



Skiing, birds and biodiversity in the Alps

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In the Alps, the skiing industry holds a prominent role as a factor impacting the natural environment because of the large-scale changes it causes. Since the beginning of the 1900s, ski tourism has greatly altered parts of the Alpine environment, where the only human activities were previously low-intensity agriculture and grazing. The most dramatic effect is represented by the construction of ski-pistes for downhill skiing, which causes removal of vegetation and part of the soil during construction. This involves significant impacts on ecosystems along a broad altitudinal range that may have impacts in both forest and treeless zones, effects being evident at both habitat and landscape levels. The combined length of ski-pistes in the Alps is estimated at several thousand kilometres, and thus the total area affected may be very large. Here, we summarize some of the key impacts of skiing on animal communities, taking examples from studies on birds, but also mammals and invertebrates, using evidence drawn mostly from the 10 years of research we have carried out in the western Italian Alps. For birds, several studies have demonstrated negative effects caused by the construction of ski-pistes in both forest and alpine grassland, which may be due to the creation of a highly disturbed and resource-poor habitat. For some species such as tetraonids, direct impacts are detectable, for example collisions with infrastructure associated with ski-pistes which can severely affect local populations (Buffet & Dumont-Dayot 2013). In addition to the effects of habitat degradation and destruction caused by construction of the ski-piste itself, there appears to be a negative edge effect whereby bird communities have lower species richness, and/or lower occurrence rates, close to the ski-piste, which is again evident for both forest (Laiolo & Rolando 2005), where plots at ski-piste edges present lower bird species richness and Shannon diversity than those located in the forest interior or at the edges of pastures, and Alpine grassland bird communities (Rolando et al. 2007), where plots at ski-piste edges have a lower abundance of grassland species. This suggests that the construction of ski-pistes has a negative effect at a wider landscape scale. This is corroborated by detailed studies on Black Grouse *Tetrao tetrix*, which have shown negative effects (through physiological stress) caused by off-piste skiing (Arlettaz et al. 2007). The evidence overall therefore indicates that for birds at least, skiing may have negative effects at a landscape scale which may impact on populations, rather than just cause a local shift in bird distributions. This has been shown for grassland species richness, and the probability of occurrence of Water Pipit *Anthus spinoletta*, Northern Wheatear *Oenanthe oenanthe* and Black Redstart *Phoenicurus ochruros*, which decreased significantly with increasing extent of ski-piste edge. Predictions of species occurrence, made by applying models of probability of occurrence to different scenarios of habitat change, showed expected detrimental impacts of a relatively small



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increase in ski-piste extent of 10%, but also that grassland restoration on existing ski-pistes could result in significantly increased occurrence rates of alpine grassland species (Caprio et al. 2011). In general, ski-pistes are perceived by birds as detrimental features of the alpine landscape, and to minimize their impact, new, environmentally friendly ways of constructing pistes should be developed, which could include habitat restoration and management to obtain a level of grass cover such that edges of ski-pistes are no longer perceived by birds.

Other animal groups may be similarly affected by the construction of ski-pistes. For most small mammals, ski-pistes are perceived as ecological barriers. Ski-pistes represent habitat loss and are ecological, semi-permeable barriers to small mammals (Negro *et al.* 2013). For invertebrates below the treeline, all community parameters of brachypterous carabids (reduced wings or wingless) decrease significantly from forest interior to open habitats (i.e. ski-piste or pasture), whereas those of spiders and macropterous carabids (full-sized wings) increase from forest interior to open habitat. Ski-pistes show lower values than pastures in all community parameters (Rolando *et al.* 2013a). Above the treeline, brachypterous carabids, spiders and grasshoppers decrease significantly from natural grasslands to ski-pistes. This is not the case for the guild of macropterous beetles, which is composed of species with contrasting ecological requirements (Rolando *et al.* 2013a). Furthermore, butterfly abundance has been shown to be higher on forest ski-pistes, because in mid-summer these grassland strips were more abundant in flowers than nearby pastures. However, butterfly diversity was lower by comparison with pastures, both because of the lower flower diversity and because of the higher isolation and/or smaller area of ski-pistes (Rolando *et al.* 2013b).

Future research should concentrate on the mechanisms underlying breeding habitat selection in birds in the Alps, in order to understand if the avoidance of ski-pistes and surrounding areas by birds is underpinned by direct disturbance, physical alteration of habitats or factors affecting productivity (e.g. feeding resources, predation, brood parasitism). Furthermore, there is a need to evaluate whether the effects on bird populations are extensive enough to be responsible for demographic impacts at a wider scale.

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