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CHAPTER 8

Impacts of Outdoor Winter Recreation on Alpine Wildlife and Mitigation Approaches: A Case Study of the Black Grouse

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Abstract: Outdoor winter recreation is exerting an increasing pressure upon alpine biodiversity. There is an urgent need to better understand the detrimental effects on wildlife in order to propose targeted mitigation measures. This chapter summarizes the main results of a still ongoing research about the impacts of outdoor snowsports on black grouse, a regionally declining bird species. Black grouse was chosen as a model species because, in the European Alps, it inhabits exclusively treeline ecosystems, where most outdoor winter activities take place. We investigated the physiological (stress and energetics) and behavioural (activity budget) responses of free-ranging radio-tracked black grouse to human disturbance in winter, while assessing demographic effects. We then modelled areas of conflict between black grouse and winter outdoor recreation, which resulted in spatially-explicit prescriptions for mitigating its impacts. We finally discuss various issues around practical implementation of winter refuges for Alpine black grouse conservation.

Keywords: Black grouse, conflict zones, demography and distribution, mitigation measures, modelling, physiological and behavioural responses, treeline ecosystems, winter refuges.

INTRODUCTION

With a steadily growing world population (another 47% predicted by the year 2070 [1]) and an increase in the average human's standard of living, *i.e.* more financial resources per capita and more time to be devoted to leisure activities, the tourism industry is expected to undergo further tremendous developments in the near future. In spite of the current financial crisis, which is affecting peoples' revenue in several parts of the world, most scenarios still predict a continuous,

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Christian Rixen and Antonio Rolando (Eds)

almost exponential increase in recreational activities for the next decades, resulting in a growing pressure on the environment. On the one hand, recreation necessitates infrastructure (housing, transportation networks, *etc.*), which will further encroach on natural and semi-natural habitats, on the other hand people will penetrate deeper into ecosystems which were until now largely void of human presence. A good illustration of the latter is the growing tourist industry in Antarctica.

In the face of these threats to the environment and biodiversity, it is imperative to develop novel conservation approaches to enhance the chances of survival of wildlife occurring in sensitive habitats. Especially at risk are habitats which are not protected by legislation, for instance those situated outside national parks and nature reserves. Here we first need to identify species that would greatly suffer from the spread of recreational activities, based on the assumption that mitigation measures directed towards the most sensitive species will indirectly benefit less sensitive ones as well. Second, the effects of recreation disturbance on these species as well as their tolerance thresholds have to be determined in order to define the most suitable measures to mitigate any detrimental impacts. Third, we need to know what are the species' basic requirements (*e.g.,* minimum area of suitable habitat, among other critical resources) in order to make sure that wildlife refuges created to buffer against recreational disturbance offer the whole palette of ecological needs. Finally, spatially explicit information about both species habitat use and human outdoor-recreation is necessary in order to recognize and anticipate major zones of wildlife-human conflicts so as to place refuges at the most suitable locations within the wide landscape. Although wildlife can habituate to human presence to some extent [2], until the preconditions for habituation are exactly known, conservative approaches based on the precautionary principle are necessary to permit adjustments of wildlife to the growing constraints imposed by recreational activities.

Outdoor snowsports represent one of the most rapidly growing sets of recreational activities. They often take place in naturally fragile habitats, namely boreal and alpine ecosystems, where wildlife has already to cope with the immense challenge imposed by the harsh environmental seasonality: here sedentary organisms have evolved very finely tuned ecophysiological adaptations to survive in winter [3]. The European Alps today represent the first destination for outdoor winter sports in the world [4] and a substantial part of Alpine habitats is already affected by

these activities. Not only have ski resorts burgeoned at an extremely rapid pace in the second half of the 20th century, but free-ride sports are currently undergoing a very rapid and massive development [5].

We launched an ambitious research programme in 2002 in southwestern Switzerland, with the aim to better understand and anticipate the conflicts generated by human outdoor recreation to wildlife during winter. To that endeavour we selected one of the most emblematic species of Alpine biodiversity: the black grouse *Tetrao tetrix*. This bird is considered as an ideal model organism because it occurs the year-round exclusively in treeline ecosystems where ski infrastructure concentrates and where most outdoor snowsports, including off-piste free-ride activities, take place [6-8]. It is also a species which has some symbolic cultural value that may attract public awareness and sympathy. In addition to its flagship function, black grouse is hunted in many areas, thus still bearing some economic value [9]. Finally, it probably plays the role of an indicator species of ecosystem integrity, given that it requires a complex habitat mosaic during reproduction [10], while this high habitat heterogeneity certainly promotes Alpine biodiversity as a whole [11].

