PROTECTING FAUNA AND FLORA IN SENSITIVE AREAS CROSSED BY LINEAR TRANSPORTATION INFRASTRUCTURE

George Kollaros, Antonia Athanasopoulou, Vasiliki Kollarou

Democritus University of Thrace, Vas Sofias 12, 67132, Xanthi, Greece

Abstract

The effects of road projects on flora and fauna are examined and discussed in an effort to make suggestions for mitigating measures. The Egnatia Road motorway has been selected as basis for a full research on the issue, since it is a modern infrastructure with multiple beneficial social impacts, as well as economic benefits. In the part of the road in Eastern Macedonia and Thrace Region completed recently and its vertical axes the main problem is the habitat fragmentation for the terrestrial species. Flora is impacted mainly in the verges of the road. Large and smaller mammals, amphibians, reptiles and birds are all affected to a different degree. Protective measures can be implemented towards the confrontation of both primary and secondary effects; those proposed (overpasses, underpasses, fencing etc.) are not the only alternative solutions, but they have been proven very effective in the case of transportation infrastructure in Greece.

Key words: *impact, transportation infrastructure, flora, fauna, protection*

1. INTRODUCTION

Flora and fauna constitute fundamental elements of the ecosystem and more generally of a region's environment. All genera and species of plants and animals surviving without human support are described by the terms flora and fauna, respectively. The impacts of the construction and operation of transport systems on the flora and fauna are categorized as primary or direct and secondary or indirect. Primary impacts are due mainly to deforestation or cleaning in area occupied by the project. The consequences in that case are habitat loss, habitat fragmentation, interruption of biochemical cycle, damage of aquatic habitat and corridor restrictions. Secondary effects are manifested through the pollution of the aqueous environment that supports the ecosystem or other effects, and the impacts of the project, its construction activities, and its operation, thereby impacting the ecosystem.

No matter their importance and size, roads are constructions with serious negative effects on wildlife. The most obvious impact of road traffic is direct mortality (Jackson and Fahrig 2011, Iosif et al. 2013). Roads and motorways impose fragmentation in the long term, i.e. they isolate subpopulations of species (including reptiles) because they cross-cut their habitats (Vujović et al. 2015).

When roads are examined for their impacts on flora and fauna, different design parameters or structural components should be considered. In this data matrix, the design speed, the length of the road, the cross section (width of carriageway, number of lanes, shoulders), the slope of embankments, elements of horizontal and vertical alignment (radii, slopes), drainage structures, bridges, tunnels, intersections, earthworks and construction materials are included. The permanent land take and right of way are also of interest.

Animal mortality due to collision is an unfavorable consequence of road construction and function resulting in reduced numbers of local populations (Fahrig and Rytwinski, 2009) as well as in decreased exchange rates among populations found on opposite sides after the opening to traffic, commonly termed "road barrier effect" (Ascensão et al. 2016).

A commonly encountered effect of road development projects, after their opening to traffic, is the permanent and irreversible fragmentation. This impact is especially significant when terrestrial species with large territories, like bears or wolves are affected (Ripple at al. 2014). Mitigation measures for the problem could be designed in early stages (Glista et al. 2009). These can be described as precautionary, like the provision of dry corridors alongside the roadway through the increase of bridge

spans or of routine character, like the construction of wildlife underpasses, “green bridges”, and tunnels for smaller animals, reptiles and amphibians.

In the present work, the effects of linear infrastructure projects on the most vital environmental elements –the flora and fauna – are examined. A large development project, the Egnatia Road motorway, has been selected as basis for a full research on the issue. The part of the road in Eastern Macedonia and Thrace Region has been completed recently and what it remains are some vertical axes. It seems that the main problem is the habitat fragmentation for the terrestrial species. Large mammals, amphibians, reptiles and birds are all affected to a different degree. Flora is impacted mainly in the vicinity of the road, close to its edges. Protective measures can be implemented towards better geometric design and reduction of road killing; those proposed are not the only option, but they have been proven very effective in the case of transportation infrastructure in Greece.

