Fragmentation effects on wildlife habitats of planned transport infrastructure in protected metropolitan greenspace. The case of Barcelona, Spain

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Abstract. Collserola Park is situated within the greater metropolitan area of Barcelona, close to the Mediterranean coastline. The park occupies some 8,500 ha of predominantly Aleppo pine (*Pinus halepensis*) and Holm oak (*Quercus ilex*) woodlands with a high diversity of wildlife habitats. Wildlife have been monitored here for over 15 years and detailed data are available on the habitat requirements of a variety of mammal species with large territorial requirements such as the common genet (*Genetta genetta*) and the wild boar (*Sus scrofa*).

In recent years there has been considerable urban expansion in the Barcelona metropolitan area. As a consequence, many wildlife habitats in Collserola park are now effectively isolated from those of other nearby natural areas by a ring of major transportation infrastructures and urbanised ground. Several roads, including a fenced motorway and a railway, also cross the park within its boundaries leading to internal habitat fragmentation and limiting wildlife movements. The recently published 'Transport Infrastructure Plan for Catalonia' envisages the development of major new roads and railways within and around Collserola in the coming years (2006-2026).

Consideration of available data regarding wildlife requirements, in combination with detailed GIS analyses of the future infrastructure scenario, permits interpretation of likely habitat fragmentation effects and other impacts on certain wildlife species in Collserola Park.

Urbanisation processes beyond the park's administrative boundaries, facilitated by infrastructure development, are already leading to significant habitat loss and alteration in remaining metropolitan greenspace, thus lowering critical threshold levels for sensitive species within the park. Our results indicate that these threshold limits are likely to be approached or surpassed in Collserola as a consequence of the development of this new infrastructure plan. As such, this plan could seriously jeopardise the long-term viability of wildlife populations in Collserola Park and undermine its overall ecological integrity.

Key words: wildlife habitat, fragmentation effects, metropolitan area, Barcelona, Collserola Park, GIS analyses

1. Introduction

The Barcelona Metropolitan Area (BMA) covers some 3,200 km^2 (Fig. 1) and has a population of approximately 4 million inhabitants. In such areas, periurban habitats currently represent an ever increasing scenarios for wildlife, while at the same time these same habitats are subject to important anthropic pressure and major territorial transformations, due largely to the development of infrastructure and the process of urban expansion. Urban areas and infrastructure cover almost a fifth of the BMA and increasing urban sprawl means that habitats are becoming more and more fragmented. In the last 25 years as much new urban areas have been constructed as had previously

been occupied in the entire history of the region, without major increases in population size. As a consequence, Marull & Mallarach (2005) estimated that two thirds of the BMA has either low ecological connectivity or none at all due to the continued fragmentation of habitats and the barrier effect generated by transport infrastructure and artificial ground.

Fig. 1. Ortophoto view of the Barcelona Metropolitan Area (delimited by white line) covering some 3,200 km^2, with Collserola Park indicated at its centre. Note the greenery of the forested mountainous areas in contrast to the greyish urbanised ground along the coast and inland to the north of Barcelona

Collserola Park, with 8,500 ha of mostly Mediterranean woodland and scrub, is situated in the heart of the BMA, where the current territorial planning framework (the 'General Metropolitan Plan' *PGM* from 1976, and the recently updated 'Transport Infrastructure Plan for Catalonia 2006-2026' *PITC*) augers intensified fragmentation and loss of habitats in this important area for wildlife, recently included in the Catalan proposal for Natura 2000. In Collserola, the relationships between different species and the main problems that affect this type of territory have been studied for the last fifteen years (Llimona *et al.* 2005). The present study illustrates these problems and some of their effects on wildlife, using as examples several case studies undertaken in the Park in relation to mammals with large and medium territorial requirements, such as the common genet (*Genetta genetta*), the wild boar (*Sus scrofa*) and the red fox (*Vulpes vulpes*), including the use of radio tracking techniques (Camps & Llimona 2004; Cahill *et al.* 2003a). This information has allowed for examination of the problems which the accelerated transformation of territory has on periurban natural areas (see Llimona *et al.* 2005; Llimona *et al.* in prep.).