As the effects of winter outdoor sports activities on black grouse in winter can often not be fully disentangled from factors influencing the species in summer, our project also included a module devoted to the specific niche requirements in summer, with a major focus on breeding hens. The latter because black grouse population dynamics is mainly determined by reproductive success [12], which depends both on weather conditions during the first stages of the chick rearing period [13] and the availability of favorable breeding grounds [14]. The breeding grounds consist of a fine-grained arrangement of grassland, shrubs and trees, and provide a good supply in invertebrate prey for the precocial chicks that need huge quantities of protein-rich food to boost their rapid growth [10, 15, 16]. In the European Alps, this habitat mosaic is typically found along the treeline, located at the interface between the subalpine forest and alpine meadows. This research on species' summer ecology and breeding habitat requirements was also necessary because major land use changes currently affect Alpine ecosystems [17], for instance abandonment of grazing on alpine pastures, which may irremediably lead to shrub and forest encroachment and to the consequential loss of vast areas of suitable breeding habitat. Based on our

findings, recommendations have been made to foresters for targeting habitat management measures (P. Patthey, V. Braunisch & R. Arlettaz, unpublished report) which may further enhance the effects of the disturbance-minimizing strategies that result from our findings in winter (see [18]).

By investigating the effects of human disturbance on various aspects of black grouse ecology we developed an integrated research programme; this contrasts with most studies which usually focus on only one among several issues. Moreover, in addition to providing applicable management recommendations, we try in this programme to push towards implementation in order to bridge the gap between research and action typically encountered in conservation biology [19, 20]. The first section describes the scientific evidence gathered so far by the winter research module that investigated, and is still investigating, the effects of human activities on black grouse in winter. First, we studied the impact of outdoor snowsports on physiology (stress ecology and energetics) and behaviour; second, we quantified the demographic consequences of snowsports infrastructure and activities. Based on this, we finally discuss the underlying mechanisms which may affect species demography and individual fitness.

Drawing from the available evidence, the second section provides management recommendations for a better winter coexistence between humans and black grouse. Here we shall see how spatially-explicit models of assessed and predicted conflicts were used for refined planning of visitors steering measures, and briefly discuss the adaptive potential of black grouse to human presence. Finally, we address issues around pragmatic implementation of public steering measures, such as techniques for marking winter wildlife refuges and for having the boundaries of these refuge areas respected by snowsports people.

I. Research on Human-Wildlife Conflicts in Alpine Treeline Habitats

1. Impact of Outdoor Snowsports on the Eco-Physiology and Behaviour of Black Grouse

Although it has been claimed long since that outdoor winter recreation disturbs wildlife in alpine habitats, quantitative assessments of disturbance effects have remained scarce until recently. By measuring the metabolites of corticosterone, the stress hormone of birds, we could quantify, non-invasively and from faeces

collected from snow burrows [21], the stress response elicited by human disturbance upon black grouse in the Swiss Alps. Working in both comparative (measure of chronic stress response) and experimental (acute stress response) frameworks, we could show first that black grouse living in natural, not or little disturbed treeline habitats have a significantly lower general concentration of faecal corticosterone metabolites than individuals occurring either in highly disturbed (ski resort areas) or moderately disturbed habitats (places outside ski resorts with backcountry skiing, snowboarding and showshoeing) (Fig. (**1**), [22]). The fact that the latter two categories did not differ statistically between each other suggests that even moderate levels of disturbance, such as that caused by off-piste activities, are enough to elicit a chronic stress response in the birds. This actually has direct implications for conservation: refuges with almost no disturbance must exist in the landscape if we want to avoid any negative effects of human disturbance on the birds' physiological state.

