Masterarbeit im Studiengang
“Environmental Management-Management Natürlicher Resourcen”

Assessment of the use of crossing structures by mammals along Egnatia Motorway in Northern Greece

by
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Foreword

The present Master Thesis was carried out from June 2010 to January 2011, as part of the Masters of Science program “Environmental Management” at the Ecology Centre of the Christian Albrecht University of Kiel. The research part was conducted at the Egnatia Motorway section of Northern Pindos in Greece, in cooperation with the NGO Callisto (www.callisto.gr).

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Abstract

The aim of the present research was to investigate the use of the crossing structures along Egnatia Highway, by the surrounding wildlife.

The increasing highway infrastructure affects environments and wildlife populations in a negative way mainly through their fragmentation. Egnatia dissects the sensitive area of Pindos, which is one of the last refuges for large mammals in Greece.

Twenty nine passage structures were monitored over a 37 km highway stretch. The passages were monitored in July and August 2010, using three different methods, marble dust tracking beds, automatic cameras and hair traps.

The passage use by the species was compared according to their surrounding vegetative and topographic characteristics and their openness ratio. Wild animals tended to prefer forested and open areas but also areas with fields and roads. According to the openness they showed a preference of mid to high openness ranges.

It is argued whether location of the crossing structures or structure design is more important in their efficacy. Mitigation plans should include a variety of crossing structures of mixed size classes, to provide greater permeability to multiple species and their behavioral profiles.

Keywords: mammals, highway, crossing structures, culverts, underpasses, overpasses

1. Introduction

Human societies rely greatly on road infrastructure. The easier the transport of people and goods, the more prosperous the economy can become. Commerce, exploitation of resources and tourism, are only few examples of the many that demonstrate the importance of the mobility of individuals, wares and services within a country.

Due to the essential role that roads play in the society, their infrastructure in many countries, including Greece, is continuously increasing or being improved. The total length of national and provincial roads has risen from 32.927 kilometers to 38.963 kilometers, by 6036 kilometers that is, from 1964 through 2007 (National Statistical Department of Greece, 1978). While this growing web of roads has positive effects on human societies, it affects the environment in an adverse way. Problems arise during the use of roads as well as during their construction period and are related to vegetation, wildlife, aquatic ecosystems and the fluxes of water, sediment and chemicals (Forman et al., 2003).

A basic impact of roads is that they take up space, which immediately causes direct habitat loss for the flora and fauna (Gutzwiller, 2002; Forman et al., 2003). Apart from direct habitat loss, a degradation of habitat quality can also be attributed to roads (Harrison and Bruna, 1999; Forman et al., 2003). Pollutants penetrate the surrounding areas and the noise affects several species in a negative way (Reijnen et al., 1996; Spellerberg, 1998). Moreover, wild animals are influenced by the increased contact with humans and human land use activities (Coffin, 2007).

Roads tend to act as barriers with many adverse consequences on the environment. Mobility of animals is disrupted, and migration or dispersal is hindered either through lack of habitat continuity or through mortality associated with road crossing (Forman et al., 1998; Trombulak and Frissell, 2000; Coffin, 2007). This leads to a fragmentation of habitats and populations, with effects upon their viability (De Santo and Smith, 1993; Forman, 1998; Coffin, 2007). The existence of smaller populations together with the reduced gene flow between them increases the possibility of extinction (Forman et al., 2003). Loss of biodiversity is another negative effect attributed to habitat fragmentation (Fahrig, 2003).

The need of a multidisciplinary approach to overcome these problems led to the introduction of road ecology. Road ecology concerns the interaction of organisms and the environment linked to roads and vehicles (Forman et al., 2003). The goal is to foresee the negative effects of roads on species and ecological systems and to mitigate and compensate these successfully.

It is an intricate task to assess the barrier effect of a road, as this affects species differently, depending on an animal’s behavior, dispersal ability, and population density (Forman et al., 2003). Additionally, the width of roads and their traffic density also determines the barrier effect of a road (Fahrig et al., 1995; Yanes et al., 1995). Of the different types of mitigation measures that have been employed, most of their success rates remain unknown (Glista et al., 2009). Types of mitigation techniques include wildlife fencing, underpasses or overpasses, warning signs, lower speed limits, mirrors, reflectors, highway lighting, ultrasonic warning, whistles, habitat alteration, hazing animals from the road and public awareness programs (Forman et al., 2003).

In this study we examined the effectiveness of crossing structures for the movement of wild animals, at the newly constructed Highway of Egnatia. It stretches through the whole of Northern Greece starting at the port of Igoumenitsa and ending at the Greek-Turkish border at Kipoi, with a total length of 670 km (Egnatia Odos). It is also part of the European route E90 which starts from Portugal crosses through Spain, Italy, Greece and Turkey and ends in Iraq. (Egnatia Odos). The Highway was gradually given to traffic, with its complete length being functional as of the year 2009.

The construction of Egnatia was one of the largest motorway projects in Greece of the last years. The travelling time from Igoumenitsa to Kipoi has been reduced from 11 hours 30 minutes to 6 hours 10 minutes (Egnatia Odos). In terms of financial growth, through the quicker and easier transportation of goods and people, Egnatia is a construction of national and international importance.

Nevertheless, in terms of the surrounding ecosystems such a construction can only pose threats. In its western part, Egnatia motorway dissects one of the last remaining refuges for large mammals in Greece, namely the Pindos Mountain Range.

The Pindos Mountain Range is a series of parallel limestone ridges situated in the western Continental Greece and extends along a northwest-southeast axis from Albania to the Gulf of Corinth. The range is a chaotic one, with many distinct massifs and very few passes. The only pass of any significance is at Metsovo, which links Thessaly and Epirus (McNeill, 1992). It hosts populations of carnivores such as *Ursus arctos*, *Canis lupus*, *Vulpes vulpes*, *Felis silvestris*, *Mustela* sp., *Martes* sp., *Meles meles* and ungulates such as *Sus scrofa*, *Capreolus capreolus*, *Rupicapra rupicapra* and also populations of *Lepus europaeus*, *Erinaceus concolor* and *Sciurus vulgaris*. Some birds present in the mountain range are *Aquilla heliaca, Aquilla chrysaetos, Falco biarmicus* and *Dendrocopus leucotos.* Serpents such as *Coronella austriaca, Coluber austriaca, Natrix tessellate* are present, as well as amphibians like *Triturus alpestris, Bombina variegata, Rana graeca, Bufo viridis* and *Salamandra salamandra*. The forest coverage consists of pine (*Pinus nigra*, *Pinus heldrecheii*), fir (*Abies cephalonica*, *Abies pectinata*) oak (*Quercus cerris*, *Quercus aegilops*, *Quercus robur*, *Quercus conferta*, *Quercus ilex*) and beech (*Fagus sylvatica*). Above timberline is an alpine stratum of meadow grasses and small shrubs. The vegetation survives here due to the remoteness of the Pindos and due to the fact that its relief is dissected (McNeill, 1992).

To the northwest of the constructed motorway, at the height of the mountain range, lies the national park of Pindos, while SPA (Special Protection Areas) and SCI (Sites of Community Importance) areas belonging to the Natura 2000 network, surround Egnatia at that height (Geodata). Thus, the motorway interrupts habitat connectivity in a sensitive area for wildlife. In fact, since the highway is surrounded by fencing, habitat continuity is limited to the width of the crossing structures, enhancing the barrier effect. Nevertheless, the fencing is responsible for keeping wildlife mortality rates due to collisions with vehicles low (Clevenger et al., 2001b).

