Long-term monitoring of wildlife roadkills in Collserola Park, Barcelona. Results from the first 15 years

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Abstract. Collserola Park (Barcelona) is a protected nature area occupying 8,500 ha. The park is subject to intense human pressure and includes an extensive transportation network made up of surfaced roads, forest trails and even a motorway and a railway line which form a major transport axis that crosses the Park.

As part of a wider study concerning the impact of transportation infrastructure on wildlife, roadkill data gathered since 1991 were analysed. These data come from several sources, basically from Park technical staff, wardens and from occasional roadkill studies. Since 2004 a more specific monitoring has been carried out of roadkills on roads and forest tracks in the Park by means of pre-established transects in order to obtain quantitative indices. In total, 865 roadkill incidents have been incorporated in the Park's wildlife GIS database, of which 56% correspond to mammals, 20% to birds, 16% to reptiles and 8% to amphibians. This high percentage of incidents associated with mammals is related to the different detection rate of mammals in comparison to other groups. The mammals with the highest incidence of roadkills are wild boar *Sus scrofa* (21.4%), which have increased sharply in the last few years, hedgehogs, *Erinaceus europaeus* and *Atelerix algirus* (20.7%), squirrels *Sciurus vulgaris* (15.0%) and rabbits *Oryctolagus cuniculus* (14.4%).

Roadside habitats were characterised by means of 100 m wide buffers established around roads and overlapped with GIS land use maps of the Park. Also, other factors linked to the road itself were considered in analysis, such as the daily average density of traffic (DAD: vehicles/day) and velocity. Analysis of the incidents shows a positive relationship between the number of roadkills/km and DAD. On the other hand, there was also a seasonal trend to roadkills with a peak at the end of spring which coincides with the period population levels is maximal (presence of juveniles).

Incident black spots were identified, which differ according to species and which in the case of the wild boar, for example, coincide with connection zones between the two main forest areas of the Park.

Finally, it should be highlighted that roadkills are not necessarily the main impact of infrastructures, at least for most species concerned, but rather their effects are added to other impacts such as the barrier effect and habitat fragmentation which can have more damaging effects at the population level.

Key words: black spots, conservation, mammals, mortality, roadkills

1. Introduction

The study of roadkills is becoming more and more important in the management of natural spaces and especially in wildlife conservation (Trombulak *et al*. 2000; Malo 2004; Saeki 2004). Due to the continuous expansion of road infrastructures and the increase in traffic, as well as the problems derived from road safety, it is becoming a topic of major concern (Bennet 1991; Müller & Berthoud 1997; Forman 2003).

Roadkill data collected from 1991 in Collserola Park have been analysed as part of a wider project on the impacts of transportation infrastructures on wildlife. This project examines other impacts such as habitat fragmentation, barrier effect and connectivity. The main objective of this work is to measure the effect of roadkills on the Park's wildlife: the effect of road mortality on certain species and location of black spots. The aim of this study is to determine the characteristics of wildlife roadkills in Collserola park in relation to the main species affected, the phenology, the roadside habitat and traffic aspects.

2. Study area

Collserola Park occupies some 8,500 ha of protected land in the middle of the Barcelona metropolitan region, which is surrounded by more than three million inhabitants. The park is under great anthropic pressure, an obvious example of which is the extensive network of transportation infrastructures; 7.6 km of motorways, 70 km of conventional roads and 42 km of forest trails open to traffic. There is a central transportation axis crossing the park north to south formed by a motorway, a conventional road and a railway line than run parallel to each other and divide the park into two large forested areas.

The Collserola mountains are covered mainly by a forest of Aleppo pine (*Pinus halepensis*) and Holm oak (*Quercus ilex*). Notwithstanding the high level of anthropization, the park is of great natural interest, not just because of its metropolitan context, but in its own right due to the existence of elements of high ecological value (Raspall *et al.* 2004) for which it has recently been included in the Natura 2000 network.