2. Methods

The study of territories and animal movements in relation to transport infrastructure allows for interpretation of possible barrier effects and problems of isolation. Observed displacements between known animal radiolocations in Collserola Park were compared with simulated displacements obtained by randomising the direction of movement and maintaining the same point of origin and length of displacement. Displacements were randomised for fox and wild boar using ArcView 3.2 and the *Alternate Animal Movement Routes* extension (version 2.1, Jenness 2005).

From the analysis of core area (interior habitat areas unaltered by edge effects) as a habitat fragmentation parameter, the current transport infrastructure scenario in Collserola Park was compared with a possible future scenario as envisaged under the planning framework for the BMA. Analysis of core area habitat was undertaken for the genet with Fragstats 3.3 (McGarigal & Marks 1995, and see explanations on its use in Collserola in Cahill *et al.* 2003b) and ArcView 3.2 Spatial Analyst extension using 4m x 4m pixel grids generated from habitat maps for this species in Collserola based on previous radiotracking studies (Camps & Llimona 2004).

The concept of core area attains special relevance in the study of impacts generated by habitat fragmentation. Edge effect buffers were estimated between different habitat classes and infrastructure types based on data available for the genet from Collserola (Camps & Llimona 2004), as well as from literature available on this subject (see for example Forman *et al.* 2003).

3. Results

3.1. Isolation and barrier effect: case studies of two generalist species in Collserola Park – the red fox and the wild boar

Figure 2 shows the radiolocations, home ranges (95% minimum convex polygon) and core areas (50% minimum convex polygon) for a male red fox and a female wild boar followed during eight and eleven months respectively in the western sector of Collserola Park. Both of these are species with relatively large territorial requirements in the context of Collserola, with home ranges of 880 ha and 417 ha respectively in these two particular cases. Both home ranges clearly show part of their boundary delimited by the presence of large motorways, on the periphery of the park by the A-7 motorway in the case of the red fox and internally by the E-9 motorway in the case of the wild boar. Simulation of trajectories between consecutive animal radiolocations in comparison with observed trajectories (Figs. 3 and 4) shows that although some crossings of motorways were expected both for the red fox and the wild boar, in reality not one crossing of such infrastructures were observed during radiotracking of these two individuals. In contrast, low traffic volume conventional roads within the park were crossed to varying degrees by these individuals, more often than expected in the case of the fox and less often in the case of the wild boar (Fig. 4).

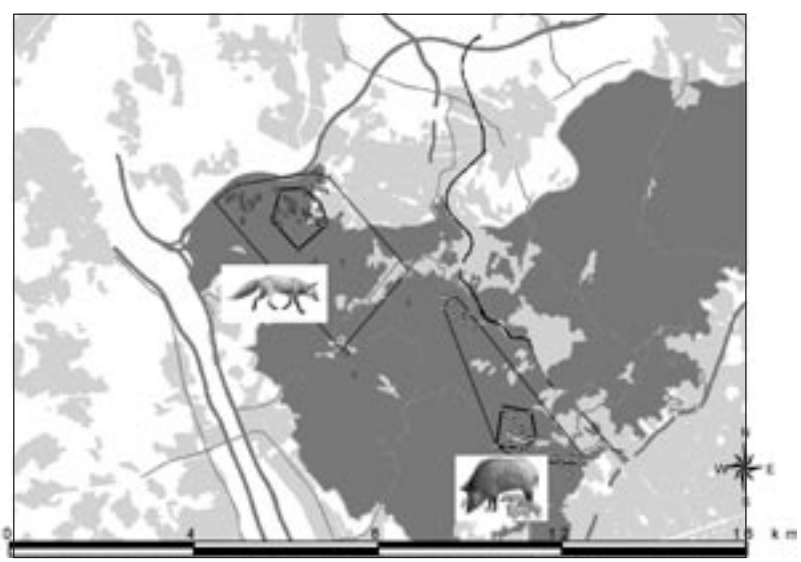

Fig. 2. Radiolocations, home ranges (95% minimum convex polygons) and core areas (50% minimum convex polygons) for a male red fox and a female wild boar in Collserola Park (hatched area). Light grey areas are urban ground and heavy grey lines are main motorways in the study area. The city of Barcelona lies to the lower right of the image