Relative research projects about road effects on wildlife and the effectiveness of crossing structures have been conducted all around the world. Several in Canada (Clevenger et al., 2001a; McDonald and St. Clair, 2004; McGregor et al., 2008; Clevenger and Sawaya, 2010) and in Spain (Mata et al., 2008; Grilo et al., 2009), but also in Sweden (Olsson and Widen, 2008), the Netherlands (Reijnen et al., 1996), Czech Republic (Rico et al., 2007), United Kingdom (Rondinini and Doncaster, 2002), Australia (van der Ree et al., 2009), and USA (Boarman and Sazaki, 2006). Yet, the total amount of research is minuscule considering the magnitude of the road system and its ecological effects, as well as the many environmental controversies flagged by the public (Forman et al., 2003).

2. Materials and methods

2.1. Area of study

The study took place along the National Highway of Egnatia in Western Macedonia, in Northern Greece (Figure 1). A length of 37km was studied that extended from the village Panagia to the city of Grevena. The section from Panagia Interchange to Venetikos Interchange was given to traffic in 2009, while the section from Venetikos Interchange to Grevena South Interchange was given in 2008 (Egnatia Odos).

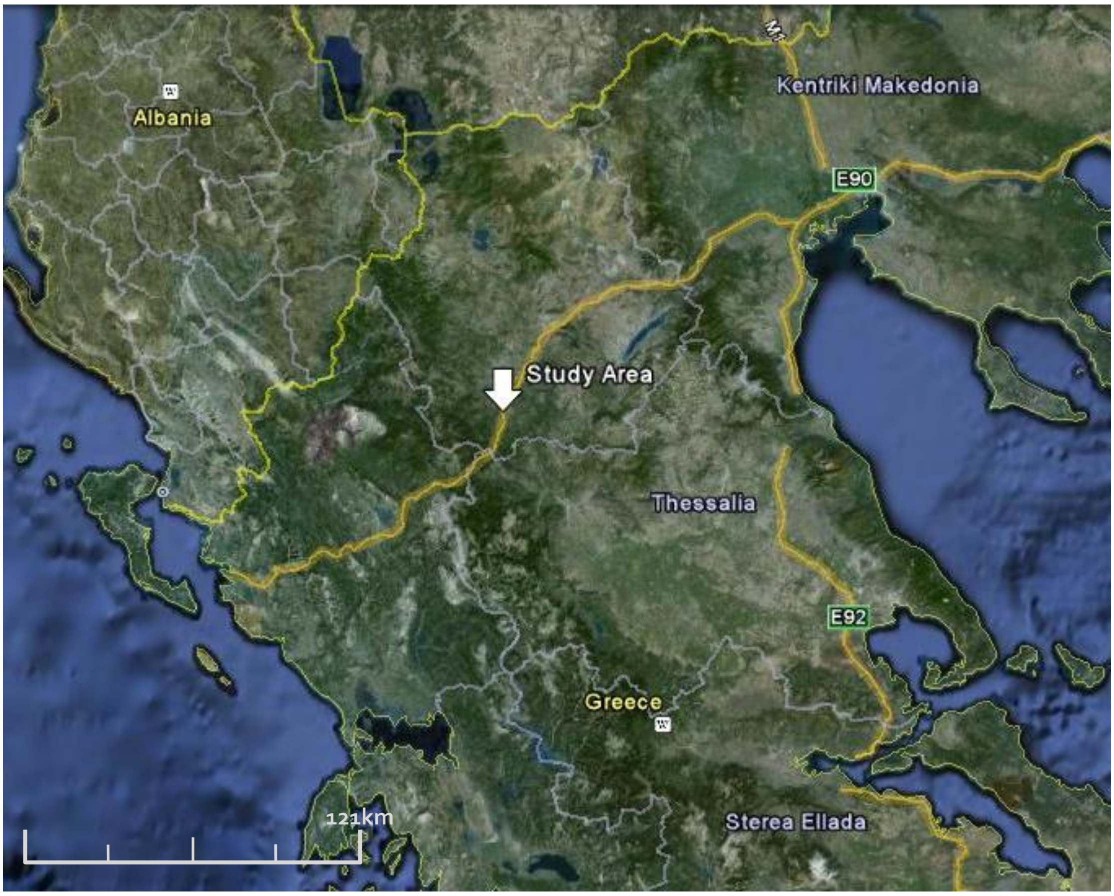

Figure 1 Study area (Source: Google Inc.)

The total width of the Egnatia highway is 24.5m (or 22.0 m at certain adverse mountainous sections) and consists of a dual carriageway separated by a central reserve, with two traffic lanes and a hard shoulder per direction (Figure 2) (Egnatia Odos). Throughout all of its length, the highway is surrounded by fencing. Its purpose is to protect both wildlife and drivers from collision. The initial fencing had a height of 1,5 meter and a mesh size of 17 by 10 centimeters. Due to its inadequacy, an additional fence was added later on with a single barbed wire above it and had a height of 2 meters and a mesh size of 5 by 5 centimeters.

The highway section lies in a mountainous region with a decreasing altitudinal gradient from the south western to the north eastern part. At Panagia the elevation is about 1000 meters and at Grevena it is about 600 meters. The area in the higher altitudes is covered by forest while as the altitude decreases agricultural land is dominant.

Figure 2 Egnatia Motorway

2.2. Passage characteristics

In the above-mentioned area we studied overpasses and underpasses of the highway others of which were constructed specifically for wildlife and others that although were not constructed as wildlife passages, can serve as such.

The constructions whose use is aimed at wildlife are the Wildlife Overpass and the Wildlife Underpasses. The Wildlife Overpass (WO), also referred to as a Green Bridge, is an overpass that is covered by natural vegetation and is intended to be used only by wildlife. It has a width of 50 metres and its concrete walls buffer the noise and prevent optical contact to the traffic. The wildlife underpasses (WU 1-3) are large concrete culverts, with a width of 5 metres and a height ranging from 2 to 6 metres.

Constructions occurring on the highway that can also be used by wildlife are the Viaducts, the Oversized Stream Culverts, the Box Culverts, the Tunnel Overpasses and the Local Roads.

The Viaducts (V) are elevated bridges that span whole valleys. Their intrusion in the surroundings is minimal, as the traffic is very distant, providing an undisturbed passage for wildlife. The Oversize Stream Culverts (OSC) are concrete culverts that are constructed in areas of streams, instead of a bridge. Their size is larger than that of wildlife underpasses. Box Culverts (BC 1-9) are constructed to channel water. They have different sizes, which can be from 2x2 m to 5x3 m. Despite their sometimes small size, they offer crossing possibilities to wildlife. Tunnel Overpasses (TO 1-13) are the areas beneath which vehicular traffic tunnels lie. Tunnels leave the above lying area relatively intact allowing their use by wildlife. In mountainous regions, they occur plentiful. In some cases, Local Roads (LR 1-3) cross under the highway providing a large opening that may also be used by wildlife.

The passages were coded with the initials of the crossing structure type and with an ascending number from northwest to southeast. Specific entrance characteristics such as height, width and length, entrance microhabitat and the vegetation and landuse of the surrounding area are shown in detail in Table 12 in the appendix. Figure 7-Figure 13 show a typical example of crossing structure types.

2.3. Passage monitoring and data collection

Along the 37 km highway section that we studied, 29 passage structures were selected for monitoring of their use by terrestrial mammals. In total 1 Green Bridge, 3 Wildlife Underpasses, 1 Viaduct, 1 Oversized Stream Culvert, 8 Box Culverts, 13 Tunnel Overpasses and 2 Local roads were selected to be monitored from the beginning of July to the end of August 2010.

Taking the available time, manpower and resources under consideration, we chose to intensively monitor an easy accessible 11km highway stretch (Figure 3) and the other 26 kilometres were monitored in a less intensive way.