As for vehicular traffic, a high number of vehicles driving through Collserola; data for the E-9 motorway in 2005 show a daily average density (DAD) of 33,561 vehicles per day. This trend has increased year after year since it was opened to traffic in 1991, as is occurring in the rest of Spain.

3. Methods

In order to conduct the current study we have used different data: (*i*) wildlife roadkill records; (*ii*) traffic data from the park's road network; (*iii*) GIS habitat map of Collserola park.

First of all, a roadkill database was available with information gathered since 1991 and introduced into the GIS of the park. Roadkill information comes from different reliable sources, mainly from technical staff of the park, wardens, other monitoring studies focused on specific fauna groups, as well as our own data. In all cases information related to location, date and species is obtained.

Secondly, from January 2004 on a specific monitoring was also been carried out of roadkills on roads and forest tracks in the park by means of pre-established transects in order to obtain quantitative indices of roadkill rates. Six transects were established along the road system of the park through different environments and with varying length, between 8.4 and 19 km. These were surveyed while driving at maximum speed of 40 km/h on roads and 20-30 km/h on forest trails. Repetitions of these gave a total of 219 transects were surveyed covering 3,199 km.

Thirdly, other factors linked to the road itself were considered in analysis, such as the DAD (vehicles/day) and velocity. Data referring to DAD and velocity for distinct individual stretches of the conventional road network in Collserola were provided by the road administration of Barcelona (Diputació de Barcelona, 2005). For analysis of roadkill data, the road network was also divided into different stretches based on those considered by the road administration for traffic monitoring. An index of roadkill rate (roadkills/km) was calculated on these road stretches, and its relationship with DAD was examined.

Finally, roadside habitats were characterised by means of 100 m wide buffers established around roads and overlapped with GIS land use maps of the Park using Arc View 3.2. Also, habitat around roadkill spots was characterisd for the four mammal species most affected by roadkills by establishing circular buffers of 100 m radius.

4. Results

A total of 865 records of vertebrate roadkills were registered in the GIS-fauna database of Collserola park (Fig. 1).