2. EGNATIA ROAD MOTORWAY – ITS PART IN EASTERN MACEDONIA AND THRACE

The Egnatia Road motorway, which is a closed dual carriageway with a central reserve, two traffic lanes and one emergency lane in each direction, runs through a very complex from a geomorphological and geological point of view area, traversing important mountain ranges, such as the Pindos mountain range, forested areas, ravines, as well as river areas and plains. The main motorway from Igoumenitsa to Kipi involves a very large number of technical works, namely 63 road interchanges, 135 bridges, 390 entrances/exits with over-bridges and underpasses, 73 twin-bore tunnels, 43 river crossings and 11 railway crossings.

In addition to the main motorway, there are 7 separate vertical motorways towards the north which connect the Egnatia motorway to road infrastructure in Albania, FYROM, and Bulgaria, and, consequently, to pan-European corridors (Helsinki-Alexandroupolis, Berlin-Sofia-Thessaloniki, Vienna-Belgrade-Thessaloniki), and 2 in the south aiming at improving Greek transport networks. Along 6% of its total length, Egnatia Road crosses protected areas. Volvi and Koronia Lakes, Evros River Delta, Vistonis Lake system, Porto Lagos, Ismaris Lake, Nestos River Delta are all wetlands included in Ramsar Convention and are included in a special Egnatia Road motorway classification (Zone II).

The section of Egnatia motorway that runs through Eastern Macedonia and Thrace is 246 km long extending from Strymonas River to Kipi (Evros). The motorway has been constructed as a dual carriageway, separated by a central reserve, with two traffic lanes and a hard shoulder per direction. Its total width is 24.5 m. (or 22.0 m at certain difficult sections). The total of the projects in Eastern Macedonia and Thrace (EMTh) Region has been completed and opened to traffic. Through the four vertical axes in the region, Egnatia motorway will be connected with the Trans-European networks. Among the vertical axes, the one crossing the plain area of Evros Regional Unit (Ardanio - Kastanies - Ormenio - Greek-Bulgarian border) and ending at the three international road gates of Greece (Kipi to Istanbul, Kastanies towards Andrianoupolis and west coasts of the Black Sea and Ormenio to Bulgaria, Romania, Moldova, Ukraine, etc.) is of particular interest. Through, the border station at Kipi Evros, the Region is expected to function as a transit for transportation between Western Europe and the Asian countries.

Possible communication cutoff of forest lands, scenic places or other important ecosystems problems could be identified and collectively described by a segmentation index definite in character (determined before the project is given to traffic and after its completion). The ecosystem communication cutoff can affect the functioning and biodiversity either due to loss of living space for the species (sites of nesting, breeding, and predation) or due to communication problems of some species.

Cut off of areas with uniform ecosystems characteristics has been a major issue in road axis alignment. The value scale of the segmentation index (nine classes according to CORINE 2000) ranges from below 0.01 (minimum) to over 100 (very strong). The index for the Egnatia Road is depicted in Table 1, for the years 2007 and 2010. In Zone II of the Regional Units crossed by the Egnatia Road axis, the

construction and function of the road in conjunction with other uses (networks, agricultural uses, etc.), has brought about the segmentation of the space at a moderate impact level (index value: 3.07) on the ecosystem. The lowest index value in the EMTh Region is located in Rhodope Regional Unit with 9.34. The highest value has been recorded in Evros Regional Unit and is equal to 30.28 (strong). It must be noted that no part of the main axis of Egnatia Road crosses the Drama Regional Unit.

Table 1. Segmentation indices of Eastern part of Egnatia Road motorway in EMTh Regional Units

Regional Unit	Fragmentation Index without Egnatia Road and the vertical axes		Fragmentation Index (Egnatia Road and the vertical axes included)	
2007				
Kavala	3.43	3.86	3.62	3.97
Xanthi	3.14		3.31	
Rhodope	3.29		3.41	
Evros	4.93		4.94	
2007 – 1 km in either side of the road				
Kavala	15.70	16.45	21.11	20.77
Xanthi	8.09		11.70	
Rhodope	7.44		14.88	
Evros	31.77		32.76	
2010				
Kavala	3.30	2.99	3.54	3.07
Xanthi	3.20		3.34	
Rhodope	3.18		3.28	
Evros	4.50		4.53	
2010 – 1 km in either side of the road				
Kavala	14.84	17.50	21.11	23.53
Xanthi	14.21		11.70	
Rhodope	9.34		14.88	
Evros	30.28		32.76	

