Bird mortality related to collisions with ski–lift cables: do we estimate just the tip of the iceberg?

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Abstract
Bird mortality related to collisions with ski–lift cables: do we estimate just the tip of the iceberg?— Collisions with ski–lift cables are an important cause of death for grouse species living close to alpine ski resorts. As several biases may reduce the detection probability of bird carcasses, the mortality rates related to these collisions are generally underestimated. The possibility that injured birds may continue flying for some distance after striking cables represents a major source of error, known as crippling bias. Estimating the crippling losses resulting from birds dying far from the ski–lift corridors is difficult and it is usually assessed by systematic searches of carcasses on both sides of the ski–lifts. Using molecular tracking, we were able to demonstrate that a rock ptarmigan hen flew up to 600 m after striking a ski–lift cable, a distance preventing its detection by traditional carcasses surveys. Given the difficulty in conducting systematic searches over large areas surrounding the ski–lifts, only an experiment using radio–tagged birds would allow us to estimate the real mortality rate associated with cable collision.

Key words: Bird collision, Crippling bias, Forensic approach, Human infrastructure, Rock ptarmigan, Ski–lift wires.

Resumen
Mortalidad de aves causada por colisión con los cables de los remontes de las pistas de esquí: ¿sólo vemos la punta del iceberg?— Las colisiones con los cables de los remontes son una importante causa de mortalidad para las diversas especies de galliformes que habitan en las inmediaciones de las estaciones de esquí alpino. Las tasas de mortalidad asociadas a esta causa resultan frecuentemente subestimadas como consecuencia de los diversos factores que pueden reducir la probabilidad de detección de los cadáveres. Así, por ejemplo, el posible desplazamiento de las aves heridas después de la colisión representa una importante causa de error llamada sesgo por mutilación (crippling bias). La estima de las pérdidas resultantes correspondientes a aves que mueren lejos de la vertical de los remontes es un aspecto de difícil cuantificación que normalmente se evalúa mediante búsquedas sistematizadas de restos a ambos lados de estas estructuras lineales. Mediante el uso de técnicas de rastreo molecular hemos sido capaces de detectar que una hembra de lagópodo alpino voló unos 600 m después de colisionar con un cable remontador, distancia a la cual el ave no hubiese sido detectada mediante los métodos de muestreo tradicionales. Debido a la dificultad de llevar a cabo búsquedas sistemáticas sobre superficies extensas alrededor de los remontes, tan solo el radio seguimiento de las aves permitiría una estima consistente de la tasa real de mortalidad asociada a la colisión con cables.

Palabras clave: Colisiones de aves, Sesgo por mutilación, Enfoque forense, Infraestructuras humanas, Lagópodo alpino, Cable remontador.

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Introduction

The skiing activities in recent decades have had a profound impact on the alpine landscapes of many European mountains. In the French Alps and the Pyrenees, a recent survey conducted by the Mountain Game Observatory counted a total of 252 ski resorts with 3,117 ski or chair lifts for a total length of some 2,575 km (Observatoire des Galliformes de Montagne, 2006). Several studies have reported adverse effects derived from the development of winter tourism on alpine wildlife and particularly on grouse species (Miquet, 1990; Menoni & Magnani, 1998; Martin, 2001; Watson & Moss, 2004; Arlettaz et al., 2007; Thiel et al., 2008; Patthey et al., 2008). Among these negative effects, the mortality of birds colliding with cables has been considered as one of the main causes of the decline of grouse abundance close to ski resorts. Indeed, grouse species seem particularly vulnerable to strike–wire mortality (Bevanger, 1995) and a recent survey of 252 French ski resorts confirmed this point (Observatoire des Galliformes de Montagne, 2006; Buffet & Dumont–Dayot, in press). Generally, mortality resulting from human infrastructures such as ski–lift cables, power lines or fences is estimated by counting animals found dead underneath or close to the human infrastructures (Bevanger & Brøseth, 2001; Barrios & Rodriguez, 2004). However, some injured birds may continue moving for some distance after striking and death can occur several hundred meters further away. This bias, known as the crippling bias, refers to animals which can be found dead far from the infrastructures and therefore not counted in estimates of mortality rate related to the structures. Widening the searching areas on both sides of ski–lift corridors would clearly help to produce more realistic estimates of collision mortality rates (Bevanger, 1999), but the width of the searching zone is not easy to define. In this paper, we report on a case of rock ptarmigan (*Lagopus muta muta*) mortality related to a ski–lift collision at a Pyrenean ski resort. Using molecular tracking, we demonstrated that this bird travelled several hundred meters after striking a ski–lift. Finally, we discuss the difficulty in estimating the different biases associated with cable collision.