The 11 km kilometre section that extended from the river of Venetikos to the city of Grevena we divided in two parts. The first part extending from the river of Venetikos to the Venetikos Interchange had been in use for 1 year, while the part extending from the Venetikos Interchange to Grevena South Interchange had been in use for 2 years. Along this section of the highway, a crosing structure was present at about every 500 meters. The passages were selected in a way to include all passage types in the monitoring and in the most balanced way possible under the given circumstances.

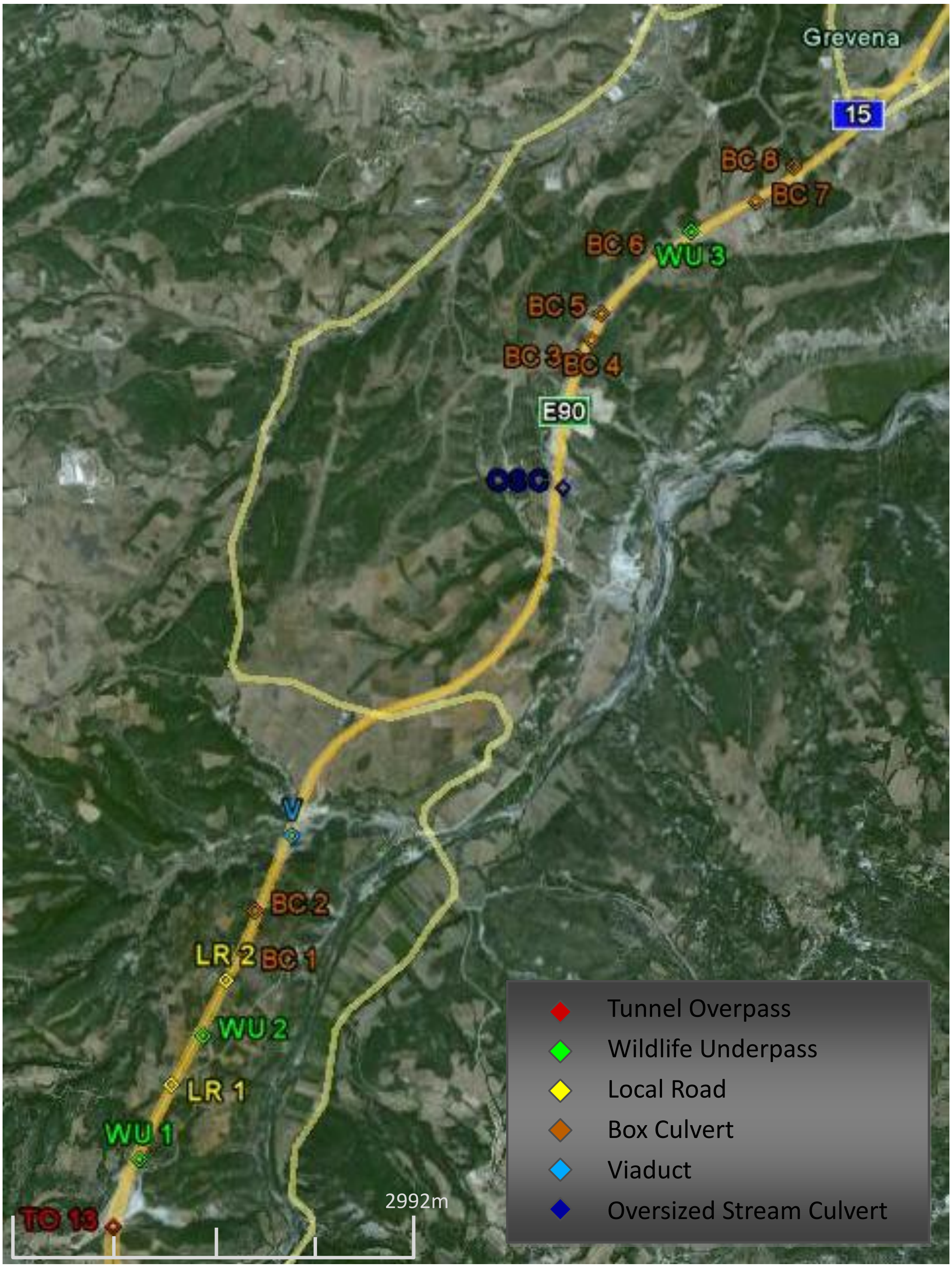

Figure 3 Monitored crossing structures along the 11km motorway stretch, from Venetikos to Grevena (Source: Google Inc.)

On the remaining highway stretch, we monitored the Tunnel Overpasses and the single existing Wildlife Overpass.

The remaining 26 km stretch was monitored in a less intensive way. Specifically 11 tunnel overpasses and one wildlife overpass were monitored (Figure 4). The first and farthest tunnel overpass was omitted, as access to it was proven very difficult.

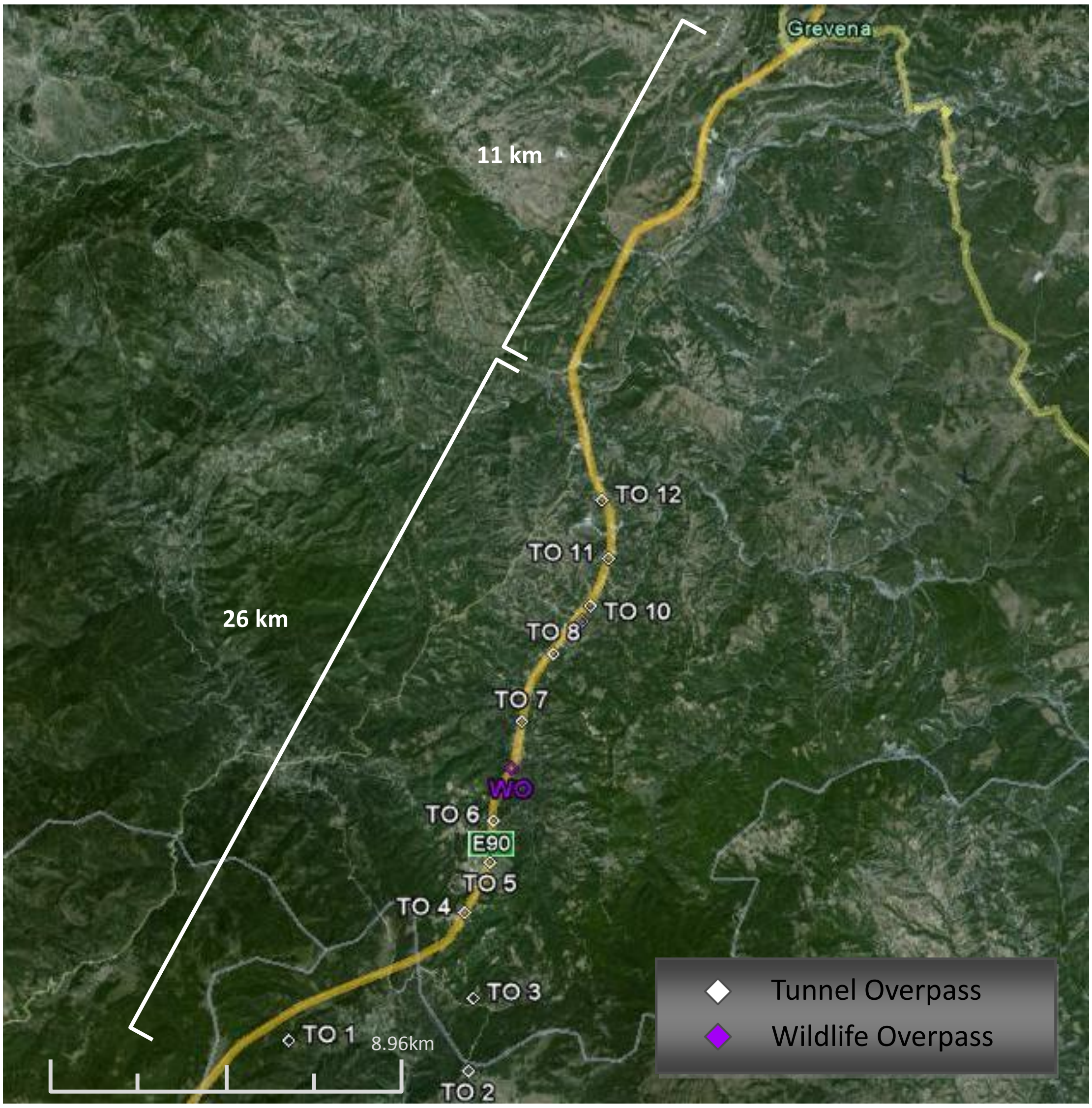

Figure 4 Monitored overpasses on the 26 km stretch from Panagia to Venetikos and relative position to 11 km stretch (Source: Google Inc.)

