A statistical GIS-based analysis of Wild boar (*Sus scrofa*) traffic collisions in a Mediterranean area

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ABSTRACT - This study was aimed at analysing the most relevant environmental variables involved in vehicle–wild boar road collisions in a Mediterranean area, starting from a territorial information system implemented in a GIS environment. Landscape structure indices and local qualitative and quantitative variables were correlated to identify the most frequent predisposing factors of collisions. Statistical tests of the considered parameters indicated a higher frequency of collisions in the evening hours of late summer and autumn (P<0.05) compared with daytime and night-time, localized nearness to attraction points (feeding or resting sites; P<0.001) and closeness to no-hunting areas (P<0.001). In addition, local road parameters (shape of road, visibility at road sides, etc.) considerably increased the risk of collisions.

Key words: Wild boar, Road collision, GIS, Landscape structure.

Introduction – The rise in ungulate populations in Europe which has taken place over recent decades (Festa-Bianchet, 2007), together with the development of road infrastructures, the intensification of vehicular traffic, and the increase in habitat fragmentation (Seiler, 2004; Fahrig, 2003) has led to an increase in road collisions with motor vehicles (Groot-Bruinderink and Hazebroek, 1996). Administrators and wildlife managers are consequently having to face numerous problems: social problems (road safety), economic questions (damage compensation) (Cocchi and Toso, 2008), ethical issues because of the death or injury of animals (Mazzocchi, 2008) and ecological dilemmas (the expansion and/or probability of survival of the species) (Bona et al., 2006; Spellerberg, 1998). In Italy, a partial computation of road accidents caused by wildlife shows an increase over the recent decades, mainly in areas where ungulate populations are numerous (Northern and Central Italy). Wild boar is one of the species that causes traffic collisions, more frequently in certain seasons of the year and at certain times of the day (Groot-Bruinderink and Hazebroek, 1996). This may be due to an increased mobility for biological reasons (feeding, rutting) or as a consequence of human disturbance (Sodeikat, 2003). To date, there are few scientific studies in the literature concerning this issue in the context of a Mediterranean environment. The use of GIS as assessment support is increasing in many management contexts, often as a predictive tool (Johnston, 1998; Broseth, 2000; Pelorosso et al., 2008). The aim of this research was to utilise GIS to identify the most relevant variable causes of vehicle-wild boar collisions in a Mediterranean area, both at landscape and local scale, considering a range of environmental and social factors.

Material and methods – The study was conducted in the Viterbo Province (Lazio Region, Italy). This 3,612 km² province in the centre of the Italian Peninsula consists of a flat coastal area and a hilly inland area, with a population density of 85.8 inhabitants/km². Its climate is Mediterranean; the
predominant land use is arable land (47%) followed by hardwood (22%) and orchards (16%) (mainly vineyards, olive, chestnut and hazelnut grooves). The road network consists of 1,553.7 km, of which 39.2 km are highways, 37.2 main roads and 1,477.4 secondary roads.

Since there is no centralized system for collecting data on road collisions caused by wildlife, all possible holders of vehicle-wildlife collision data were contacted (Police, Veterinary service, Regional and Local Administrators). Date, time, location (georeferenced), type of vehicle and animal species involved were recorded for every collision. A total of 60 collisions involving wildlife in the period 2003 to 2006, 55 of them caused by ungulates were recorded (46 by wild boar). The analysis was carried out only for the wild boar species. Data were grouped depending on the quarter (November-January, February-April, May-July, August-October), and the time (daytime, evening or night-time). The quarter November-January corresponds to the wild boar hunting season. The following local scale parameters were measured: distance to the nearest arable land, orchard, river and wood from the point of collision (POC); the presence or absence of hedges or other visual barriers; road shape (straight/curved) and visibility of road sides (none/adequate/good) were recorded (by visual inspection). Other parameters were recorded at landscape scale (GIS analysis) (Table 1). Moreover, some spatial patterns, within a buffer with a radius of 500, 1,000 and 2,000 m from the POC, were analyzed using a GIS based on the regional government’s 1:10,000 digital land use map. The information was processed with ArcView 3.2 (ESRI™, Redlands, California, USA).