2.1. Flora in Eastern Macedonia and Thrace Region

The zone occupied by a transportation project must be cleared from all plants. This is a direct and immediately noticeable impact. In linear projects (roads, railways) the deforestation zone usually does not cause serious harm because the surface is a small percentage of the wider area. Moreover, planting of the slopes, traffic islands, high road cut benches etc. serving also other needs of the project make partial restoration. However, in the project planning process, it is necessary to specify locations to be avoided (e.g. tree clusters of outstanding beauty) or to be suitably protected (e.g. deep natural flow lines where a special micro-ecosystem may exist for the protection of which a bridge of greater span may be provided, designed in such a way that there will be no need for formwork scaffolding that will annoy or destroy the flora locally). In extensive works, the problem is exacerbated. Even in these

projects, it is possible for recovery, at least partial. In any case, appropriate plant selection must be made, mainly from those existing in the area.

The flora of Nestos Straits, a true 23,800 acres botanical garden, is comprised from over 500 species, 23 of which are characterized as important and some of them are protected by international treaties. The combination of continental and Mediterranean climate makes the dominating conditions ideal. Among the particularly important species of flora, *Haberlea Rodopensis*, *Iris Reichenlachii*, *Coniolimon sortorii*, *Saxifraga stribrhyi*, *Satureja pilosa*, *Trachelium jacquinii*, are included.

Protected species in the area surrounding the Nestos River are: *Anacamptis pyramidalis* (L.) L.C.M. Richard (protected, by the Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES, also known as the Washington Convention), *Orchis laxiflora*, *Orchis morio*, *Orchis papilionacea* Linaeus 1759, *Epipactis helleborine* (Tsiftsis, et al. 2007), *Orchis tridentate* Scopoli 1772, *Himantoglossum caprinum*, *Salvinia natans*, *Serapias lingua*, *Ophrys oestrifera*, *Serapias vomeracea*, *Trapa natans*.

Furthermore, ten species are considered important and are under the special protection regime of one or more national and international treaties: IUCN Red List, European Red List of Globally Threatened Animals and plants, CITES (Convention on International trade in endangered species of wild fauna and flora, 1973) and the 67/1981 Presidential Decree for protected species. These plants are: *Atropa bella-donna*, *Cephalanthera rubra*, *Galium asparagifolium*, *Goniolimon sartorii*, *Haberlea rhodopensis*, *Jovibarba heuffelii*, *Ophrys scolopax subsp. cornuta*, *Ophrys mammosa subsp. mammosa* (Desf.) Soo ex E. Nelson 1962, *Orchis coriophora subsp. fragrans*, *Trachelium jacquinii subsp. rumeliacum.*

The rare species of wild apple *Eriolobus trilobatus,* an endemic tree of Southern Evros, is one of the most rare trees in Greece and has been included in the 2009 Red Data Book of Rare and Threatened Plants of Greece and Bulgaria under the characterization vulnerable and endangered, respectively. *Eriolobus trilobatus* L. is considered threatened since in its habitat fires, road openings, forestry works and other activities are happening which due to small number of trees could make the species extinct from the area (Papalazarou et al. 2009).

In mountainous Xanthi, 1,150 square kilometers are covered by forests. Beech and oak dominate (about 80% of the total area). In the area of Koula, between Gyftokastro -the highest peak in Thrace (1,827 m) and the village Dimario, a rare conifer of unique beauty, the *Pinus peuce*, grows. Its needles are in fascicles (bundles) of five. The Balkan pine, *Pinus peuce*, is listed in 2010 IUCN (International Union for Conservation of Nature) Red List of Threatened Species.

The Pangeo Mount in Kavala Regional Unit has three discrete vegetation zones: (a) maquis shrub land or macchia where yews, cedars and other evergreen species dominate, (b) higher than 700 m and up to 1,700 meters beech, pine, chestnut, oak and a few birch forests are found and (c) meadow landscapes with many flower species. Some of the endemic species of Pangeo flora are: *Arenaria filicaulis tedii, Campanula pangaea, Centaurea pangaea, Chondrila uromoffii (C. lenae), Campanula orphanidea, Erysimum drenowskii, Fritillaria drenovskii, Haberlea rhodopensis, Viola grisebachiana (*protected by Natura 2000)*, Viola perinensis, Saxifraga ferdinandi-coburgi.* Other rare species are: *Aquilegia vulgaris, Dianthus superbus, Paeonia peregrine, Omphalodes lusiliae, Lilium martagon ssp cataniae*, and *Viola delphinantha.*

2.2. Fauna in Eastern Macedonia and Thrace Region

The Balkan chamois (*Rupicapra rupicapra balcanica*) is found in both parts of Rhodope range (east and west). In the Greek part of the range, the species spreads in two areas: a) in the Frakto Virgin forest area of Drama Regional Unit not crossed by the Egnatia Road and b) in the wider area of Koula (Drama and Xanthi). The population size in the second region is 20-30 individuals and the habitat used amounts about 53 square kilometers. There is no evidence of crucial impact on both the species and its habitat by the construction and function of Egnatia Road motorway.