Three different methods of monitoring were used. The first consisted of spreading marble dust or raking pre-existing dirt at the entrances of the passages in order to be able to recognize the tracks of the animals that went through. The material was spread into a 4-8 millimeter thick and a 1 meter wide bed, along the whole length of the entrance and towards the inside of it, so that light rainfall would not affect it. Due to the regular use of Local Roads by vehicles, only the sidewalks were monitored, leaving the road surface unmonitored. In the case of the Wildlife Overpass, a suitable area in the center of the passage was selected, where it was relatively easy to loosen up the soil and create a track bed (Figure 5). Each time a passage was visited the animal species, their direction and the size of the footprints were noted, together with the state of the material bed. Afterwards the bed was leveled into a smooth surface. The entrances were checked every two to five days from the beginning of July until the end of August of 2010. The Wildlife Overpass was checked every 7 days. The animal tracks were identified with the assistance of two field guides of the mammals of Europe (Corbett and Ovenden, 1980; McDonald and Barrett, 1993).

Figure 5 Track bed on Wildlife Overpass

The second method used in order to monitor the passages was motion activated wildlife cameras. The cameras used were Reconyx RC55 RapidFire™ Color IR (Reconyx,Inc.). In total, six spots were chosen at six different passages were cameras were set up. Due to a high risk of theft in the area, the passages were chosen according to their provision of suitable mounting, securing and camouflaging possibilities. The cameras were positioned in a way to point to the entrances of the passages and if that was not possible, then onto the only pathways leading away from them. Data were also used from a seventh camera that had been positioned earlier in the Viaduct, by Yorgos Iliopoulos, a scientist working on wildlife issues in the area. The camera was positioned along a path, which channeled most movements through the Viaduct. The use of the cameras was only complementary, as it was not possible to fully monitor the passages by cameras. The cameras were set up between the 8th and the 21st of July 2010 and remained active until the 8th of September 2010, except for one which was removed earlier on camouflage destruction grounds.

The third method used, specifically to monitor Tunnel Overpasses, was the hair trap method. This method was restricted to monitor the use of the TO by brown bears. The hair trap method is based on the habit of male adult bears to rub themselves against tree stem like poles, during the reproductive period in a way of marking their territory. The method consists of wrapping barbwire around electrical power poles in a spiral with 30 centimetre intervals and up to a height of 2 meters (Karamanlidis, 2007). In this case, 13 tunnel overpasses were monitored on which Charilaos Pilidis, in a previous project, had fit the electrical poles with barbwire in 2008. Repairs were made wherever necessary and 5 additional poles were fitted with barbwire over the Venetikos tunnel overpass. The monitoring consisted of visiting poles periodically and collecting hair wisps or recognising signs of marking activity. 12 tunnel overpasses, located within the 26 km of less intensively monitored highway, were monitored every 15 days while the Venetikos tunnel overpass was monitored every 7 days. The monitoring took place from the end of June to the beginning of August of 2010 and from the end of June to the beginning of September 2010, respectively. In Table 1 there is a listing of the tunnel overpasses, their length and the number of electrical poles that were monitored over each.

Table 1 Length of tunnel overpasses and number of electrical poles over each

Tunnel Overpass	Tunnel Overpass Code	Length (km)	Monitored Electrical Poles
Panagias	TO 1	2,7	0
Sirtou	TO 2	1,5	4
Ag. Triados	TO 3	0,4	4
Ag. Paraskevis	TO 4	0,5	4
Agnanterou	TO 5	0,7	1
Prionion	TO 6	0,7	4
Green Bridge	WO	0,05	5
Velanidion	TO 7	0,8	3
Nika	TO 8	0,5	4
Lagkadion	TO 9	0,4	4
Sigra	TO 10	0,3	3
Kilomatos	TO 11	1	2
Karatza	TO 12	0,7	3
Venetikou	TO 13	0,7	7

2.4. Data analysis

2.4.1. Footprint and camera data

The data were inserted into a spreadsheet application to allow further manipulation. The automatic camera data were incorporated into the footprint data so that overlapping was avoided. Out of 25.396 photographs the ones of human or wildlife activity were sorted out. This excess of photographs can be attributed to the false triggering of the cameras by tree branches and vegetation that were set into motion by windy or stormy weather.

An individual was considered to have made a passage pass-through if photograph sequences showed an individual exiting or entering a passage or if footprints of the same species and direction were found on both entrances of a passage. A possible pass-through was considered when the entering or exiting of a passage was not evident on photographs whereas could not be definitely excluded, or when individuals' footprints were found only at the one entrance of the passage and only in one direction. This occurred in cases of partial or total destruction of the bed by rain or livestock. In the case of footprints near the entrance area with no indication of a pass-through or in the case of photographs showing only the use of the entrance area and not the use of the passage itself, it was considered as a no pass-through. Livestock was measured as an entity, so when a herd of sheep or goats crossed through a passage, it was considered as one pass-through and not as the sum of pass-throughs of each sheep or goat separately.

2.4.2. Hair trap data

Concerning the electrical power poles, hair wisps were collected and kept separately, together with the exact coordinates of each pole. If a pole had more than one hair wisps on it, each was collected separately in case they belonged to different individuals. The collected hair wisps were then handed over to colleagues for genetic analysis. In this project, only the presence or absence of adult male brown bears was of interest and therefore recorded.

2.4.3. Comparison of passage use

For analyzing the data, the observed species were grouped into categories. The resulting categories are wild animals, domestic animals, human activity and brown bears. In many cases, wild animals were difficult to be distinguished from relative domestic animals. That was especially the case with *Canis lupus* and *Canis familiaris*. In order to distinguish these two species one has to be very experienced in footprint recognition. Therefore, in our case, to avoid false appreciations we only distinguished these species when photographic evidence was available. Otherwise, the footprints were considered to belong to the domesticated species. The same applies for the species *Felis silvestris* and *Felis silvestris catus*, as both species were present in the area and could only be differentiated upon visual evidence. *Ursus arctos* was kept in a separate group due to its importance as a protected species and due to its easy discrimination from all others.

The box culverts and the wildlife underpasses were classified according to their surrounding vegetative and topographic characteristics (Table 2). This was done under the assumption that the surrounding habitat of an entrance has an influence on its usage by the different animal species. The passages were separated in five classes according to the surroundings that were present in a conceivable square area of 100 x 100 m around each of their entrances, with the entrance being in the center of the one of the square's sides (Table 3). The first class includes the passages that are surrounded by forested areas or open areas (fo/op). With "open area", grassland or sparsely vegetated soil is meant. The second class includes surroundings of forested areas, open areas, shrubs and streams (fo/op/sh/st). The third class refers to surroundings of forested areas, open areas and fields (fo/op/fi). The fourth class consists of passages with surroundings of forested areas, open areas, shrubs, fields and roads (fo/op/sh/fi/ro). The fifth class comprises surroundings with fields and roads (fi/ro). From the first to the fifth class the human influence on the habitat follows an increasing trend.