Fig. 3. Simulated (straight grey lines from ten random repetitions) and observed crossings (straight black lines) of roads and motorways by a radiotagged male fox in Collserola Park. Data from 94 linear displacement routes based on consecutive localisations. Light grey areas are urban ground and the city of Barcelona lies to the lower right of the image

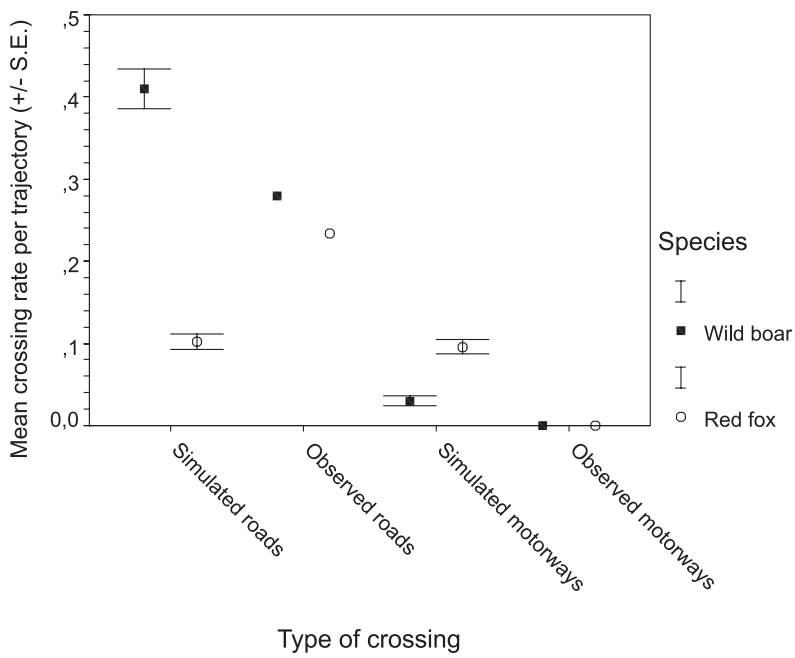

Fig. 4. Simulated (ten random repetitions) and observed crossings of roads and motorways by a radiotagged male fox and a female wild boar in Collserola Park. Data from 94 and 86 linear displacement routes based on consecutive radiolocalisations for fox and wild boar respectively

3.2. Edge effect and loss of core area habitat through fragmentation by infrastructure

The evaluation of the extent of edge effect emanating from linear infrastructure is complex and at local scales is almost an artisan task, but in general average ecological effects are considered to reach some 300 m away from roadsides, with effects on sensitive forest species attaining between approximately 300 m and 800 m (Forman & Deblinger 2000). From a foraging point of view, an optimal territory shape would approximate a circle, with a central key element from which to forage (refuge, lair, breeding area, etc.). In this sense, although even when habitat could be utilised right

up to the immediate edge of a fenced road or railway, its barrier effect would impede location of an ideal circular territory centre at a distance of less than one radius length from the infrastructure. As such, key elements within this band attain suboptimal status. The mean home range size of male genets in Collserola is 113 ha (Camps & Llimona 2004). A circle with such a surface area has a 600 m radius, and this distance was considered here as the maximum extent of edge effect adjacent to fenced infrastructures such as motorways and railways susceptible to producing barrier effect on genets. For unfenced conventional roads, half a radius length, 300 m, was taken as an average effect distance. Such figures are in line with average effect distances as previously indicated by Forman & Deblinger (2000), and although applied here specifically on the genet, could probably be considered as applicable for average effects on forest systems in Collserola.