A quantitative landscape patch analysis was then conducted, using “Patch analyst 2.3” of ArcView, for each group (buffers with mostly arable lands and orchards). The number of patches (NUMP), mean patch size (MPS), patch size standard deviation (PSSD), total edge (TE), edge density (ED) and mean patch edge (MPE) for every buffer were extrapolated. Mean shape index (MSI), average weighted mean shape index (AWMSI), mean patch fractal dimension (MPFD) and area weighted mean patch fractal dimension (AWMPFD) as measures of landscape fragmentation, complexity and ecotones were considered (McGarigal and Marks, 1994). ANOVA and Fisher LSD test were carried out on the vehicle-wild boar collision data, while chi-square analysis were performed on the qualitative variables and T-test on the landscape structure. All the analysis were performed using the software Statistica (2006).

**Results and conclusions** – The statistical analysis of vehicle-wild boar collisions showed a higher incidence during the evening hours (P<0.05) compared with daytime and night-time. Considering the quarter, the collision statistics showed a tendency (P<0.1) to be more frequent during the periods November-January and August-October, compared to the February-April and May-July periods.

The chi-square analysis on the qualitative variables at a local scale showed that most of the colli-

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**Table 1. Landscape scale measured variables predisposing collisions, considering percentage of cover for 500, 1,000 and 2,000 m on both sides of the road as quantitative variables.**

| Qualitative | Quantitative |
|-------------|--------------|
| Presence of no-hunting area – 1,000 m (P/A)¹ | Resting sites² (%) |
| Presence of drive hunting team – 1,000 m (P/A)¹ | Summer feeding sites³ (%) |
| Hunting day (Y/N) | Autumn feeding sites⁴ (%) |

¹Presence/Absence; ²Hardwoods, bushes and scrubs; ³Irrigated crops, non-irrigated crops, orchards; ⁴Olive, chestnut and hazelnut groves.

The chi-square analysis on the percentage of orchards. This is largely ascribable to the high land fragmentation of the Viterbo province, where small cultivated arable lands or orchards are often close to woods or uncultivated areas.
sions occurred in the vicinity of arable lands ($\chi^2=24.133$, $P<0.001$) and woods ($\chi^2=15.116$, $P<0.001$), mainly where wooden ditches or impluvia intersect or skirt the road. In the hilly areas, there were high numbers of collisions where orchards (chestnut and hazelnut groves) bordered woods ($\chi^2=11.636$, $P<0.001$); however, this happened more frequently during late summer and autumn. There were no statistical differences between points where the road was straight or curved ($\chi^2=2.689$, $P=0.101$), but collisions occurred more frequently in points where the visibility at road sides was poor ($\chi^2=10.533$, $P=0.005$), or points where hedges or other visual barriers were present along the roadside ($\chi^2=16.200$, $P<0.001$). The analysis of qualitative variables at landscape scale showed a high frequency of collisions in road sections close to no-hunting areas ($\chi^2=11.756$, $P<0.001$), which did not occur in the proximity of woods where drive hunting is usually carried out. The comparison between days when collisions occurred and drive hunting days showed no correlation. These results suggest a shift during the evening hours from resting sites to feeding sites in the period August-October and a greater mobility, probably due to the rut, in November-January quarter. The investigation into the quantitative variables at landscape scale confirmed the local scale findings. The landscape structure analysis showed no significant difference in the patch parameters, even if clustered into groups (high % of arable land, or high % of orchards). This is largely ascribable to the high land fragmentation of the Viterbo province, where small cultivated arable lands or orchards are often close to woods or uncultivated areas.

The results show that GIS and statistical analysis are powerful tools which could be implemented in strategic and targeted decision-making for wildlife planning, taking into account road networks and landscape structure. Building on this new approach, it would be useful to develop models that predict higher risk-prone road sections where mitigation measures, both at local scale (road fencing, crossing structures, etc.) and at landscape scale, could be adopted.

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