Material and methods

The study was carried out in the Err–Puigmal ski resort located in the eastern French Pyrenees (N 42º 23' – E 2º 05'). This small ski resort ranges from 1,830 m to 2,700 m above sea level and includes two chair–lifts and seven ski–lifts. Five cases of rock ptarmigan mortality related to ski–lift collisions have been observed following the building in 2005 of a new ski–lift, called The Montserrat. On 10 VI 2008, we found a severely injured female rock ptarmigan at about 600 m from the Montserrat ski–lift (fig. 1). The bird died a few minutes after capture and a post–mortem examination revealed that its right wing and right leg were broken. During a survey carried out three days later under the ski–lift, we found some rock ptarmigan feathers just under the cables (fig. 1). Genomic DNA of both samples was extracted from the tip (~3 mm) of feather samples and from muscle tissue in the case of the corpse, using silica columns (e.Z.N.A Kit of OMEGA BIO–TEK) and following the manufacturer's protocol. Both samples were tested with 14 microsatellite markers. The relevant DNA fragments were amplified using Polymerase Chain Reaction (PCR). To maximise efficiency and minimize costs, these PCRs were performed in four multiplexes using the QIAGEN multiplex kit following the manufacturer's protocol. Thus, PCR were performed in a 10 µL volume and contained 1µL of extraction product, 1x of 'Qiagen Multiplex PCR Master Mix' and 0.2 µM of primers. Cycling protocol contained an initial denaturation of 15 min at 95ºC followed by 30 cycles of 30s at 94ºC, 90s at the annealing temperature of 57ºC (for all markers) and 1 min at 72ºC, followed by a final extension of 30 min at 60ºC. PCR products were electrophoresed on an automatic sequencer (CEQ™ 8000, Beckman Coulter) and genotypes were determined using the fragment analyzer package from Beckman Coulter. We genotyped the two samples six times in order to reach a genotype consensus and to avoid genotype errors due to false or null alleles for the samples of low quality*, i.e.* feathers (Valière et al., 2007).

Deviation from Hardy–Weinberg expectancies and linkage disequilibrium were tested using the global tests in FSTATv.2.9.3.2 (Goudet, 2001). The level of significance was adjusted for multiple testing using Bonferroni correction. Furthermore, polymorphism was estimated over all loci using the allelic richness (AR), expected heterozygosity (H_e), and F_{IS} computed with FSTAT v.2.9.3.2. This was performed with 34 supplementary DNA samples. These 34 supplementary DNA samples were isolated from moult feather or muscle removed from birds found dead during census or radio tracking. These samples, found in a radius 60 km around our ski–lift, had already been used in a genetic study of a metapopulation of the species focusing on the Pyrenees (Bech et al., 2009). This study indicated that the samples belonged to a single population (named 'Carança–Puigmal') (Bech et al., 2009). In order to check the power of our markers, we computed the probability of identity (PI) index corrected for small samples of individuals (PI unbiased) using GIMLET v.1.3.2 software (Valière, 2002). This index indicates the probability that two unrelated individuals in a population share a multilocus genotype. Very low PI values (PI values of $2.0 \cdot 10^{-5}$ are considered as low (Paetkau & Strobeck, 1994)) suggest high power to distinguish between two individuals. We then matched the genotypes obtained from the samples to check whether they belonged to the same individual.

Results

After Bonferroni correction we did not detect any deviation from Hardy–Weinberg expectations or any linkage disequilibrium. Our microsatellite panel revealed a high polymorphism degree characterised by a mean allelic richness (AR) of 5.457, a mean expected