The golden or common jackal (*Canis aureus*) populations are found in Eastern Macedonia (Vistonida Lake and Nestos River) and Thrace (Evros River and Komotini Lagoons), in discontinuous and

fragmented ranges. The density of the species in those areas is about 3 individuals per square kilometer. The population has been reduced because of various reasons, like the habitat loss, highway construction, collisions with vehicles, illegal use of poisonous baits, and fires. Nevertheless, the populations in EMTh Region are healthy and stable showing no signs of decline.

Throughout Europe, the wolf is protected by the legislation, with the Convention on the Conservation of European Wildlife and Natural Habitats (known as the Berne Convention) and the Council Directive 92/43 EEC of 21 May 1992 on the conservation of natural habitats and wild flora and fauna (usually called the Habitats Directive). Since 1991, the wolf is no longer considered detrimental species in Greece, where the threats for its survival are mainly anthropogenic. The collisions with vehicles on roads cause significant number of wolf deaths. Fenced roads restrict movement as well as access to prey. Roads with fences also prevent wolves from dispersing to other regions. Fragmentation of habitat and isolation of wolf populations are caused by linear transport infrastructure. So, the species is made vulnerable to diseases, inbreeding or even to illegal killing and on the other hand it could not re-colonize other European territories.

The Egnatia Road motorway and its vertical axes fragment the brown bear (*Ursus* arctos) spreading zone which was a single piece in the past. This fact heralds unfavorable scenarios in terms of communication and connectivity ability of the bear population between extensive areas of the habitat, which may have implications in gene flow and genetic diversity of the population.