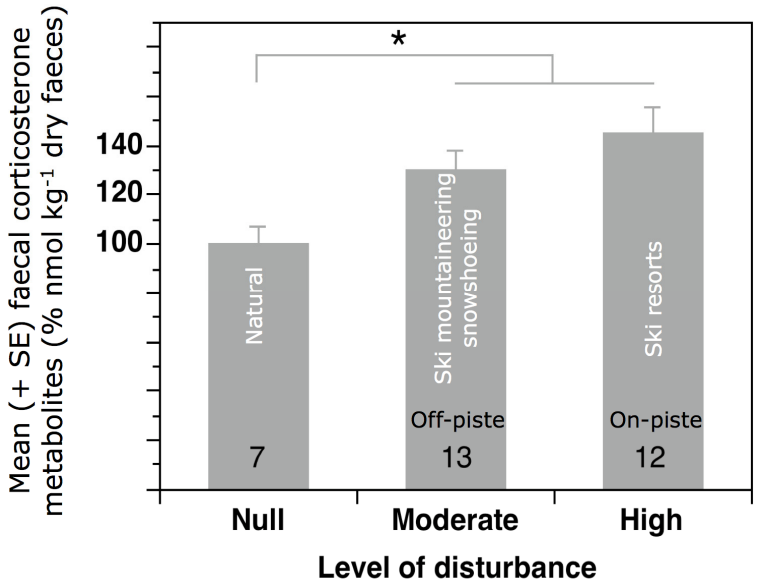

Figure 1: Concentration of corticosterone metabolites, as retrieved from faeces collected from snow burrows, with respect to levels of disturbance by outdoor winter recreation (null and limited disturbance: natural habitats; moderate disturbance: off-piste activities such as backcountry skiing and snowboarding, as well as snowshoeing; high disturbance: on-piste activities such as skiiing and snowboarding stemming from skilifts). Since birds were not flushed for collecting the droppings, this approach quantified differences in the birds' corticosterone basal level, *i.e.* measured the chronic stress faced by birds in different contexts (adapted from [22]).

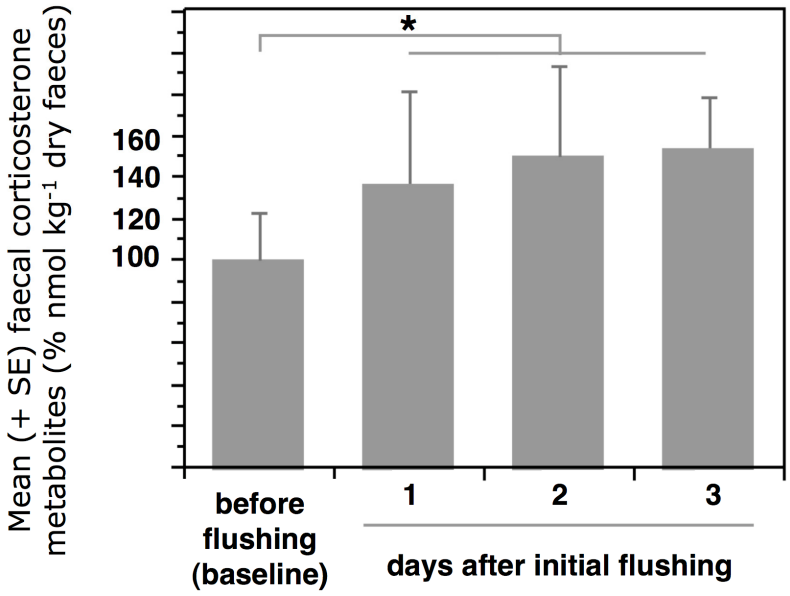

Figure 2: Concentration of corticosterone metabolites as retrieved from faeces collected from snow burrows of black grouse cocks flushed experimentally over a period of 4 days. Birds were equipped with a radio-transmitter, which enabled localization and targeted flushing. The initial baseline concentration of corticosterone metabolites corresponded to the material collected at the first flushing event, the droppings having been deposited in the snow burrows before any disturbance by humans. This experiment enabled us to estimate the acute stress response of the birds (adapted from [22]).

We then conducted disturbance experiments with cocks that were repeatedly flushed in order to measure acute stress response. The birds were equipped with radiotransmitters, which enabled us to locate them and their snow burrows where we targetedly collected the faeces left behind. The material collected at the first flushing attempt served as a control of individual basal stress hormone level. Birds responded to daily disturbance with increasing concentrations of faecal corticosterone metabolites, showing a rapid increase at the beginning and a leveling off of the concentration at the end of the experimental sequence (Fig. (**2**), [22]). This demonstrates the existence of an acute stress response to anthropogenic disturbance.

It remains difficult, however, to understand the interplay between both chronic and acute stress and their effects on birds' fitness since we could not capture and measure the birds repeatedly; they were manipulated only at the initial capture

event when they were marked with a radiocollar. Due to the difficult terrain it would be difficult to improve on this as regards the Alpine black grouse. Nevertheless, using the radio-collared birds, we could show behavioral responses that indicate negative effects of disturbance on the birds' energy budget: first, there was an apparent increase in foraging bout duration in the day following flushing (Arlettaz *et al.* in prep.); second, human disturbance provoked extra energy expenditures because the birds could no longer benefit from the thermal buffer of the igloo for a while after flushing; at least this applied when snow conditions rendered borrowing possible (Arlettaz *et al.* in prep.).