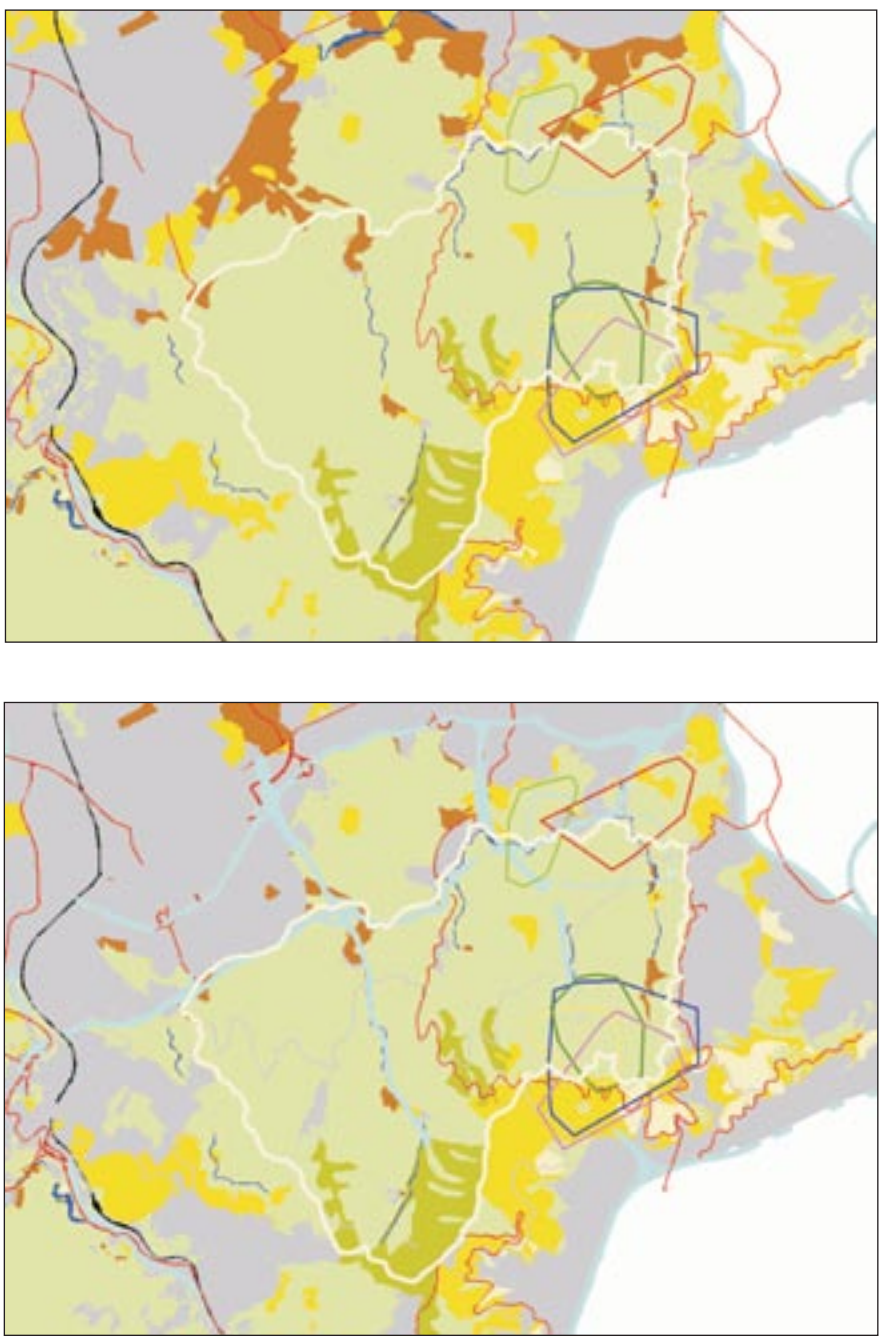

Fig. 5. Location of six genet territories (from Camps 2002) in the eastern sector of Collserola Park in relation to the current transportation network (above) and under the possible future scenario (below) as envisaged by territorial plans (PGM 1976 and PITC 2006-2026)