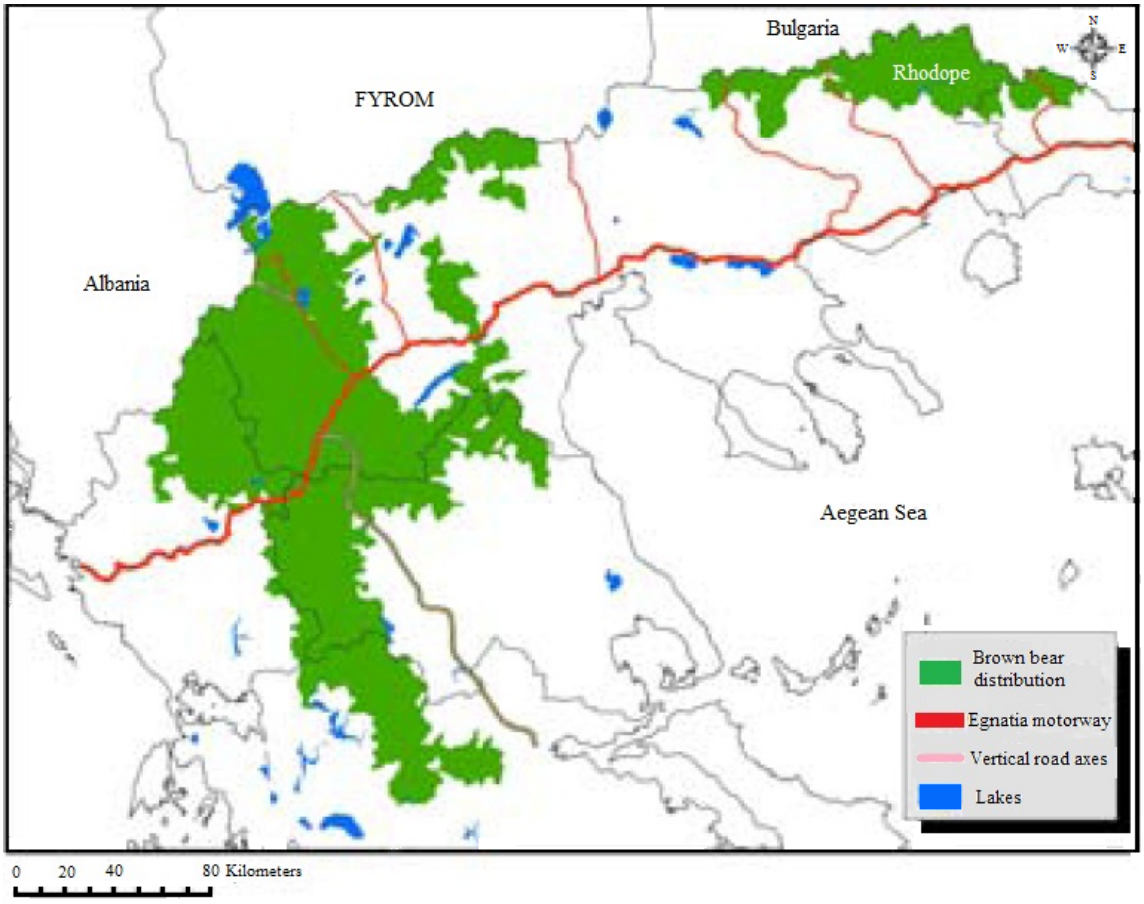


Fig 1. Map showing the areas where brown bear is located and the relative position of Egnatia Road

The map in Fig 1 shows the brown bear distribution. Only for the period 1998-2010, fifty-three (53) bear deaths have been recorded in road accidents on the National road network in the country (Karamanlidis et al. 2011). The exacerbation of the phenomenon is mainly due to the fragmentation of

the bear habitat as a result of the rapid development and densification of the road network, especially the large closed highways such as the Egnatia Road motorway.

Lynx lynx Linaeus 1758 is a critically endangered species according to IUCN classification. The Euarasian lynx is the third in size carnivorous species in Europe, mainly living in the forests. Its populations in Macedonia and Thrace have been reduced due to extinction of small animals, like *Capreolus capreolus* and *Rupicapra rupicapra*, being part of its feeding preferences.

The majority of road accidents where wild animals are involved are mainly due to vitiated provision of appropriate technical measures and compensation structures (special crossings - passes - special fencing) as well as road marking measures for the safety of drivers and wildlife. Smaller species like hares (*Lepus europaeus* Pallas, 1778), red foxes (*Vulpes vulpes*), badgers (*Meles meles*), European otters (*Lutra lutra*) and squirrels (*Sciurus vulgaris*) are found in the area of the EMTh Region, but they are not affected (minimum numbers of mammalian road mortality) by Egnatia Road. The uncertainty of these estimates is counterbalanced by the numbers of animal-vehicle collisions recorded the last years.

The richest in amphibian species areas in Greece are Macedonia Hepeirus and Thrace, in this order. At the Nestos River Delta up today eleven amphibian species have been recorded. These are shown in Table 2 along with species found in the Rhodope Mount Range. Fire-bellied toad (*Bombina bombina* Linnaeus, 1761) occurs in a small area in Evros Regional Unit exhibiting fragmented distribution and is classified as endangered species. Two of the species listed in Table 2, *Bombina variegata* and *Triturus cristatus* are included in Appendix II of the 92/43/EEC Directive on the conservation of natural habitats and of wild fauna and flora.

Table 2. Amphibian species in Nestos riverside ecosystem and in Rhodope Mount Range

Scientific name	**Common Name**	**Spreading/Protection / Population status**
Triturus vulgaris	Smooth newt	common/protected
Triturus cristatus	Northern crested newt	rare/protected
Hyla arborea Linaeus 1758	Common tree frog	common/protected
Rana ridibunda	Marsh Frog	common
Rana dalmatina	Agile frog	common/protected
Bufo bufo Linaeus 1758	Common toad	common/protected
Bufo viridis	European green toad	common/protected
Bombina variegata	Yellow-bellied toad	common
Rana graeca	Greek stream frog	common
Rana temporaria	European common frog	common
Salamandra Salamandra	Fire salamander	common
Triturus alpestris	Alpine newt	common/protected

3. MITIGATION STRATEGIES FOR ROAD AND TRAFFIC ECOLOGICAL IMPACTS

Fauna underpasses and overpasses are commonly installed to facilitate animal movement. Crossing structures, though designed for large mammals, often enable safe passages for smaller species exhibiting high vulnerability to roads. There is a need for more attention to the function of overpasses as habitats themselves, particularly when reptiles and amphibians are involved.

