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LANDSCAPE INTEGRATION OF FREEWAYS: HOW DOES IT AFFECT ROAD KILL RATES?

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Abstract: Some ecological processes are affected by the transportation infrastructure development. The barrier effect caused by roads, which alters the movement patterns of terrestrial wildlife and increases its road kill risk, is just an example. Road kills must be considered both from environmental and highway safety perspectives, and are related to road permeability and to the surrounding environment. This paper compares the landscape fragmentation caused by two freeways in Navarra (north of Spain) by analyzing both their landscape surroundings and the potential road permeability, and comparing them to road kill rates of medium-sized terrestrial wildlife. As a result, some road design recommendations have been drawn up.

Introduction

The construction of transport infrastructures, urban development and agriculture are the causes of fragmentation that are most quoted in the bibliography. These activities alter the structure of the landscape and, therefore, the ecological processes associated with it (Saunders et al. 1991; Merriam and Wegner 1992; Collinge 1996; Fahrig and Grez 1996; Laurence 1997; Laurence et al. 1997; Wigley and Roberts 1997; Laurence et al. 1998; Scott 1999).

The impact of linear transport infrastructures on fauna has been intensively studied in North America and different European countries since the seventies. In Spain, these studies have been more recently developed. The scientific community, the administration, and ecologists have become aware of its importance, and research has proliferated. Workshops have been organized and manuals have been edited on the subject (Velasco et. al. 1992; A.T.C. 1999; Rosell and Velasco 1999).

As a result of the construction and operation of linear transport infrastructures, ecological processes suffer changes that have a direct and indirect impact on fauna. Two examples are the change in the movement patterns of terrestrial wildlife (Curatolo and Murphy 1986; Murphy and Curatolo 1986; McLellan and Shackleton 1988; Trewhella and Harris 1990; Beier 1995; Cameron et al. 1995; Lovallo and Anderson 1996) and the risk of accidents (Wilkins and Schmidly 1980; Coulson 1982; Davies et al. 1987; Aaris-Sorensen 1995; Drews 1995; Groot-Bruinderink and Hazebroek 1995; Ashley and Robinson 1996; Madsen 1996; Romin and Bissonette 1996a; Romin and Bissonette 1996b; Lehnert and Bissonette 1997), both results of the barrier effect caused by linear infrastructures. The importance of accidents must also be considered not only from the environmental perspective (wildlife population conservation), but also from the point of view of road safety, considering the social and economic consequences that these collisions have.

On the other hand, the fragmentation cause by a road may vary depending on its characteristics and the landscape in which it is located. This report compares the fragmentation generated by two freeways (A-15 y N-240-A), each of which has a different relation to its surroundings and a different level of integration in the landscape. It should be mentioned here that, just as this report refers to landscape with the ecological meaning of the word (Forman and Godron 1981; González Bernáldez 1981), landscape integration is used in more than a purely aesthetic sense.

Study Area

The roads studied are located in the province of Navarra, in the north of Spain (see figure 1). Both set off from the same point (Irurtzun), the A-15 in a north westerly direction and the N-240-A due west, effectively forming a triangle (see figure 2).

Fig. 1. Navarra's location.

Some of the characteristics of the two roads are similar. In the first place, they are both of approximately the same length (the A-15 is

26 km long and the N-240-A is 29 km). In the second place, traffic density is very similar (around 10 000 vehicles per day). Thirdly, they are both four-lane roads. In the fourth place, they have the same type of fencing, and finally, the study area belongs to the Euro-siberian region. Forest vegetation on the higher altitudes consists of beech woods (*Fagus sylvatica*), with Common Oaks (*Quercus robur*) in the valleys and White Oaks (*Quercus humilis*) on the sunniest slopes.