Table 2 Passage surroundings

	BC 1	**BC 2**	**BC 3**	**BC 4**	**BC 5**	**BC 6**	**BC 7**	**BC 8**	**WU 1**	**WU 2**	**WU 3**
forested	*	*	*	*	*		*	*	*	*	*
open	*	*	*	*	*		*	*	*	*	
stream		*									
shrub		*			*						
field	*		*			*	*		*	*	*
road					*	*	*				*

Table 3 Passage classification

	Class	**Passages**
1	fo/op	BC 4, BC 8
2	fo/op/sh/st	BC 2
3	fo/op/fi	BC 1, BC 3, WU 1, WU 2
4	fo/op/sh/fi/ro	BC 5, BC 7, WU 3
5	fi/ro	BC 6

Moreover, the passages were categorized into four classes according to their openness (Table 4 & Table 5). The openness ratio is defined as the equation width x height/ length (Yanes et al., 1995).

Table 4 Passage openness

Passage	Openness (m)
WU 1	1,11
WU 2	0,93
BC 4	0,58
WU 3	0,37
BC 5	0,34
BC 1	0,15
BC 8	0,13
BC 6	0,10
BC 2	0,09
BC 7	0,09
BC 3	0,07

Table 5 Passage openness classes

Classes	Passages
[0,06-0,27)	BC 1, BC 2, BC 3, BC 6, BC 7, BC 8
[0,27-0,48)	BC 5, WU 3
[0,48-0,70)	BC 4
[0,70-0,91)	
[0,91-1,12)	WU 1, WU 2

3. Results

3.1 Footprints and automatic camera data

Throughout the study period, 610 visits to the passages were recorded, in the 598 of which the individuals crossed or possibly crossed Egnatia using one of the monitored passages.

The species identified using the passages are shown in Table 6, categorised by the four groups of brown bear, wild animals, domestic animals and human activity and by whether they passed through the passages, might have passed through or just visited the entrance area.

Table 6 Total activity of species at all passages combined, according to pass-through behaviour

Species	Activity			Total
	Pass-through	Possible pass-through	No pass-through	
Brown bear	8	6	1	15
Total brown bear	**8**	**6**	**1**	**15**
Deer	1	1	-	2
Fox	14	46	3	63
Hare	6	12	-	18
Hedgehog	19	27	-	46
Mustelid	15	39	-	54
Rat	-	2	-	2
Wild boar	-	1	-	1
Wildcat	-	2	-	2
Wolf	26	-	-	26
Total wild animals	**81**	**130**	**3**	**214**
Cat	1	17	-	18
Dog	82	76	-	158
Domestic cat	2	1	-	3
Goat	-	1	-	1
Livestock	67	23	1	91
Total domestic animals	**152**	**118**	**1**	**271**
Bulldozer	3	-	-	3
Car	10	-	-	10
Human	38	36	-	74
Motorbike	5	-	-	5
Shepherd	15	-	-	15
Truck	3	-	-	3
Total human activity	**74**	**36**		**110**
Total	**315**	**290**	**5**	**610**

Table 7 presents the individual pass-throughs and possible pass-throughs, sorted by species and by the passage used. The most frequent visitors of the passages were dogs, followed by livestock and humans. The next frequent in visiting the passages were foxes, mustelids and hedgehogs.

Table 7 Total pass through activity at each passage, with pass-throughs and possible pass-throughs combined

Passages / Species	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	LR1	LR2	OSC	V	WO	WU1	WU2	WU3	Sum
bear		4		3		1	1	1			2	2	1				**15**
deer										1			1				**2**
fox	7	6	2	2	3	1	15	3			5	2	9	1	6		**62**
hare							1				5		12				**18**
hedgehog	1		7	12	2	4	9	4		2			1	3	1		**46**
mustelid	2		3	7	13	5	5	5	1	1	2			2	4	4	**54**
rat							1			1							**2**
wild boar													1				**1**
wildcat		2															**2**
wolf											7	19					**26**
cat		3		2	1		1	3		1				4	3		**18**
dog	1	1	7	11	20	8	5	32	7	6	21	1	4	10	11	10	**155**
domestic cat							3										**3**
goat													1				**1**
livestock	2		1	2	3	11	2	5	5	5	5		2	21	11	11	**86**
bulldozer														1	2		**3**
car											1		8	1			**10**
human	1	2	3	4	3	8			2		16	13		2	3	14	**71**
motorbike								4						1			**5**
shepherd								3						9	3		**15**
truck													3				**3**
Sum	**14**	**18**	**23**	**43**	**45**	**38**	**43**	**60**	**15**	**17**	**64**	**37**	**43**	**55**	**44**	**39**	**598**

The average crossings (actual and possible) of the species categories, per surroundings classification are shown in Table 8. Brown bear use indicates a preference of more natural surroundings without ruling out the use of more human affected environments. Wild animals tended to prefer forested and open areas but also areas with fields and roads. They were present in all habitat surroundings though. Domestic animals had a presence in all sorts of surroundings with a preference in forested and open areas and a tendency to avoid habitats with streams. Human activity was spread throughout all surrounding types, to a lesser extent though than wild and domestic animals. The presence was least in areas of streams and most in areas with fields and roads.

Table 8 Average crossings of species groups per passage surroundings class, during the monitoring period

Species Groups \ Passage Classes	fo/op	fo/op/sh/st	fo/op/fi	fo/op/sh/fi/ro	fi/ro
brown bear	2,0	4,0	0,0	0,3	1,0
wild animals	16,5	8,0	9,8	17,7	10,0
domestic animals	27,5	4,0	17,8	18,7	19,0
human activity	5,5	2,0	6,5	5,7	8,0

The average crossings (actual and possible) of the species categories, per openness classification are presented in (Table 9). In relevance to the openness of the passages, brown bears tended to use either passages of low openness (0,06-0,27) or mid to high openness (0,48-0,70). Wild animals preferred mid to high openness ranges (0,48-0,70) followed by low (0,06-0,27) and mid ranges (0,27-0,48). Domestic animals mostly used passages of a high openness (0,91-1,12) followed by mid openness (0,27-0,48). Human activity was mostly recorded in passages of high openness (0,91-1,12), followed by mid openness (0,27-0,48) passages.

Table 9 Average crossings of species groups per passage openness class, during the monitoring period

Species Group \ Openness Classes	[0,06-0,27)	[0,27-0,48)	[0,48-0,70)	[0,91-1,12)
brown bear	1,2	0,0	3,0	0,0
wild animals	13,8	11,0	21,0	8,5
domestic animals	14,2	22,5	15,0	30,0
human activity	3,5	8,5	4,0	11,0

3.2 Hair trap data

From the controls over the tunnel overpasses along the less intensively monitored highway stretch, the data of Table 10 resulted. Most tunnel overpass visits appeared in the control of the 30th of June, with 16 hair wisps found on poles over six of the tunnel overpasses. In the control of the 15th of July 4 hair wisps were found over two tunnels and scats near one pole, indicating bear presence. In the control of the 7th of August 2 hair wisps were found and one removed barbwire also indicating bear presence.

Table 10 Hair wisps found on electrical poles, over the tunnel overpasses of the secondary research stretch, sorted by date

Tunnel Overpass	Electrical Pole	30/6/2010	15/7/2010	7/8/2010
TO 2	1	1		
	2			
	3	2		
	4			
TO 3	5		1	
	6			
	7		scats at 5 m	
	8			
TO 4	9	1		
	10	3		
	11	1		
	12			
TO 5	13			
TO 6	14			
	15			
	16			
	17			
TO 7	18			
	19			
	20	1		
TO 8	21		3	
	22			
	23			barbwire down
	24			
TO 9	25	1		
	26	2		
	27			
	28			
TO 10	29	1		
	30			2
	31			
TO 11	32			
	33			
TO 12	34	1		
	35			
	36	2		

From the controls of the Venetikos tunnel overpass, which was within the intensively monitored area, the data of Table 11 resulted. Eighteen hair wisps were found during the monitoring period and one case of a torn down barbwire was noted. All but two poles were visited at least twice, from one or more individuals each time.