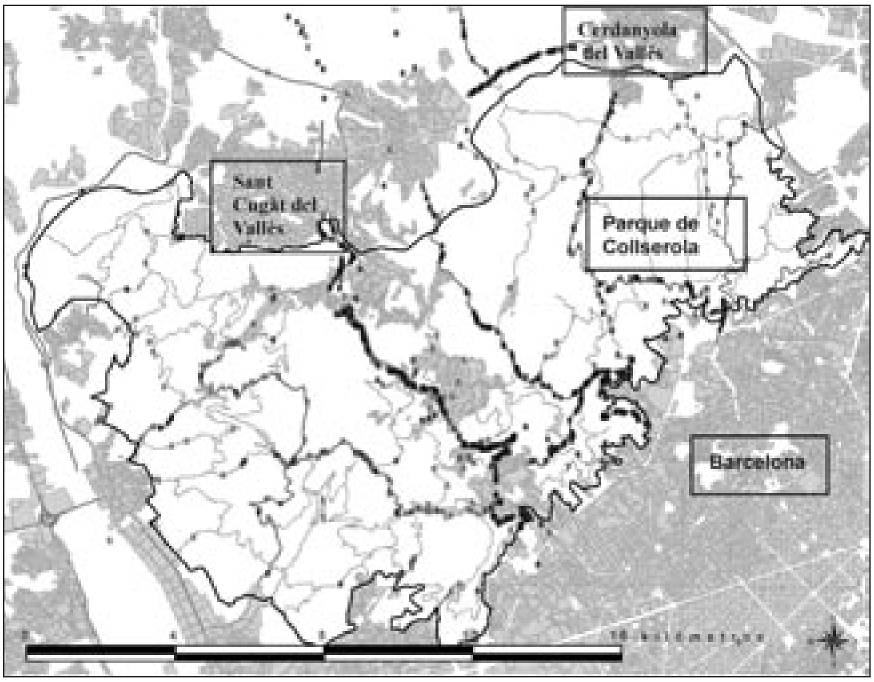

Fig. 1. View of roadkill registers in Collserola Park

Of these, 57% were mammals; 20% were birds, 16% were reptiles and 8% were amphibians. Seventeen different species of mammals were recorded which represent 81% of terrestrial mammals present in the park. The five most affected species account for 71% of all mammal records and correspond to wild boar *Sus scrofa* (21.4%), hedgehog – mostly *Erinaceus europaeus* (20.7%), squirrel *Sciurus vulgaris* (15%) and rabbit *Oryctolagus cuniculus* (14.4%) (Fig. 2). The North African hedgehog *Atelerix algirus* is also present at low density in the region, but generally in our case it was not practical to distinguish the two species in roadkills and as such they are considered here together generically as hedgehogs.

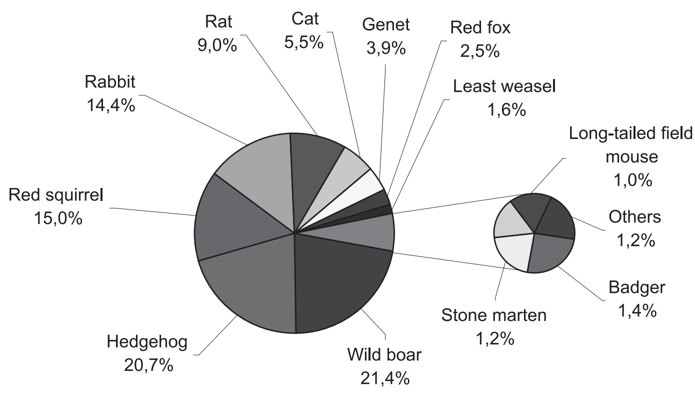

Fig. 2. Species distribution of roadkills in Collserola Park. Series 1991-2005 (n=487)

Between 2004 and 2005, a total of 157 records of mammal roadkills were registered in Collserola park (Fig. 3). Of these, only ten registers were obtained from specific monitoring of transects, underlining the importance of roadkill records obtained on a routine day to day basis in the park. As such, these data were all considered as highly useful in characterising wildlife roadkills given the important volume of information they represent. In this regard, mammals were considered the most useful group for describing roadkill traits given their high representation in the sample.

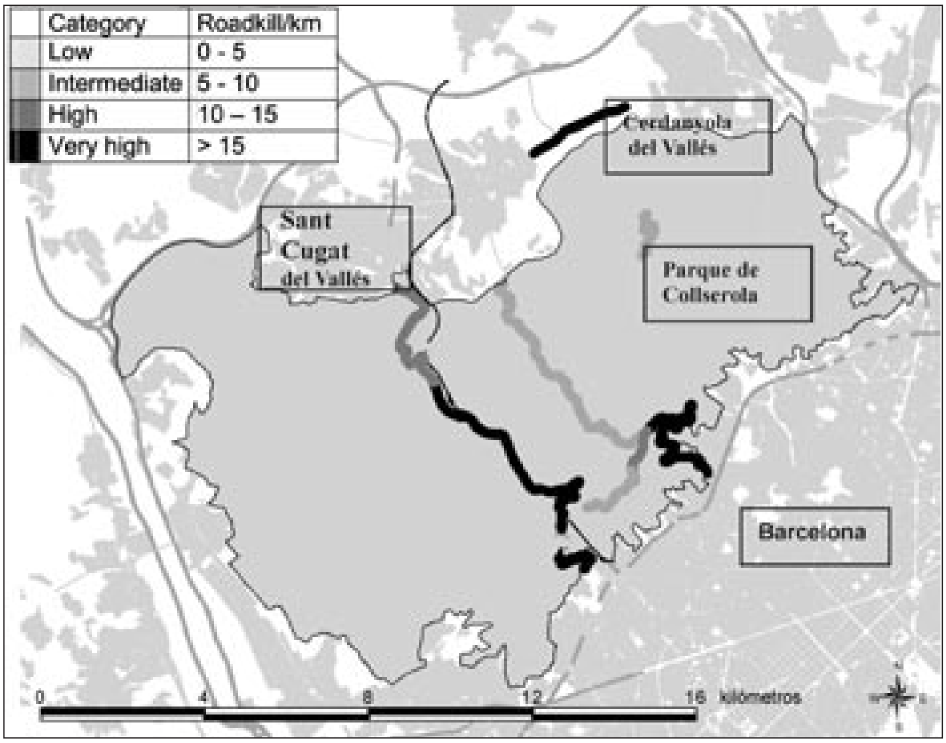

Fig. 3. Mammals roadkill kilometric index in the road sections of Collserola Park conventional roads