2. Consequences of Outdoor Winter Recreation for Demography and Distribution

One of the main limitations while working with scattered and elusive birds like black grouse is the challenge of collecting data about their health status and reproductive ability. This problem is exacerbated in black grouse because they are difficult to capture, which complicates measures of physiological state, reproductive ability and other fitness consequences of anthropogenic disturbance. Moreover we had to work almost exclusively with cocks because they were easier to capture than females: most cocks were mist-netted on leks while displaying.

To overcome these logistic obstacles, we had again to rely on a comparative framework, testing whether local black grouse presence and abundance correlate negatively with the intensity of human use of the landscape in the winter time. Indeed, we found that suitable wintering grounds – as identified by a habitat suitability model – were less frequently used or even abandoned by black grouse in the presence of snowsports, with ski-resorts and the associated ski-tourism having a stronger impact than off-piste activities. However the latter were more widespread, thus affecting a larger area [23]. In addition we could show that the density of black grouse cocks displaying in spring was much lower within and close to ski resorts and peaked in natural, less disturbed habitats (Fig. (**3**), [24]). Currently, we are analysing our radiotracking data to estimate survival rates of birds within and outside ski resorts; this long term individual-based approach will be complementary to the comparative assessments of bird abundance described above and possibly provide more hints about the mechanisms at play in the

observed demographic response of black grouse to the encroachment of human recreational activities.

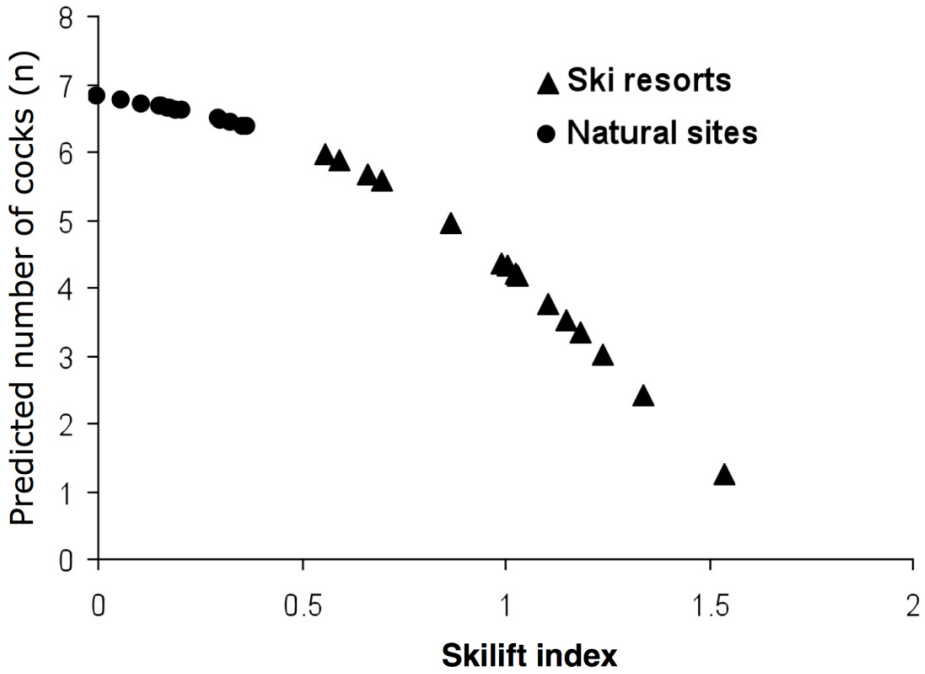

Figure 3: Predicted number of cocks displaying along 1.5 km treeline transects in relation to skilifts occurrence (the compound «skilift index» considers density of skilifts and distance to them). Covariates such as habitat type as well as hunting pressure have been accounted for in the modeling, with the figure representing a projection of the sole effect of skilifts on cocks abundance. In the study area, 44% of black grouse potential wintering area is affected by ski infrastructure and associated recreational activities (Adapted from [24]).