An overpass structure allows passage of animals above the road, since their attempt to cross directly on the pavement put them at risk to be killed or injured by collisions with the through traffic (McGregor et al. 2015). Overpasses can be divided to land bridges, canopy bridges, glider poles, local traffic management devices, and -in small minor roads- typical overpasses. This last category refers to a narrow bridge above the major linear infrastructure to allow human access across the road. Land bridges, also known as eco-ducts or wildlife bridges have a width of 30 to 70 meters and they extend over the road. They are planted with vegetation and enhanced with other features such as logs, rocks, etc. Canopy bridges are suspended over the moving vehicles using ropes or poles tied to vertical poles or trees. In some cases, animals that move gliding can be provided with vertical poles on the road verge or in the centre median so as to have a way of intermediate landing or launch.

An underpass allows the passage of animals below the major linear infrastructure. Underpasses can be categorized as culverts, tunnels and bridges. To facilitate the movement of terrestrial fauna, it is proposed to configure crossings (stone roof culverts) with adequate opening and at distances capable to ensure unhindered communication between areas on either side of the road, where it is not guaranteed by the structures along the route. The design of the sewer must also be such that the outlet is visible from the entrance the nozzles are flush with the ground or, if this is not possible, provision must be made to facilitate the movement e.g. provide ramps with suitable inclination. Because the through movement of the animal species is made through the technical works of the road, the openings should have a minimum cross section of 2.00 m x 2.00 m.

Usually, tunnels are round pipes of relatively small diameter, e.g. <1.5 m and may also be termed “ecopipes”. The underground passages for small animals in Egnatia Motorway consist of pipe sections (circular or rectangular) with diameters no larger than 0.4 to 2.0 m. Unlike culverts, which are primarily built to allow the flow of water under the pavement, the transitions for small animals are exclusively serve the protection of certain animal species. However, it is possible for both functions to be combined. In sites where culverts are used in a routine basis, the best solution is to improve their design to make them suitable as fauna passages. However, where it is not necessary to build culverts, wildlife transitions should be made to increase the mobility of small animals. These fauna transitions may also be made where it has been found a high mortality of small species. This is particularly the case of badgers, rabbits or otters (in Pangeo Mount, Nestos Delta, and Rhodope range). On the other hand, exclusion fences and road railings could slow down animals trying to leave the pavement, thus increasing the road kill risk.

The diameter for the cyclic passages is usually elected to be 1.5 m and for rectangular tunnels, the length ranges between 1.0 and 1.5 m. A diameter of 0.3-0.5 m may be suitable for badgers, but not for all other types of small animals. In addition, maintenance is more difficult for smaller tunnel diameters. The rectangular tunnels are preferable for amphibians, and possibly other species, because the vertical walls provide better guidance. The materials that may be employed are concrete or metal pipes, but the metal surfaces are avoided by some species, e.g. rabbits. The minimum slope to avoid flooding of the underpass is 1% and the maximum gradient is 1:2. Access to the animals in the underpass must be unhampered. Annual maintenance of the underpass is necessary for the first 2 to 10 years, since dropping waste at the entrance of the passageway is a common problem.

In order choose an overpass or underpass construction, several factors should be taken into account; first, the topography, since in hilly terrain overpasses are preferred, while in a flat area where the underground water horizon is not very high, underpasses must be constructed. The overpasses have the advantage that the vegetation can easily grow and larger number of animal species can used it. Another significant factor is the type of bio-societies and habitats developed in the region. Animal species favored by humid conditions prefer the underpasses, while species living in dry environments use overpasses. Many of the Egnatia Road tunnels constructed using the “cut and cover” technique, like the twin tunnels shown in Figure 2, give the opportunity to terrestrial species to move from one side of the road to the opposite avoiding any risks for vehicle collisions.



Fig 2. Twin tunnels with overpass structures to help animal crossing in Egnatia Motorway

Bridges are structures maintaining the grade of the road or elevating the traffic above the surrounding land, giving animals the chance to pass under the road. Their primary function, when the aim is to mitigate the barrier effect of linear infrastructure, is rather to facilitate the movement of human traffic or the water drainage, and secondarily the passage of wildlife.