There was a seasonal trend to mammal roadkills, with a peak at the end of spring which coincides with the period of maximum population levels due to the presence of juveniles (Fig. 4).

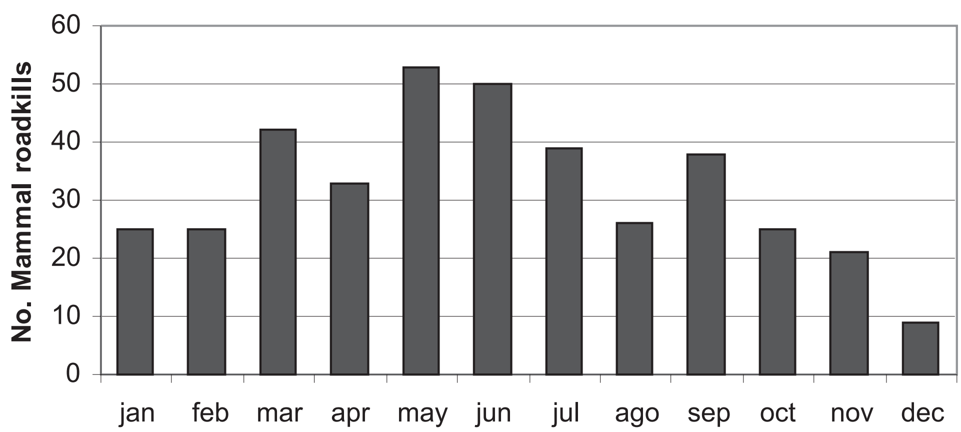

Fig. 4. Monthly distribution of mammal roadkills in Collserola Park (n=386)

With regard to the type of infrastructure, 86% of registers were from conventional roads, 6% from forest trails and only 5% of the data correspond to E-9 motorway, which is clearly underrepresented in the sample due to the practical difficulties of surveying this particular infrastructure. The remaining records (3%) correspond to roadkills in urban areas within the park. As such analysis of data for road mortality in Collserola was limited to registers from conventional roads. The roads considered in this analysis have DADs between 1,300 and 10,000 and average vehicle speeds of between 50 and 90 km/h, with very few stretches of over 90 km/h.

Mammal roadkill rate was highly variable among different road stretches in the park, ranging from 0.22 to 17.36 ind./km (Fig. 5) and was correlated with DAD (R^2= 0.82). The relationship between roadkill rate and DAD adjusts to an asymptotic logarithmic curve with a threshold of roadkills at DAD values of around 10,000 vehicles per day (Fig. 5). This result coincides with the theoretical model presented by Müller & Berthoud (1997), according to which, with increasing traffic, the number of roadkillls increases up to a point beyond which noise and vehicle movements repel more animals from attempting to cross the road.