3. Inferring Underlying Mechanisms

Our current results indicate lower population densities within and near ski resorts, compared to areas with intermediate disturbance caused by free-ride activities and more natural areas with no or very little anthropogenic disturbance [23, 24]. The precise mechanism leading to this spatial pattern still remains to be unraveled. There are indeed two possible pathways. First, recreation may weaken birds directly due to frequent disturbance: for instance the costs entailed in chronic or acute stress, or the energetically costly behavioral changes like repeated flushing may translate into increased mortality or breeding failure. Second, the effects could be indirect, for instance mediated through an increased predation rate on

nests, young or adults in ski resorts compared to areas less frequented by humans, as observed in the ptarmigan [25]. It has been demonstrated, for instance, that red fox densities tend to be higher close to ski resorts [26], which may thus increase the predation pressure on the birds. We are presently investigating this aspect in the Swiss Alps (G. Wittwer, P. Patthey & R. Arlettaz, unpublished). Both factors are of course not mutually exclusive and effects may even be additive. To get further insight, we are currently analysing the information collected from all black grouse captured so far to see whether individual's condition varies between habitats with different intensities of anthropogenic disturbance. To that endeavour we shall use both information about body condition as well as data on prevalence and intensity of parasites in faeces (M. Lingg, P. Patthey & R. Arlettaz, unpublished data). Combined with data on individuals' survival (estimated with a capture-mark-recapture framework based on radiotracking surveys), this information may enable us to better appraise the mechanism leading to reduced black grouse population densities in highly disturbed areas.

II. Drawing on Solutions for Human-Wildlife Cohabitation

1. Localizing Conflict Zones

Once the negative effects of disturbance of wildlife by outdoor winter sports were assessed, the task remained to find ways to mitigate these effects. The first decisive step for an effective implementation of such measures was the spatially explicit identification and quantification of human-wildlife interference. To that aim, we built a spatially-explicit habitat suitability model predicting areas of human-wildlife conflict in the western Swiss Alps, with the idea to recommend the creation of winter refuges in the areas with major actual and potential conflicts [23]. Our approach considered three «actors», modelled independently: black grouse, skiers (both on-piste skiing and off-piste backcountry skiing, including snowboarding), and snowshoers.

Based on photographs taken from a plane some days after a heavy snowfall and an intense snow-sports activity, the tracks of our three «actors» (footsteps and snow burrows of black grouse, tracks of skiers and snowshoers) were mapped along an extensive, several hundred km long treeline transect (Fig. (**4**)), (the