With regards to other characteristics considered in landscape integration analysis, however, the two roads are different. On the one hand, the N-240-A goes through a relatively wide and flat valley, next to another regional road, the railway and the river Araquil. It separates two large mountain ranges with large wood masses. The area it crosses is quite heavily populated. On the margins of the A-15 there are 8 settlements with a total of 1 534 inhabitants, considering a 500-metre area of influence around the two roads (according to the Local Census of 1996), whereas in the vicinity of the N-240-A, there are 19 settlements with 16 126 inhabitants. The number of inhabitants per kilometer of road, then, is 57.3 people km^{-1}, whereas for the N-240-A it is as high as 471.3 people km^{-1}. The activities of the population are different in each of the areas. The population in the towns crossed by the A-15 is more concentrated in the primary sector, whereas the population affected by the N-240-A is more related to the industrial sector. In fact, the N-240-A landscape has been more altered by man (there are more settlements, with much more industry, and the valley is made up of meadows and an occasional group of oaks) and the woods from the hills only come close to the roads in four concrete areas. In two of these four areas, the woods are on both sides of the road.

On the other hand, the beginning of the A-15 runs next to the river Larraun, with a complex topography due to how narrow the valley is. This problem has been solved by the construction of tunnels and viaducts. It continues through some areas in which the valley is wider, and others in which it rises half way up the slope. Its highest point is on a long sloping stretch that ends in a tunnel. It finally falls with the help of viaducts until it reaches the river Leizarán. The surroundings in general are less populated and more abrupt and the landscape is more varied.

To sum up, it can be said that the two roads are also different as far as their visual integration in the landscape is concerned. The N-240-A is visually better than the A-15. While the A-15 has some sections with bare large embankments and cuttings, the N-240-A crosses a constant topography (a valley), and an area with more human involvement.

Methodology

To analyze the potential permeability of the roads, all the passes that affect both roads have been inventoried. Their utility has then been evaluated for large and medium sized wild mammals, based on the characteristics that articles and studies on the subject have classified as important, such as the location, access, substrate, construction materials and dimensions of each pass (Singer et al. 1985; Velasco et al. 1992; S.E.T.R.A. 1993; Foster and Humphrey 1995; Yanes et al. 1995; Rodríguez et al. 1996; Keller 1997; Müller and Berthoud 1997; Rodríguez et al. 1997; Rosell et al. 1997; Rosell and Velasco 1999). It is assumed that the passes that these animals use will also be used by smaller fauna (S.E.T.R.A. 1993; Müller and Berthoud 1997; Carsignol 1999), although this is not the main subject of this study. The passes have been classified in three groups. The first consists of passes with a high level of permeability (large viaducts and tunnels). The second includes overpasses and underpasses that provide for a certain level of potential fauna permeability, and the third is passes that are not considered as adequate for use by wildlife.

In order to analyze the effect the roads have on the mortality of terrestrial wildlife, a sampling was taken, on a weekly basis, of large and medium sized mammals, knocked down between May 1999 and May 2001. Furthermore, the Road Conservation Service for both roads collaborated with the research team to ensure the most accurate data possible. The road-kill rate for each 100 m (number of animals killed hm^{-1} $year^{-1}$) and the average for each road (number of animals killed km^{-1}) have been calculated. It is from these mortality rates that the worst stretches for the running down of mammals have been identified, such as certain 100m sections in which the road-kill rate far exceeds the average.

Results

The A-15 has a series of structures that provide it with a high level of permeability, 3 tunnels and 6 viaducts. There are also several overpasses and underpasses, four of which have a certain level of permeability. According to the study area description, the A-15 has several large slopes that isolate the road from the rest of the landscape, and in these areas it is impermeable. The N-240-A has several overpasses and underpasses, but none of them guarantees permeability. These permeable points are identified on figure 2.