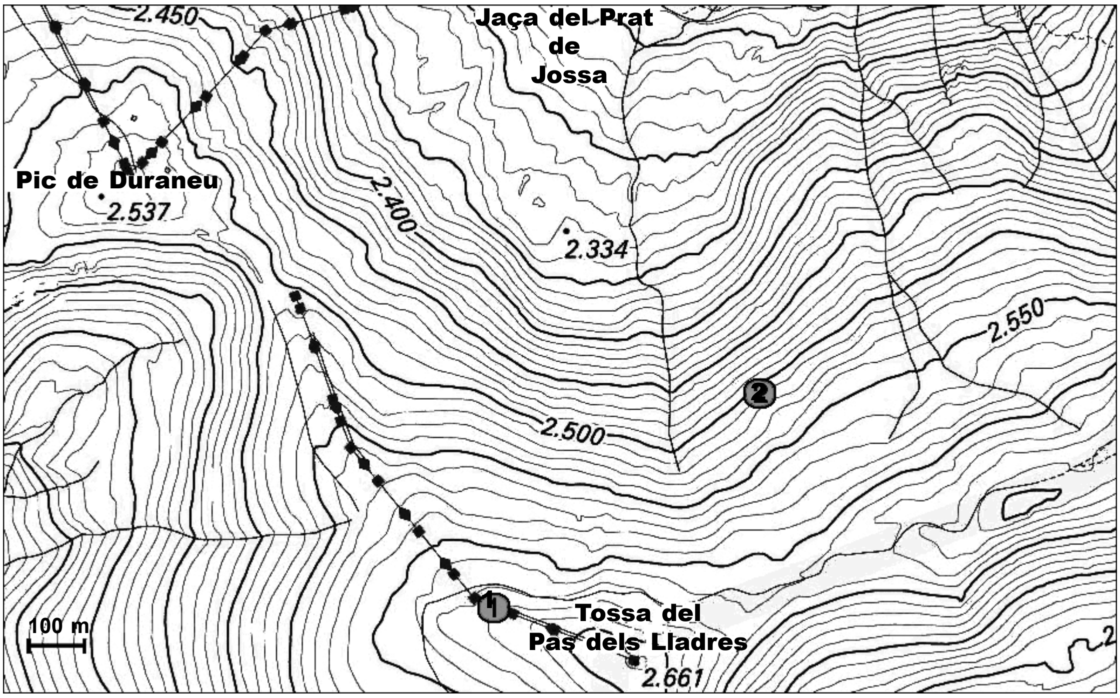

Fig. 1. Topographic map of the upper part of Err–Puigmal ski resort. The lines with diamonds figure the ski–lifts: 1. Location where the feathers were found (wire–collision); 2. Location of the rock ptarmigan hen carcase (map from Institut Cartografic de Catalunya).

Fig. 1. Mapa topográfico de la parte superior de la estación de esquí alpino de Err–Puigmal. Las trazas con rombos representan los remontes: 1. Lugar donde se encontraron las plumas (colisión con cable); 2. Localización del cadáver de la hembra de lagópodo alpino (mapa del Institut Cartogràfic de Catalunya).

heterozygosity (H_e) of 0.637, and a F_{IS} value of 0.148. The probability of identity was $1.216 \cdot 10^{-12}$, indicating that our microsatellite markers are polymorphic enough to distinguish between two individuals from our sampled population. For each sample, the six genotypic profiles obtained were identical, indicating that there were no false alleles and no null alleles. The genotype comparison between samples (*i.e.* collected under the ski–lift and on the rock ptarmigan corpse) gave strict identical genotype profiles for all microsatellite markers. Feathers found under the ski–lift thus came from the female rock ptarmigan corpse. By inference, this result shows that the injuries had been caused by the collision. The steep slope under the ski lift probably facilitated the distance travelled by the hen after the collision (fig. 1).

Discussion

Mortality related to collisions with wires, cables or fences is of major concern for the conservation of tetraonid populations (Bevanger, 1995; Moss, 2001). Out of 835 bird deaths associated with such collisions observed from 1997 to 2009 on 225 ski resorts of the French Alps and Pyrenees, 771 involved galliformes species (Buffet & Dumont–Dayot, in press). These numbers must be considered as minimal because cases of death associated with collisions are generally underestimated because only birds found dead directly underneath or close to the ski–lift are taken into account when estimating mortality rates.Correction factors must therefore be applied to produce more realistic estimates of collision mortality rates (Bevanger, 1999). Such factors correct for different biases such as season (Bevanger & Brøseth, 2004), removal by scavengers (Bevanger & Brøseth, 2000; Morrison, 2002; Barrios & Rodriguez, 2004; Kikuchi, 2008), search efficiency (Morrison, 2002; Kikuchi, 2008), habitat structure (Bevanger & Brøseth, 2004) or crippling losses (Bevanger & Brøseth, 2004). The latter, known as crippling bias, refers to victims of collision found dead outside the search zone. The rock ptarmigan mortality case reported in this study clearly fits this definition. Whereas our study shows the usefulness of a forensic approach for a better identification of the mortality cause, we cannot evaluate the magnitude of the underestimation related to crippling bias. The long distance reported in this study between the corpse and the ski–lift suggests that underestimation associated with crippling losses could be much greater than usually thought. As suggested by Bevanger (1995), an experiment using radio–tagged birds would allow a better estimation of crippling losses beyond the direct mortality rate associated with cable collision.

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