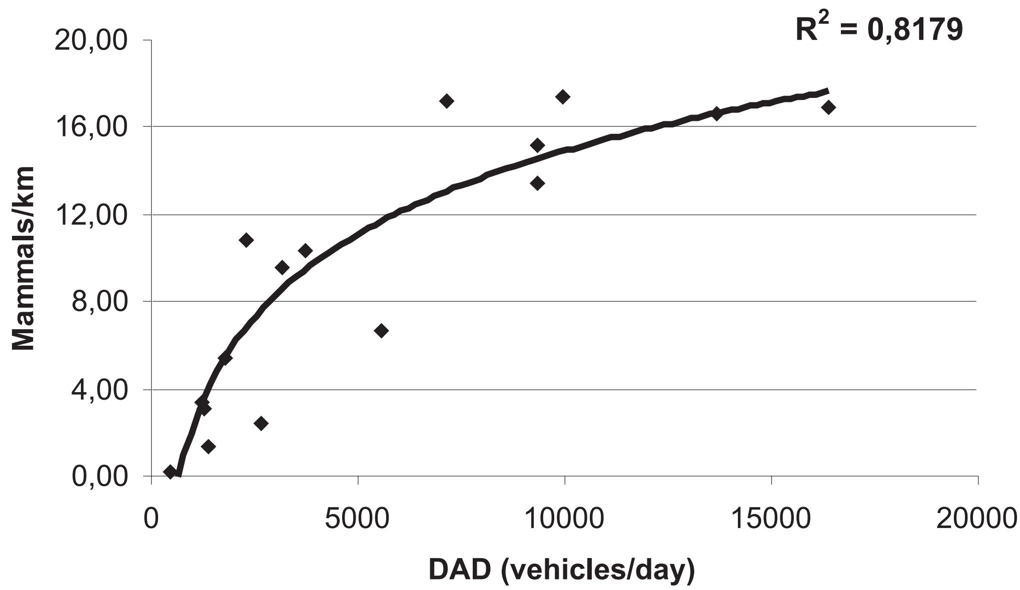

Fig. 5. Relationship between mammal roadkill rate and DAD (daily average density) on different road-stretches

Habitats around roadkill registers were characterised for the four species most affected by road mortality in the park; wild boar, hedgehog, rabbit and red squirrel (Fig. 6). The results show that roadkill spots for wild boar and red squirrel happen mostly in forested areas, on the other hand the hedgehog and the rabbit show a much higher percentage of open environments (crops, dry grass-lands…).

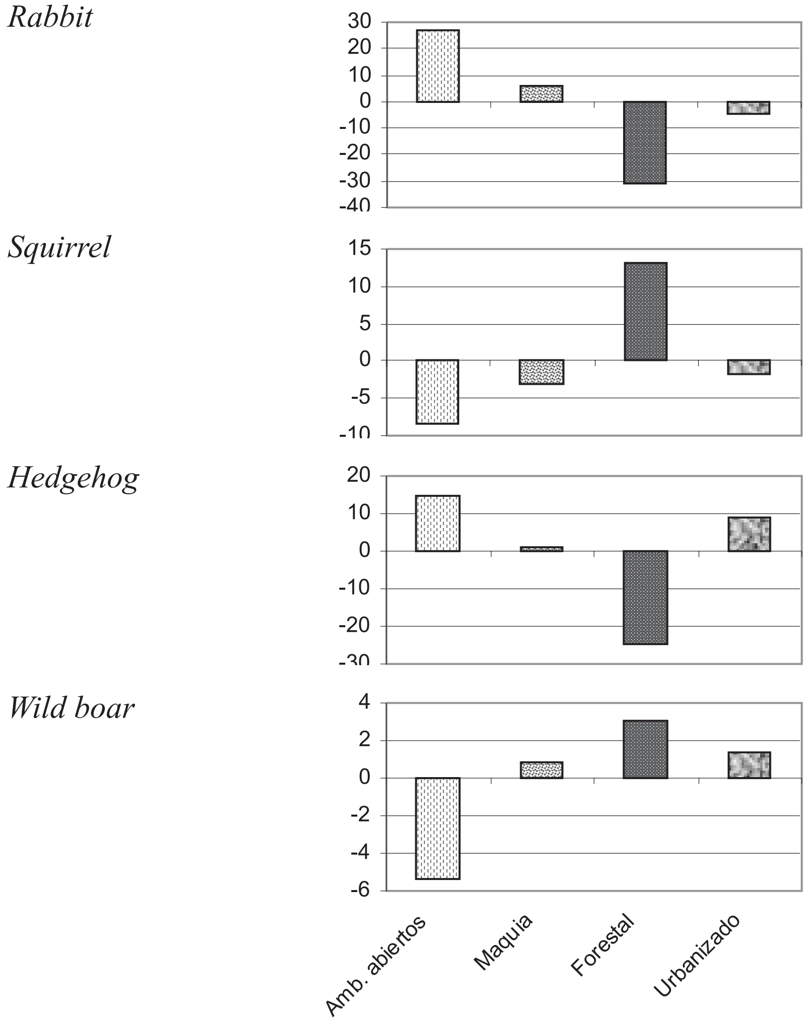

Fig. 6. Habitat selection around wildlife roadkill locations of the main species affected by this problem in Collserola (wild boar, hedgehog, rabbit, red squirrel)