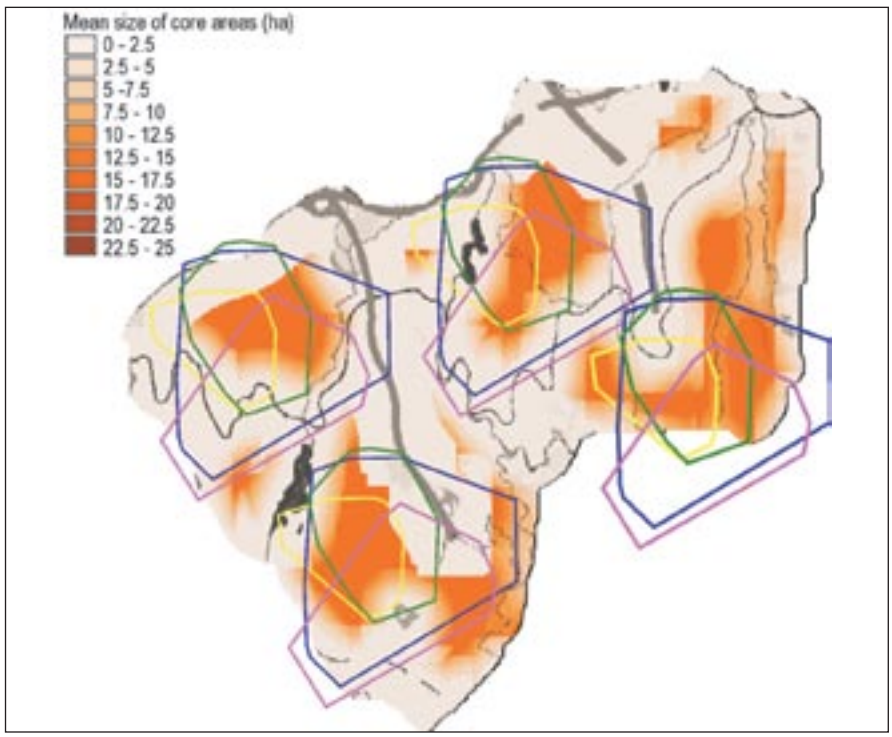

Fig. 6. Map of predicted core area habitat remaining under the possible future infrastructure scenario in Collserola in relation to size and locations of functional territorial groups (male, largest polygon, and three females) of the common genet. Functional group at bottom right is from known territories whilst the other three represent possible hypothetical locations for territories in the future scenario

