higher than **1.5** such as large culverts, underpasses, viaducts and bridges have to be considered as the main “avenues” for the wildlife circulation in a more general and strategic approach.

At the level of the proposed interventions for crossing structures there are two differences compared with the foreseen in the initial project proposal:

1) The first difference is that the final number of the structures which are proposed and planned to be upgraded is 56 instead of 50. The increase of the number is due to combination of the importance of the crossing structures with the budget availability for the improvements.

2) The second difference is related with additional categories of technical tasks assumed as very important and have been included, such as, the removing and pruning of bushes and trees, the construction of ramps and ledges, the addition of natural materials on the entrance sides, fence improvements, the covering of pits and other interventions as already have been described in **fig. 4.6.2**.

Also, comparing these differences with the management needs, except for bush plantings (50 crossing structures need bush plantings and some few trees plantings) it's remarkable that:

- 28 need mainly removal of debris
- 16 need trees removing or pruning
- 6 need construction of ledges
- 16 are related with the improvement of the fence.

The first three categories sum 50 interventions (out of 162, with a percentage of 31%) which are related with the flooding and water management of the culverts. Having into account the overall climate change status and the fact that according to the Strategy for the Climate Change Adaptation of the Region of the Western Macedonia (Περιφέρεια Δυτικής Μακεδονίας 2019) and the phenomenon of 3-days-raining after long dry periods already exists, the following conclusions can be extracted:

1) During the design of a road, hydraulic, climate change and connectivity issues have to be taken into account concluding to the modern need of larger culverts and bridges (Ledec 2019, World Bank 2018).
2) The management of vegetation at the entrances of culverts of a highway as well as the overall roadside verges management has to follow an adaptable and effective strategy, following the local needs and the principle of "any case a unique case" (Georgiadis et al 2020).
3) Maintenance of the transport infrastructure has to be supported by permanent monitoring strategies combining technical with environmental supervision.

Further conclusions will be extracted during the implementation of the structure improvements under action (C2) of LIFE "Safe_Crossing" project, taking into account the practical needs that will emerge during both the interventions and the foreseen maintenance, in combination with the results from the camera monitoring session that will follow and the inspections of structures regarding their improved functionality for wildlife with emphasis on the target species *Ursus arctos**.

Overall it is important to note that the cooperation of three different project actors/partners (COSMOTE, CALLISTO and EGNATIA ODOS SA) each one having brought its state of the art on know-how but also innovative techniques, methods and tools in his field of knowledge and expertise, achieved a combination of complementary approaches which optimized the outcome of action A4 thus contributing in preparing the ground for the implementation of the relevant concrete conservation action (C2) and also in achieving one of the project's global objective.

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