A measure with proved value in reducing road kill caused by wildlife-vehicle collisions is the provision of fencing along the transportation infrastructure, which keeps the animals off the road. Well designed and maintained fences are so effective that the collision reduction reaches the 80%, if not totally avoided. This fence effectiveness make the roadway appear in the landscape as an impermeable barrier requiring crossing opportunities for wildlife. This can be assured by gaps in the fence itself, or through the construction of overpasses and underpasses. If there is a combination of fences and safe crossing, then along with their protective role, fences could also guide animals to sites of easy passage. Extra measures like warning signs, painted crosswalks on the pavement or speed reducing devices (speed bumps) make fences more effective. In Figure 3 the installation of fences in Egnatia Road is shown.



Fig 3. Fencing in along Egnatia Road in EMTh Region

Depending on the species to be protected, many different types of fences or screens could be used. Figure 3 shows the type of fencing used in Egnatia Road's part in Eastern Macedonia and Thrace Region. Standard wildlife fencing is about 2.4 m high, so as to discourage large animals enter the road corridor. Also, wooden poles may be replaced by metal ones. Supporting poles should be buried to a depth appropriate for the type of species in the area, in order to prevent animals from digging under the fencing. Depending on the species there are many different types of fences or screens. Badgers or other species of medium size can be protected with fencing of finer mesh.

3.1. Protection measures for avifauna along roads like Egnatia Road

The major impacts on the populations of fauna and their habitats due to road construction can be grouped into six main categories (Fahrig and Rytwinski 2009; Bissonette and Cramer 2008):

- Loss and degradation of habitat
- Isolation
- Direct killing
- Creation of new habitats ecotones and communication corridors (passageways)
- Emission of chemicals, noise and lights
- Manmade changes in space's use

With the construction of the road, loss of natural habitats and agricultural land is noted that may eventually take up a large area. For a road width of 30 m, the loss per kilometer is 30 acres for the base substrate. On major roads, a similarly large area is required for additional spaces on both sides.

Roads like the Egnatia Road motorway or other national highways having large widths and high functioning speeds, can also serve as barriers to the movement and dispersal of species of the terrestrial fauna. Insurmountable obstacles to terrestrial animals (mammals, reptiles, amphibians) are roads that are closed, fenced and with high tiers. Roads are also causing problems in feathered species such as insects, or even in birds. However, roads do not act as an isolation agent for the movement and spreading of birds. Fragmentation of bird habitat exists when the road passes through forests or when it isolates part of a wetland. When a segment (forest cluster or wetland section) is very small, it does not any longer have any value as a habitat (e.g. conditions for nesting or coverage are not fulfilled). To avoid bird killing in the area of road embankments, care should be taken for the roadside vegetation, the development of which will contribute in increasing the altitude of bird flight line, so as to minimize collisions with passing vehicles.

Habitat degradation is evident at wetlands, like the Nestos and Evros River Deltas, where the hydrological effects must be carefully controlled. The impacts identified at rivers and wetlands are:

- Changes in the groundwater level
- Changes in surface water circulation and salinity
- Discontinuity of water flow in rivers at sites where culverts and bridges are constructed, due to careless construction where next to the culvert or bridge the water digs or because the culvert is placed very high creating a discontinuity in the water flow.
- Increase in turbidity during the construction phase or later, in the case of routes passing near rivers especially in steep grades.
- Isolation of wetland parts such as wet meadows and small regional wetlands where the road passes through the wetland or at the edge of the main wetland.
- Destruction of riparian vegetation very significant for fauna in the case of a route passing parallel along a river in order to facilitate its alignment.

These changes directly affect plant communities and fauna living or fed in these wetlands.