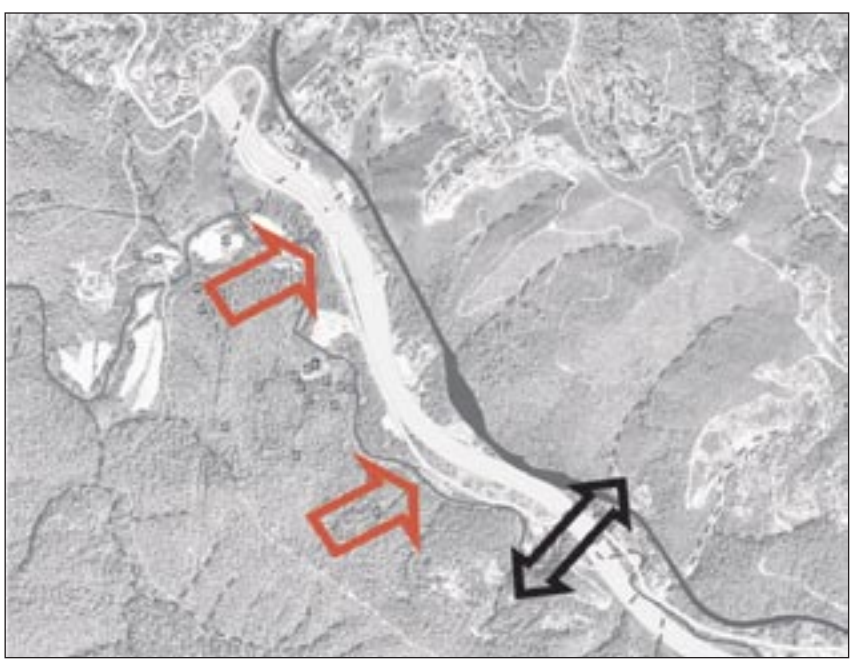

Fig. 7. Internal barrier in Collserola Park due to the juxtaposition of three transport infrastructures: the fenced E-9 motorway (wide grey), the BV-1462 road (thin grey) and the fenced FGC railway line (black). Grey dots are radiolocations of a wild boar, all located to the west of the transport axis. The double headed arrow indicates the site for the proposed construction of a wildlife fauna passage on the FGC railway line, coinciding with an existing viaduct on the motorway and the presence of the Vallvidrera stream

Figure 5 shows the current and possible future transport infrastructure network in the forested eastern sector of Collserola Park as envisaged under the present land planning framework for the Barcelona Region, based on the previsions of the 1976 General Metropolitan Plan (PGM) and the recently updated previsions for transport infrastructure contained in the Transport Infrastructure Plan for Catalonia 2006-2026, which largely coincide with those of the original 1976 PGM. There are essentially four main components of these plans with regard to Collserola Park: firstly, two new fenced infrastructures crossing through the Park approximately from north to south, either as motorway or railway (not yet clearly defined), with tunnels through the mountains close to the city of Barcelona (Fig. 5). The third component is a ring road to the north of the Park, between the towns of Sant Cugat and Cerdanyola, and finally a transversal high-capacity road running roughly west to east through the Park interior (Fig. 5). In the eastern sector of Collserola Park the coincidence and criss-crossing of these infrastructures would have especially negative fragmentation impacts on wildlife habitats. In this sector the territorial requirements of the common genet have been studied in detail (Camps & Llimona 2004), allowing for valid interpretations of probable fragmentation effects in this area. Figure 6 shows a map of the core area habitat which would remain if all envisaged infrastructures were finally to be developed, with the annual home ranges of four adult genets superimposed. In the case of the genet, functional territorial units (consisting of one male territory overlapping two or three female territories), in Collserola Park cover an average of 220 ha in size (Llimona *et al.* in prep.). As can be appreciated from Figure 6, although such units would approximately fit in the intervening habitat fragments remaining in the future infrastructure network, they would only partially encompass areas containing core area habitat.

4. Discussion

The case studies presented here on the red fox and the wild boar illustrate the barrier effect that exists in Collserola Park for species such as these with relatively large home ranges, leading to both internal fragmentation and also isolation from other natural areas in the metropolitan region. Wild boar and other ungulates are indeed known to use crossing structures on motorways less frequently than other vertebrates, but in contrast foxes often use them regularly (Mata *et al.* 2005). In this sense, it should be highlighted that the increasing degradation of natural habitat beyond the Park's limits in certain areas on the periphery of Collserola may also inhibit this species from crossing such structures.

Ironically, the formal establishment of the Natura 2000 network may indeed make it more and more difficult to conserve unprotected habitat beyond the sharply drawn limits of protected areas, and sadly certain areas of known value as ecological corridors in the Barcelona Metropolitan Region, as well as those identified recently by Forman (2004), have still received no real protection or incorporation within a true ecological network. In this sense, priority must be given in the case of Collserola to preventing new fragmentation on the internal level and also to *de-fragmentation,* in so far as is viable. To give an example, Figure 7 illustrates the barrier effect caused internally in Collserola Park by the juxtaposition of three parallel infrastructures: the fenced E-9 motorway, a heavy trafficked unfenced road (BV-1462), and the fenced FGC railway. As part of a study on the problem of collisions between trains and wild boar on this railway (Cahill *et al.* 2005), a proposal has been made for the construction of a large wildlife underpass on the FGC line at a site which coincides with the presence of a viaduct on the E-9 motorway (Figure 7), and where the Vallvidrera stream criss-crosses the BV-1462 road. This point represents the only viable option for restoring connectivity across all three infrastructures in this central area of Collserola. This particular case underlines the importance of *preventing* fragmentation, given the often very complex difficulties of de-fragmenting *a posteriori*.