5. Discussion

Collserola Park provides very interesting framework for the study of road mortality. Revision of 865 records of fauna roadkills gathered since 1991 in the Park, gives a first approach to the impact of wildlife road mortality in a periurban natural space.

Mammals rate of roadkills in our study is very high (56%) compared to results from other studies where it is around 33% (PMVC, 2003). Given the source of our information, medium sized mammals seem to be a very appropriate fauna group to carry out this type of monitoring. On the one hand they seem easier to detect, on the other hand the disappearance rate seems lower than other groups such as amphibians.

In relation to the seasonal trend of mammal roadkills, with a peak at the end of spring, according to bibliography it may be related the lack of experience of juveniles.

Although we couldn't study the effect at the population level, it is known that in some cases road mortality can be more important than mortality by natural causes as predation or illness (Forman & Alexander 1998) as it happens in Holand and Great Britain in the case of the badger (Van der Zee *et al*. 1992, Clarke *et al.* 1998). In our case, data show an effect that could be very strong on the badger population (Rafart-Plaza 2005) and it seems to appear some negative effect on hedgehog population, it should be monitorized in a close future.

Roadkills distribution on roads does not happen random but according to a cluster model (Clevenger *et al*. 2003). We found some stretches of the road where the roadkill rate is higher than average, this are known as black spots, or better, black stretches. These black stretches happen in different locations depending on the fauna species, and it seems to be related to factors linked to the road, to the roadside vegetation and biological characteristics of the species. As long as the vehicular traffic is concerned, there are several factors that ease accident rate such as traffic volume and velocity. In relation to the road design, curves or elements that reduce visibility can increase the risk of collision. Landscape features seem to be the most important factor, specially habitat quality; wildlife mortality risk increases if the road overlaps with a naturals passage of fauna such as a river, a trail etc… The existence of a big slope at one side of the road is also considered a risk factor (Malo 2004) Finally it has been observed that the existence of attraction elements in the roadside such as crops or roadside vegetation maintenance increase also the risk of collision.

In the orthophotomap a black stretch for wild boar is shown (Fig. 7). In this case, different factors explained before happen at the same time: (*i*) there is a U-turn with very little visibility, (*ii*) it is found between two straight stretches of the road where vehicles reach high speed, (*iii*) it is overlapping with a crick, which is a natural fauna passage very used by wildlife.

Fig. 7. Wild boar roadkills blackspot located in Rabassada road, Collserola Park

This work makes evident the difficulties of roadkill monitoring: driving at the right speed, visibility limitations and a high rate of corpse disappearance because of the traffic, carrion feeding or corpse removal by the road maintenance service (PMVC, 2003).

After this first approach to road mortality we consider very important to keep road transects monitoring in order to get our own standard information and still gather information from other sources. In that sense, a new link has been designed in the website of the park.

http://www.parccollserola.net/incidencies_fauna/atropellaments.htm

Finally, it should be highlighted that roadkills are not necessarily the main impact of infrastructures, at least for most species concerned, but rather their effects are added to other impacts such as the barrier effect and habitat fragmentation which can have more damaging effects at the population level.

6. Future perspectives

Our main aim in the long term is to reduce the impact of road mortality on wildlife in Collserola park. In this moment we are working in the design of first mitigation measures related to speed control and traffic reduction in conventional roads of the park. Also an agreement with train managers for first assessment has been reached in order to reduce the impact of the central axis of infrastructures.

Aknowledegements

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