Bird deaths by vehicles on roads are globally numerous; distributions by country refer to hundreds of thousands up to millions of victims (Reijnen et al. 1995; Polak et al. 2013; Guinard et al. 2012). The parameters involved are also many and can be classified in:

- Road type (asphalt or gravel surface). It is confirmed that killed birds are clearly more on paved roads than in roads with unpaved surfaces. This phenomenon is related to the vehicle speed, with increased speed limits leading to more dead birds (Legagneux and Ducatez 2013). This is probably due to the fact that increased speed creates a powerful vortex which entrains the birds. For the same speed, there are more casualties on roads with many bends in relation to roads with straight horizontal alignment. Traffic density seems to have a lesser effect. Nevertheless, the data are not warranted, since the density is continuously increased while bird populations differentiate in relation to the seasons. Deaths in the April-May period are related to the breeding activities and the reduced attention of birds, while deaths during July-September or October are associated with the dispersion of young, inexperienced birds. A hypothesis has been formulated that smaller roads present greater risk to birds, despite the smaller traffic volume, because birds are not familiar with traffic (Kociolek and Clevenger 2011). Roads with dense traffic result in "learning" and birds fly higher. Thus, high speeds on roads with little traffic appear to represent a greater risk (DeVault et al. 2014).
- Type of habitats from which the route passes, and particularly their quality as nesting spaces.
- Vegetation structure and density on both sides of the carriageway. The vegetation of the wider environment as well as at the road edges is one of the most important factors for the killing of birds. It seems that there are more victims in forest areas than in open areas, especially when bushy or arboreal vegetation exists on both sides of the road. Hedge or hedgerow is called a line of closely spaced shrubs and tree species, planted to form a barrier or to mark the boundary of an area. Multiple victims are found in hedge gaps and in cases of hedges on both sides of the road.
- Geometric characteristics of the road (width, curves, in cut or embankment). The most dangerous spots are places where the birds try to fly from one side of the road to the other. The relationship of road morphology with bird killing is differently perceived (Pons 2000). As a rule, it is concluded that: a) if the road is at the same level or higher than the surrounding area (e.g. on embankment), birds fly low; thus, more of them are killed, and b) many birds are killed at locations where the road forms a curve, even if the cars have to slow down at these positions.
- Each species behavior. Birds 'dipped' in their flight from tree to tree or from hedgerow to hedgerow often collide with vehicles. It is noted that the birds have not stereoscopic vision and they can not accurately calculate the distance to a car. The most frequent bird victims both worldwide and in the area crossed by the Egnatia motorway are sparrows (*Passer domesticus*), due to the way they fly. To avoid the cars sparrows make a maneuver and return to the place from where they started. This behavior is effective to escape from predators that hunt stalking (sparrowhawk - *Accipiter nissus*, levant sparrowhawk - *Accipiter brevipes*, hawk - *Falco tinnunculus*, common buzzard - *Buteo buteo*) but not for vehicles. The same problem exists with pheasants (*Phasianus colchicus*). Birds flying at low heights, near the ground, like the blackbird (*Turdus merula*), the Eurasian wren (*Troglodytes troglodytes*), the Sardinian warbler (*Sylvia melanocephala*), and the robin (*Erithacus rubecula*) are also exposed to collisions more than those flying straight. For example, coal tits (*Parus ater*) are very rarely killed because they often cross the roads at high altitude. Some species such as white wagtail (*Motacilla alba*) are rarely involved in road killing, although they are often found in roads. These are species that live in open environments and when vehicles approach they are successfully removed to return soon after. Instead, scavengers species are also at risk since they descend on the pavement to consume corpses of mammals, amphibians, reptiles or birds.
- Lights. The lights used to illuminate the road attract insects thus increasing the collision risk of insectivorous birds and bats. The car lights dazzle birds yielding in killing nocturnal predators or species moving during the twilight, like European nightjar (*Caprimulgus europaeus meridionalis*

E. Hartert 1986); this insectivore is attracted in less lit roads but is killed as it sits on the ground. The risk of extinction for this species in Europe seems to be largely due to the killing by cars.

4. CONCLUSIONS

Due to the distances between the road axis and the forests in the area, the only impacts on the region's flora are those arising by the deforestation and cleaning works for the construction of the main body of the Egnatia Road motorway.

The physiological behavior of animals may change after the construction of transportation infrastructures, since they learn to avoid roads to protect themselves. While the avoidance positively affects the road kill phenomena decreasing their frequency, it has a negative result decreasing the exchange rates between the sides of the road.

There are numerous endangered species in the areas crossed by the road studied in this research effort. We suggest underpasses in conjunction to other mitigation measures, like roadside fences or appropriate signage will limit road mortality for threatened large or small animal species.

Based on the indicator for the communication cut off of forests and natural beauty places it can be concluded that in general there are no irreversible impacts on the function of natural systems due to the simultaneous action of roads and other human uses localized in Zone II crossed by Egnatia Road.

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