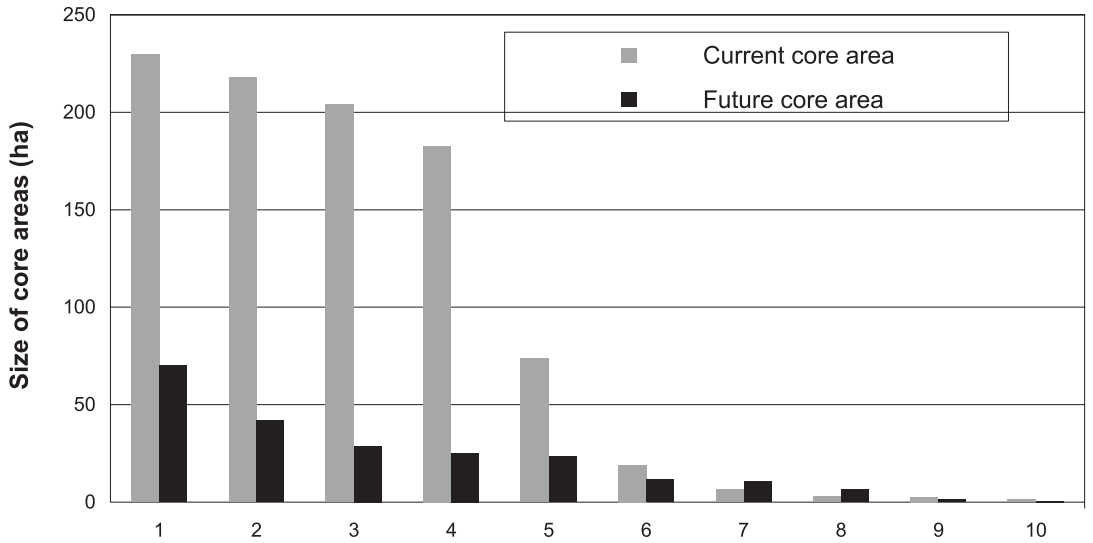

Fig. 8. Size of the ten largest patches of high quality core area habitat for the common genet in the eastern sector of Collserola Park under the current and possible future infrastructure scenarios (after Llimona *et al. in prep.*).

It is obvious that one of the goals of sustainable land planning must be to avoid surpassing critical thresholds in relation to ecosystem functioning. Nevertheless, little information is still available on what such limits are in Mediterranean ecosystems, and clearly they will often be species dependent. Medium and large sized mammals means that they can be useful as umbrella species whose conservation needs surpass those of a majority of other species occupying the same habitat. Jongman (1995) lists a range of minimum dimensions for size of habitat patches to be connected as part of a viable ecological network. Although the information is based on quite varied habitats from diverse countries and territorial plans, most minimum sizes are considered to be in the tens of hectares to the low hundreds (range 10 to 250 ha). Similarly, Marull & Mallarach (2005) established minimum sizes for 'ecologically functional areas' of between 50 and 200 ha for different habitat types in the BMA. In this context, the mean sizes of 'functional territorial units' for the common genet in Collserola, estimated as 220 ha for units of one adult male and two or three adult females, lies well in line with this concept of ecologically functional area, and can thus be taken as a minimum threshold size for unfragmented forested areas. Indeed, the minimum size established by Marull & Mallarach (2005) for dry wooded areas in general, resembling those occupied by the genet in Collserola Park, was 200 ha. At present in the eastern sector of the Park there still exist three fragments of core area habitat for the genet of more than 200 ha in size, whilst under the possible future scenario envisaged by land planning none would remain of this size, and the largest remaining fragment of core area habitat would measure only 70 ha (Figure 8), equivalent to a single female genet territory (Camps & Llimona 2004).

In summary, our results show quite clearly that the previsions regarding transport infrastructure contained in the current land plans for the BMA would surpass such thresholds in relation to core area habitat for wildlife in Collserola Park.

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