Table 11 Hair wisps found on electrical poles, over the tunnel overpass of the secondary research stretch, sorted by date

Tunnel Overpass	Electrical Pole	19/6/2010	28/7/2010	09/8/2010	16/8/2010	23/8/2010	30/8/2010
TO 13	1	3	2				
	2		4		1		
	3			2			
	4					barbwire down	
	5	1					1
	6						
	7			2			2

4. Discussion

The present study is one of few that have been conducted in Greece concerning the usage of crossing structures along highways. As Egnatia motorway, a construction of national importance, crosses through Pindos, an area of high interest for nature conservation, it is necessary to investigate its impact on the surrounding wildlife. By assessing the effects on wildlife and evaluating the mitigation possibilities, research as the present intend to enhance knowledge in that direction and promote future solutions that are harmonious with nature.

The main result of this research is that crossing structures successfully serve as connectors between habitats separated by Egnatia. The crossing structures were either especially constructed for wildlife, like the wildlife underpasses and the wildlife overpass or they served structural purposes, such as box culverts, tunnel overpasses, local roads and viaducts. Of the larger mammals present in the area all except *Rupicapra rupicapra* were proven to have used passages to cross the highway. From the smaller mammals, members of the Mustelidae family, as well as *Felis silvestris*, *Lepus europaeus* and *Erinaceus concolor* were identified using highway crossing structures. Other studies have similarly confirmed the use of crossing structures by various species (Yanes et al., 1995; Clevenger et al., 2001a; Cain et al., 2003; Ng et al., 2004; Mata et al., 2005; Ascensão and Mira, 2007).

Comparing the passage use in accordance to the entrance surroundings we reached certain conclusions. Although only few bear crossing data were available, it is presumable that there is a tendency for bears to use passages with forested or open surroundings. They do not completely avoid passages with greater human influence in the surroundings, indicating that bears do not necessarily discriminate in passage use.

This might be because bears are at the top of the food web and have no predators affecting their passage choice. Humans are the only threat to them and it is possible that they have learnt to avoid them by adjusting their activity pattern to a nocturnal one (Kaczensky et al., 2006) and thus do not need to adjust their movements according to areas with or without human influence, as humans are predominantly diurnal. According to Gibeau et al. (2002) though, grizzly bears in Alberta avoid human development and activities and the same is true for a black bear population in Florida, which avoids areas dominated by anthropogenic land uses and less forest (Maehr et al., 2003).

Wild mammals showed a preference for forested and open areas but also areas with fields and roads. All habitat surroundings though, had wild animal presence. This might represent the range of preferences of the different wild animals that appeared in this study. More data would be necessary in order to have a more detailed view on species level preferences.

Most domestic animals used passages with forest and open area surroundings and the least used passages surrounded by habitats with streams, but they generally were present in all surrounding types. Most of the domestic animals crossing Egnatia were dogs and livestock. Livestock was frequently led across Egnatia to reach pastures for feeding and then back, to return to their pen. Five or six herding and guard dogs always accompany them. That explains the high use of passages by domestic animals and explains the fact that forested and open surrounding areas were preferred.

Human use of the passages was not very high. Most human activity was recorded at passages near fields and roads, i.e. habitats that are highly influenced by humans. A large part of the human activity that was recorded was associated with the livestock.

Another parameter according to which we compared passage usage was their openness. In the case of bears, there was a tendency to use passages of mid to high openness and passages of low openness. The low openness was in passages of 2 x 2 m and a length of approximately 70 meters. The use of such narrow culverts contradicts the results of some previous research studies. Kusak et. al. (2009) reached the conclusion that bears prefer large overpasses to narrow underpasses. According to Clevenger and Waltho (2005), grizzly bears prefer high openness. Only black bears have been proven to use more constricted crossing structures (Clevenger and Waltho, 2005).

Wild animals seem to prefer passages of mid to high openness. Similarly elk and deer in Canada, avoid confining structures (Clevenger and Waltho, 2005; Ng et al., 2004). For bobcats in USA openness plays a significant role in crossing use (Cain et al., 2003) and in Portugal smaller mammals avoided longer passages (Ascensão and Mira, 2007).

Domestic animals were mostly recorded using passages of high openness or of mid openness. Human activity followed the same trend possibly due to the connection of domestic animals with humans. Their preferences were possibly not solely based on how open the passages were, but on the purpose of crossing the highway.

Concerning the hair traps, the resulting data shows that bears visited nine out of twelve monitored overpasses during our monitoring period. That shows that the tunnel overpasses are used as crossing structures over Egnatia and are thus important components for the connectedness of the opposite highway sides. This method of controlling the use of the tunnel overpasses is simple and inexpensive. In addition, by analyzing the DNA of the hair wisps one can identify individual bears. Apart from its advantages, the method has also got drawbacks, the greatest ones being that it is species and gender specific. It only provides information about adult male bears and mainly during their reproductive period. Moreover, the accuracy of the method is low, as lack of hair wisps does not mean that there was no bear crossing.

The total length of all tunnel overpasses together is 10,95 km, which is approximately 30% of the length of the highway section under examination. That is a relatively high connectedness, even without adding the length of the remaining crossing structures. In Gorski kotar, Croatia, the potential crossing structures constituted a 25% of the highway length while in Banff National Park in Canada, the connectedness is only 0,31% (Clevenger, 2000; Clevenger and Waltho, 2005; Kusak et al., 2009).

The NGO of Callisto had carried out an EIA (Environmental Impact Assessment) concerning the highway construction area, over the years 2006 to 2008. The results regarding the bears' use of Tunnel Overpasses showed that there was a center of activity over TO 12 and 13 in the years of 2006 and 2007, which in 2008 was present only over TO 12 (Callisto, 2009). Our results show a presence over TO 12 and an increased activity over TO 13. Moreover, an activity over TO 7 and 8 in year 2007 and over TO 8 in year 2008 was recorded (Callisto, 2009). The activity over those tunnel overpasses, was not very intense according to our data of 2010. In 2008 a subpopulation was active above TO 4 and 5 (Callisto, 2009). According to our data there is an activity over TO 4 but there was no activity recorded over TO 5.

The comparison of the data indicates that the subpopulation with a home range covering Tunnel Overpasses 12 and 13 is still active in the area. This is encouraging information that show that TO 12 successfully serves as a connector of the divided habitats at least for bear populations. The activity over TO 7 and 8 seems to have lessened, but this could be also a conclusion biased by the less frequent controlling than that over TO 12. It could also mean that the subpopulation of the area has shifted its home range or that it avoided the area on grounds of disturbance. Over TO 4 the activity remains as it was but over TO 5 it is no longer present indicating either a reduced connectivity of the subpopulation or a change in home range.

For the bear populations it is fortunate that several tunnel overpasses coincide with preexisting brown bear paths, as this fact aids in the reduction of the negative effects of fragmentation on their populations.

Another study along the Egnatia highway was carried out during 2005-2006, as part of a diploma thesis. The area investigated was adjacent to ours and the monitoring methods followed were similar. This study confirms the fact that box culverts, even of small size, are regularly used by several mammal species in order to cross Egnatia (Koliopanos, 2008).

The different methods used in this study in order to evaluate the use of various crossing structures over highways, gave us an insight about the efficiency of each method.