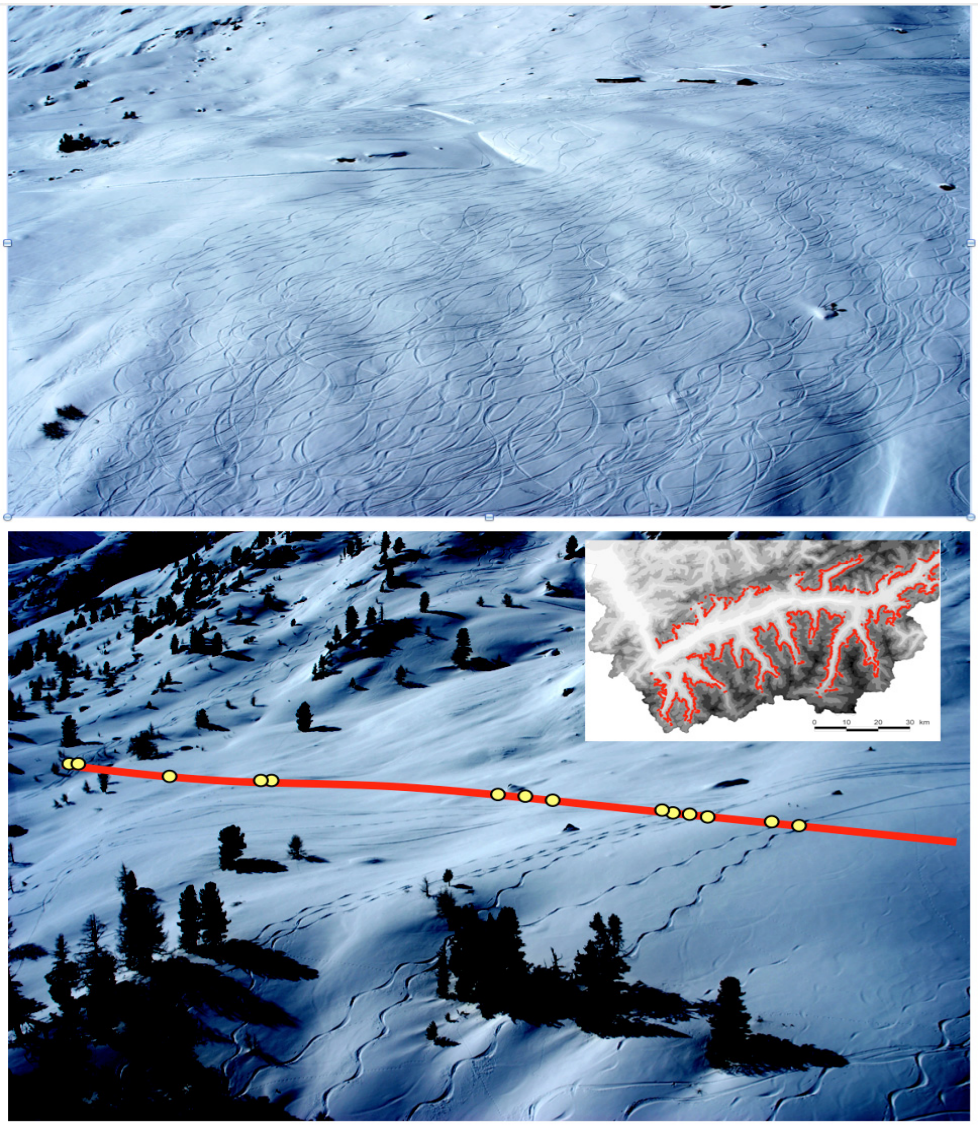

Figure 4: Upper panel: illustration of the magnitude of the disturbance elicited by skiers and snowboarders a few days after a snow fall; one major problem is that every skier wants to make their own track in powder snow, thus rapidly covering huge areas with ski tracks. Lower panel: aerial photograph of the treeline used to map the winter occurrence of black grouse (tracks in snow and igloos, the latter not visible on this picture), skiers (including snowboarders) and snowshoers (yellow dots). Spatially-explicit habitat suitability models have been built for these three «actors» to delineate major areas of conflict between black grouse and outdoor winter recreation, the conflict being defined as the probability of co-occurrence of these «actors» in the wide landscape (photography by S. Mettaz). The insert shows the 585 km long treeline photographic (plane) transect line across the area (adapted from [23]).

method is described in detail in [23]). For each «actor» we constructed a model predicting the probability of presence in dependence on the prevailing landscape conditions, which was then extrapolated to the whole altitudinal belt of potential black grouse occurrence in winter. By crossing the three «actors» layers we could finally quantify the probability of human-wildlife co-occurrence, thereby not only localizing regions with current conflicts but also predicting where conflicts could be expected in the near future given the ongoing and projected spreading free-ride activities (Fig. (**5**), [23]). Based on that analysis, we identified 31 critical conflict zones across the Canton of Valais, our main study area, where winter refuges shall be created in priority (Fig. (**6**)).

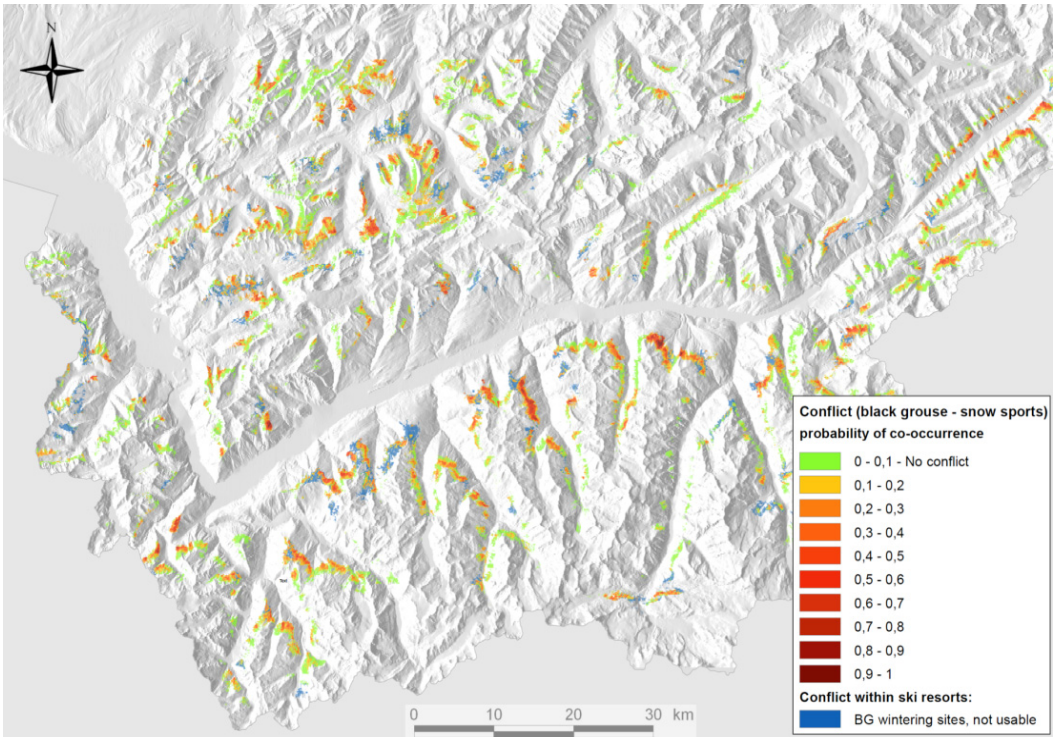

Figure 5: Map of Valais (SW Switzerland) showing the predicted intensity of conflicts between black grouse and outdoor winter recreation. Green: area with no or limited conflict, yellow: low conflict; red: intense conflict; purple: too heavy conflict, *i.e.* skilift area (Adapted from [23]).