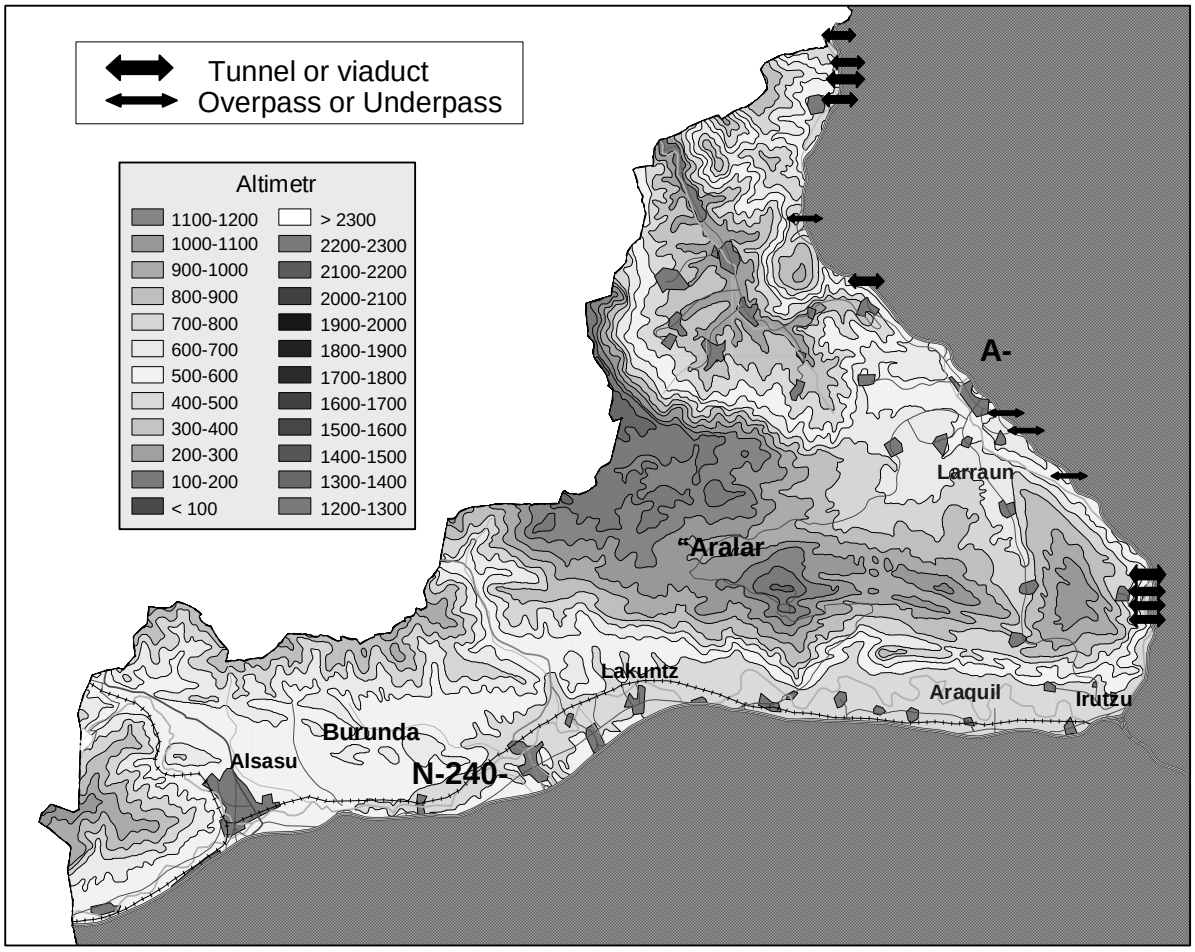

Figure 2. Permeable points in A-15 and N-240-A.

The terrestrial wildlife (large and medium sized mammals) collected in the sample were: Capreolus capreolus, Felis silvestris, Genetta genetta, Lepus europaeus, Martes foina, Martes martes, Meles meles, Mustela putorious, Mustela lutreola, Sus scrofa, and Vulpes vulpes.

During the two years of sampling, a total of 68 road deaths were recorded along the 26.7 km A-15 road, which gives an average of 2.54 deaths per kilometer over two years. Meanwhile, along the 29.3 kilometers of the N-240-A road, there were 83 deaths, with an average rate of 2.83 per kilometer over the two years.