Controlling passages via track beds is an inexpensive way to monitor animal use and can be set up almost everywhere. The size of the footprint can be measured as well as the stride length, revealing information about the size and the age of an animal. However, information from track beds gets lost easier. There are the cases of rain, which might wash away the whole track bed leaving the researcher without data and with the burden of the reconstruction of all track beds. Then there is the case of crossing vehicles or livestock that might destroy all previous tracks. Many times, there is in uncertainty concerning the footprint identification either because the footprints are not clear enough or because they have been affected by the wind. In order to avoid data loss due to destruction controls have to be done in short intervals.

When controlling crossing structures via camera many of these problems are absent. Rain or livestock crossings will not affect the data collection and the animal identification becomes much easier and with a very low error probability. Much more data is available since current automatic wildlife cameras can provide the exact date, time and temperature of the crossing event. To a certain extent, it is possible to identify individuals, acquiring in that way information on specific behavior or habits of an animal. Moreover, groups of animals can be identified and predator-prey interactions might become evident. The main drawback is that the use of automatic cameras is expensive. Another important disadvantage is that cameras are often stolen which involves data loss and more importantly economical loss.

Egnatia belongs to the highways that are surrounded by fencing. The reason, for which it was put up, is to minimize wildlife-vehicle collisions. In the beginning a fence of 1,5 meters was used, which soon proved to be inadequate as large animals could surmount it and small animals fit through the mesh holes. A second fence was added, this time of a smaller mesh size, a height of two meters and a barbed wire above it. Although wildlife-vehicle collisions have become less, at least in the case of brown bears, they still manage to climb over the fence as proven by hair wisps found in certain places on the barbed wire (personal observation).

Highways that are entirely surrounded by fencing prevent mortality caused by collisions with vehicles but at the same time they act as total barriers to animal movements (Clevenger et al., 2001b). This means that the permeability of these highways depends solely on the function of the crossing structures as habitat connectors. Thus, it is disputed upon whether fences promote population persistence or not. Jaeger and Fahrig (2004) support that for high traffic mortalities fences promote population persistence probability and for low traffic volume they reduce population persistence.

Studies on the effectiveness of crossing structures have been made in various places around the globe, but it is difficult to compare the results. Each study has a different research approach, giving a wide assortment of outcomes. Some studies have argued that the location of acrossing structure, particularly in the relation to habitat quality, is the most important feature (Yanes et al, 1995; Clevenger and Waltho, 2000; Ng et al., 2004). Other research has shown that structure design can be the most influential (Cain et al.,2003).

Therefore, general guidelines are needed to navigate future research in the right direction. Forman et al. (2003) mention some important points to be considered when planning future studies. Predefined criteria have to be developed in order to measure how well a passage meets those criteria. Human activity is likely to affect passage by wildlife and should be counted in. The estimation of the frequency of observed passage is not enough; it should be evaluated in the context of how abundant the animal is and its distribution around the structure. The passage frequencies that ensure genetic variation, maintenance of population size and minimization of extinction are necessary to be sought for.

However, efficacy of crossing structures might be expected to vary between landscapes and faunal communities (Clevenger and Waltho, 2005). Further long-term research from a range of landscapes with complex wildlife-human interactions is needed, in order to develop a general model for crossing structure performance (Clevenger and Waltho, 2005). To maximize connectivity across roads for multiple large mammal species, road construction schemes in the future should include a diversity of crossing structures of mixed size classes (Clevenger and Waltho, 2005). This strategy will likely provide greater permeability of roads by accommodating a variety of species and behavioural profiles (Clevenger and Waltho, 2005).

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Appendix

Figure 6 Egnatia highway

Figure 7 Wildlife overpass

Figure 8 Wildlife underpass

Figure 9 Viaduct

Figure 10 Oversized stream culvert

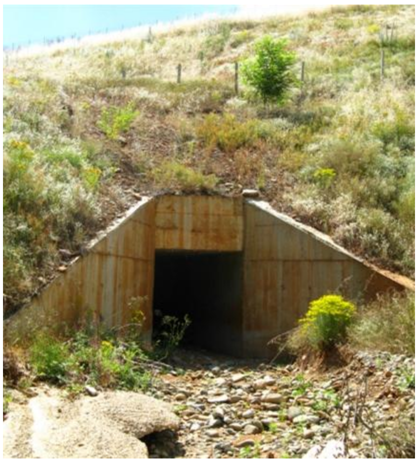

Figure 11 Box culvert

Photos by K.Tritsis

Figure 12 Tunnel overpass

Figure 13 Local road

Figure 14 Marble dust tracking bed

Figure 15 Camouflaged automatic wildlife camera

Figure 16 Hair Trap

Figure 17 Bear hind footprint

Photos by K.Tritsis

Figure 18 Bear front footprint

Figure 19 Dog footprint

Figure 20 Mustelid footprints

Figure 21 Bear scats

Figure 22 Fox (automatic camera)

Figure 23 Wolf (automatic camera)

Photos by K.Tritsis

Figure 24 Shepherd & livestock (automatic camera)

Figure 25 Wild cat (automatic camera)

Figure 26 Bear (automatic camera)

Figure 27 Bear (automatic camera)

Figure 28 Dogs (automatic camera)

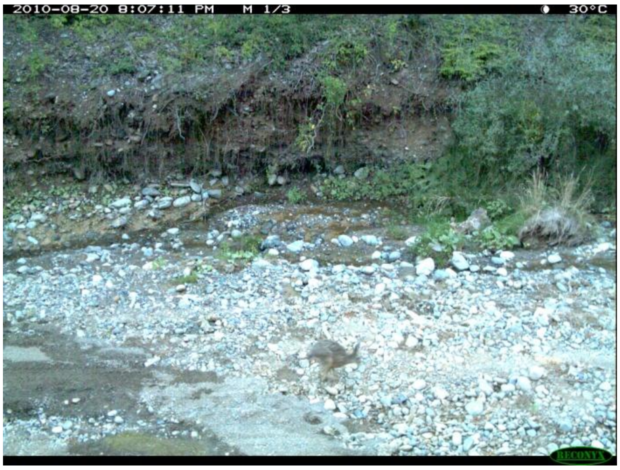

Figure 29 Hare (automatic camera)

Photos by K.Tritsis

Table 12 Passage characteristics

Characterisation	Green Bridge		Wildlife Underpass	
Code Name	**WO**		**WU 1**	
W/E Side	**W**	**E**	**W**	**E**
Width	50	50	5	5
Height			6	6
Length	27	27	27	27
Car Passable	yes	yes	yes	yes
Underpass with Road: Sidewalk	-	-	-	-
Slope	slight	slight	slight	slight
Slope Direction	E→W	E→W	W→E	W→E
Entrance Type			open	open
Entrance Substrate Condition	good	good	no substrate	no substrate
Habitat Topo	flat	construction site/ flat	flat	flat/ field
Forest Cover (Radius~500m)	forested	forested	forested	scattered vegetation
Tree Cover Type	pine/ oak	pine	oak/ acacia	oak/ pine/ acacia
Land Use (0-500m)	natural/ field	natural/ construction site	natural	natural/ agricultural
Livestock Presence in Area (0-500m)	no	no	no	no
Distance from Nearest Road	50-100	50-100	100-500	50-100
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	-	-	soil patches	soil patches
Fence Condition	solid	solid	solid	solid
Fence Type	old & new	old & new	old & new	old & new