2. Planning and Designation of Wildlife Refuges

The creation of wildlife refuges, which aim at limiting human access to key habitats of vulnerable species, has proven to be an effective tool to mitigate

effects of human disturbance [27, 28]. In black grouse, experiments with winter preserves have been successfully attempted by Albin Zeitler [7, 8, 29] in the Bavarian Alps, Germany, based on long-term behavioural observations indicating that black grouse can learn to use the quiet winter refuges if their boundaries are not too often trespassed by snowsports people, providing in addition that hunting is banned in the surroundings [29]. Such apparent peaceful coexistence might further be enhanced when temporal segregation of human and wildlife activities naturally takes place, *i.e.* when the time windows of sportspeople and foraging wildlife overlap very little, which is the case within ski resorts because sportspeople become active rather late in the morning and leave pistes in the late afternoon [29]. Things are a bit different in backcountry skiing areas because alpinists set off to excursions very early in the morning (A. Zeitler, pers. comm.).

An illustration of a beneficial interaction of both spatial and temporal separation of activities is given by the ski resort Fellhorn in the Allgäu, Bavaria, Germany, where Albin Zeitler conducted his experiments. Here, black grouse males sometimes even use the restaurant terrace in spring as a lekking arena, where they have enough time to display at dawn for a couple of hours, just before the first skiers arrive (Fig. (**7a, b**)). During the day, as long as the ski-lifts operate, the birds retreat to a ca 60 ha large winter refuge which is located next to the ski pistes. They eventually return to the skiing area for feeding after the lifts close in the late afternoon. This example suggests a great potential for habituation, if not adaptation of black grouse to human presence, as long as spatial and temporal patterns of human land use are constant and predictable ([29], A. Zeitler, pers. comm.). In this context it seems to be important, in addition, that winter refuges are combined with game reserves (hunting totally banned) so that the birds do not associate humans with predators (hunters) anymore [29]; see also [30, 31] as regards capercaillie.

According to our knowledge, gathered from radiotracking data about individuals home ranges in winter and the distance up to which human presence is tolerated (flushing distance), the size of a winter refuge for black grouse should be ca 40 ha, an area which includes a 120 m broad buffer zone corresponding to the 95% upper confidence interval of the mean observed flushing distance in females, the sex most sensitive to human disturbance (Schranz, P. Patthey & R. Arlettaz, unpublished data).

Our recommendations regarding location, size and management of winter refuges have been addressed to the cantonal administration (Valais services for Hunting, Fisheries & Widlife, and Forestry & Landscape) in 2010, in order to launch a top-down implementation procedure. In close collaboration with the cantonal game-keepers of Valais, we are currently cross-evaluating our predictions based on local observations of black grouse occurrence in order to place the refuges in the most suitable locations within the conflict zones obtained from the model, some of them being huge (Fig. (**6**)). In parallel, the Valais Field Station of the Swiss Ornithological Institute is going to approach the local stakeholders (skilift companies, local communities, *etc.*) to develop a complementary bottom-up approach and make sure our recommendations will be implemented.