In addition to this, the number of road deaths for each 100 m stretch has been recorded. From this information, continuous sections with the same road-kill rate have emerged. Consequently, we have been able to categorize stretches of varying length with having high, medium and low road-kill rates, in order to analyze their relationship with the surrounding landscape. These sections with different road-kill rates were represented on orthophotomaps. The sections with high road-kill rates amount to a total length of 7,200 m on

the A-15 (nearly 27% of it) and 8,700 m on the N-240-A (nearly 30%) and account for respectively 69 percent and 67.5 percent of road-kills.

Discussion

Having just shown that the majority of road-kills along the studied freeways occur in determined areas, an analysis of them will now help to identify and explain the possible causes.

The high road-kill-rate sections of the A-15 appear, therefore, to be related to the areas in which the topography facilitates wildlife access to the road:

- Stretches which flank large slopes and embankments and areas in which slopes, embankments and small valleys interweave. In both cases, the lay out of the landscape can draws animals to the road, producing a 'funnel effect.' (See figure 3.)
- Stretches which run along the bottom of a valley, with no permeable structures, giving them a certain permeability. Above all, when the road runs parallel to wooded areas and rivers, and where it crosses them.

Fig. 3. Stretch in which slopes, embankments and small valleys interweave.

The high road-kill rates on the N-240-A are more influenced by the proximity to the road of strips and patches of vegetation, than by the topography, which, as pointed out earlier, remains much the same throughout its length.

- Stretches where wooded areas from the surrounding hills approach the road.
- Stretches that run through wooded areas.
- Stretches where the river cuts across the road and/or runs close to it.
- Certain stream crossings or other small but significant strips of vegetation.
- The rate is particularly high in those sections where the valley narrows and there is a convergence of the factors described above.

On the other hand, stretches of the freeway with low road-kill rates have also been identified. An analysis of these areas helps us to characterize and explain the possible causes.

On the A-15, they appear to be very much conditioned by the degree to which the wildlife access to the road surface is facilitated, and the sections are the following:

- The stretches of road confined by large slopes and continuous embankments, effectively isolated from the surrounding environment.
- Stretches with a mixture of slopes and embankments and very permeable structures such as tunnels and viaducts.
- Stretches that pass nearby urban areas.

On the N-240-A, they appear to be conditioned by human pressure and the isolation of 'natural' zones.

The two roads differ in the way in which they are visually integrated within their surroundings. Thus, the N-240-A aesthetically lies better than the A-15, due principally to the fact that it runs along consistently similar topography, (the base of the valley) and its more populated surroundings, whilst the A-15 crosses a more rugged and natural landscape.

For its part, the N-240-A is less permeable to fauna, with nevertheless a higher road-kill rate, (83 deaths, or 2.83 animals per kilometer), which could be explained by the arrangement of the natural elements within a modified landscape. In turn, the A-15 has a lower road-kill rate, (64 animals, which works out as 2.54 animals per km) which appears to be related to the topography, the degree to which the wildlife has access to the freeway, and the road's permeability.

To sum up, a freeway integration into the surrounding countryside, cannot be understood as mere aesthetics. It should also be an integration that is functional, as an aesthetic perspective alone does not guarantee the interrelationship between the various elements of the landscape: the results of the road-kill-rate study bear this out.

Design Recommendations

An analysis of road-kills on the freeways studied, confirms that some general recommendations ought to be borne in mind on designing the roads, with the aim of reducing the number of fauna road deaths, improving road safety and minimizing the impact of the road upon the environment. Some recommendations to consider are the following:

- Take into consideration the arrangement of the landscape elements, (strips and patches of vegetation, rivers, the position of the hills, etc.) as well as the topography in the planning of a road course, because from an ecological perspective both influence on the number of deaths and the road permeability.
- Isolate the road from the environment in areas shown to have stretches of high road-kill rate, paying particular attention to the perimeter fence design. It would be advisable to locate the wildlife passages within these areas, as well as any structures that encourage road permeability.
- Apply corrective measures to those sections where there is a high incidence of road-kill, which in this case, as it has been showed, would only signify a small percentage of the overall length of road.

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