Characterisation	Wildlife Underpass		Wildlife Underpass	
Code Name	WU 2		WU 3	
W/E Side	W	E	W	E
Width	5	5	5	5
Height	5	5	2	2
Length	27	27	27	27
Car Passable	yes	yes	no	no
Underpass with Road: Sidewalk	-	-	-	-
Slope	slight	slight	rough	rough
Slope Direction	W→E	W→E	W→E	W→E
Entrance Type	open	open	blocked	blocked
Entrance Substrate Condition	no substrate	no substrate	no substrate	good
Habitat Topo	flat/ field	flat/ field	flat	field
Forest Cover (Radius~500m)	forested	scattered vegetation	forested	scattered vegetation
Tree Cover Type	oak/ acacia	oak/ acacia	-	-
Land Use (0-500m)	natural/ agricultural	natural/ agricultural	natural	agriculture
Livestock Presence in Area (0-500m)	no	no	yes	yes
Distance from Nearest Road	100-500	100-500	0-50	0-50
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	soil patches	soil patches	grass/ road	grass/ soil patches
Fence Condition	solid	solid	solid	solid
Fence Type	old & new	old & new	old	old

Characterisation	Local Road		Local Road	
Code Name	LR 1		LR 2	
W/E Side	W	E	W	E
Width	7	7	7	7
Height	6	6	6	6
Length	27	27	27	27
Car Passable	yes	yes	yes	yes
Underpass with Road: Sidewalk	yes	yes	yes	yes
Slope	no	no	no	no
Slope Direction				
Entrance Type	open	open	open	open
Entrance Substrate Condition	asphalt	asphalt	asphalt	asphalt
Habitat Topo	flat	flat/ field	flat/ field	flat/ field
Forest Cover (Radius~500m)	scattered vegetation	scattered vegetation	scattered vegetation	scattered vegetation
Tree Cover Type	oak/ acacia	oak/ acacia	oak/ acacia/ pine	oak/ acacia
Land Use (0-500m)	natural/ agriculture	natural/ agriculture	natural/ agriculture	natural/ agriculture
Livestock Presence in Area (0-500m)	no	no	no	no
Distance from Nearest Road	0-50	0-50	0-50	0-50
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	no vegetation/ technical	no vegetation/ technical	no vegetation/ technical	no vegetation/ technical
Fence Condition	solid	solid	solid	solid
Fence Type	old & new	old & new	old & new	old & new

Characterisation	Viaduct		Oversized Stream Culvert	
Code Name	V 1		OSC	
W/E Side	W	E	W	E
Width	400	400	6	6
Height	?	?	5	5
Length			?	?
Car Passable	no	no	yes	yes
Underpass with Road: Sidewalk	-	-	-	-
Slope	slight	slight	slight	slight
Slope Direction	W→E	W→E	W→E	W→E
Entrance Type			open	open
Entrance Substrate Condition	good	good	no substrate	no substrate
Habitat Topo	stream	stream	stream	stream
Forest Cover (Radius~500m)	forested	forested	forested	forested
Tree Cover Type	oak	oak	oak	oak
Land Use (0-500m)	natural	natural	natural	natural
Livestock Presence in Area (0-500m)	no	no	yes	yes
Distance from Nearest Road	>500m	>500m	100-500	100-500
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	-	-	no vegetation/ technical	no vegetation/ technical
Fence Condition	-	-	solid	solid
Fence Type	-	-	new	new

Characterisation	Box Culvert		Box Culvert	
Code Name	**BC 1**		**BC 2**	
W/E Side	**W**	**E**	**W**	**E**
Width	2	2	2	2
Height	2	2	3	3
Length	26	26	70	70
Car Passable	no	no	no	no
Underpass with Road: Sidewalk	-	-	-	-
Slope	slight	slight	slight	slight
Slope Direction	E→W	E→W	W→E	W→E
Entrance Type	open	open	open	open
Entrance Substrate Condition	good	good	no substrate	moderate
Habitat Topo	flat/ field	flat/ field	stream	stream
Forest Cover (Radius~500m)	scattered vegetation	scattered vegetation	forested	forested
Tree Cover Type	oak/ acacia	acacia	oak/ acacia	oak/ acacia
Land Use (0-500m)	natural/ agricultural	natural/ agricultural	forested	forested
Livestock Presence in Area (0-500m)	no	no	no	no
Distance from Nearest Road	100-500	100-500	100-500	100-500
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	grass/ soil patches	grass /soil patches	grass/ soil patches	grass/ soil patches
Fence Condition	solid	solid	solid	solid
Fence Type	old & new	old & new	old & new	old & new

Characterisation	Box Culvert		Box Culvert	
Code Name	BC 3		BC 4	
W/E Side	W	E	W	E
Width	2	2	5	5
Height	2.5	2.5	3	3
Length	70	70	26	26
Car Passable	no	no	no	no
Underpass with Road: Sidewalk	-	-	-	-
Slope	slight	slight	slight	slight
Slope Direction	W→E	W→E	W→E	W→E
Entrance Type	open	open	open	open
Entrance Substrate Condition	no substrate	good	good	moderate
Habitat Topo	flat	flat	flat	flat
Forest Cover (Radius~500m)	forested	forested	forested	forested
Tree Cover Type	oak	oak	oak	oak
Land Use (0-500m)	natural/ agriculture	natural	natural	natural/ agriculture
Livestock Presence in Area (0-500m)	no	no	no	no
Distance from Nearest Road	100-500	100-500	100-500	100-500
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	grass	grass/ soil patches	grass/ soil patches	grass/ soil patches
Fence Condition	solid	solid	solid	solid
Fence Type	old	old & new	old	old & new

Characterisation	Box Culvert		Box Culvert	
Code Name	**BC 5**		**BC 6**	
W/E Side	**W**	**E**	**W**	**E**
Width	5	5	2	2
Height	2	2	2	2
Length	29	29	40	40
Car Passable	no	no	no	no
Underpass with Road: Sidewalk	-	-	-	-
Slope	slight	slight	slight	slight
Slope Direction	W→E	W→E	W→E	W→E
Entrance Type	open	open	open	open
Entrance Substrate Condition	moderate	moderate	no substrate	moderate
Habitat Topo	flat	flat	field	field
Forest Cover (Radius~500m)	forested	scattered vegetation	no vegetation	scattered vegetation
Tree Cover Type				
Land Use (0-500m)	natural	natural/ agriculture	agriculture	agriculture
Livestock Presence in Area (0-500m)	no	no	no	no
Distance from Nearest Road	100-500	100-500	100-500	100-500
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	grass	grass	grass	grass
Fence Condition	solid	solid	solid	solid
Fence Type	old	old & new	old	old

Characterisation	Box Culvert		Box Culvert	
Code Name	**BC 7**		**BC 8**	
W/E Side	**W**	**E**	**W**	**E**
Width	2	2	3	3
Height	3	3	3	3
Length	70	70	70	70
Car Passable	no	no	no	no
Underpass with Road: Sidewalk	-	-	-	-
Slope	slight	slight	slight	slight
Slope Direction	E⟶W	E⟶W	E⟶W	E⟶W
Entrance Type	open	blocked	open	open
Entrance Substrate Condition	no substrate	moderate	good	good
Habitat Topo	flat/ field	field	flat	flat
Forest Cover (Radius~500m)	forested/ scattered vegetation	scattered vegetation	forested	forested
Tree Cover Type	acacia		oak/ pine/ acacia	oak/ pine/ acacia
Land Use (0-500m)	natural/ agriculture	natural/ agriculture	natural	natural
Livestock Presence in Area (0-500m)	no	no	no	no
Distance from Nearest Road	100-500	100-500	100-500	100-500
Distance from Nearest Village/ Human Settlement	>500m	>500m	>500m	>500m
Entrance Microhabitat (0-5m Radius)	grass/ soil patches	soil patches	grass/ soil patches	grass/ soil patches
Fence Condition	solid	solid	solid	solid
Fence Type	old	old & new	old	old & new

Declaration

Herewith I declare that the present master thesis is an outcome of my own personal work, for the composition of which I have used nothing but the sources mentioned in the citations. Moreover, I would like to declare that I have not submitted this thesis elsewhere to achieve an academic grading.

Location/Date

Signature