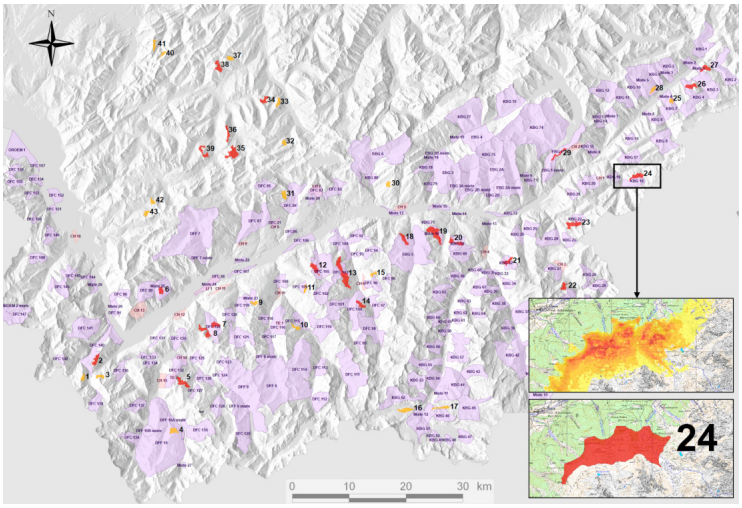

Figure 6: Map of Valais (SW Switzerland) showing a delineation of 31 principal areas with very intense conflict (red, fist priority winter refuge) and less intense conflict (orange, second priority refuge). Delineated zones correspond to homogeneous areas larger than 40 ha of uninterrupted habitat where the probability of co-occurrence of black grouse and outdoor winter recreation was greater than 40%. On the right, example of delineation of the winter refuge number 24, showing how the conflict intensity map was converted into a refuge patch. Purple patches depict game reserves: about half of our refuges are already included within such hunting reserves.

3. Concrete in Situ Mitigation Measures

Once the designation process is completed, the task is to advertise and indicate the refuges to the public. Again, the experience gathered, among others, by Albin Zeitler in the Bavarian Alps shows that appropriate marking of the designated

sites is the first important issue, which requests a local appraisal of the conditions and of course good connections with the people that will be in charge of the marking in the long run. The presence of a winter refuge should be advertised much ahead of its boundaries, for instance in hiking and backcountry skiing maps, at the main parkings and at the skilift stations (A. Zeitler, pers. comm.). In complicated topographic situations, signs must even be posted along main mountain ridges situated above the refuge in order to avoid downhill skiers to engage on a slope which will automatically lead them to the protected area, with no way to avoid its perimeter (A. Zeitler, pers. comm.).

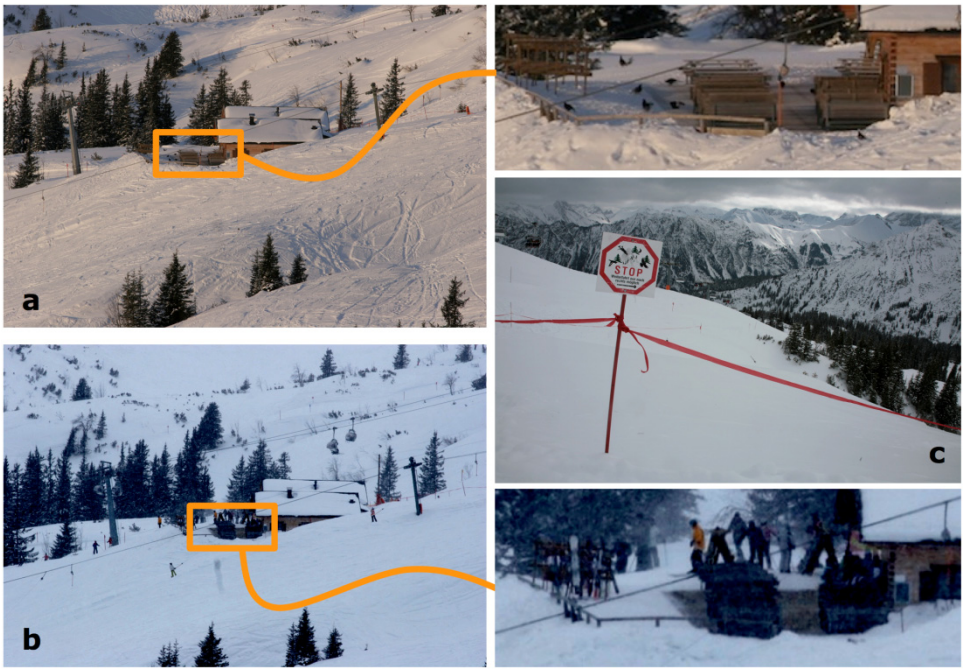

Figure 7: Black grouse can habituate to human presence even within intensively used ski resorts as illustrated here for Fellhorn, Southern Bavaria, Germany; a) 12 cocks display on the terrace of a restaurant, which is used as a lekking ground, at 6h30 am; b) 9h am: dozens of skiers use the terrace, while the black grouse have retreated into a nearby winter refuge which is well signed; c) signing the winter refuge is essential for having the skiers not trespassing its boundaries, but is still not sufficient to guarantee that the perimeter is respected.

The very perimeter of the refuge should also be indicated clearly to all users (Fig. (**7c**)). In Central Europe, the initiative «RespekTiere deine Grenzen» («Respecter c'est protéger»), launched in Austria and Switzerland, is developing transnational

concepts for marking and advertising wildlife refuges in a consistent way in order to ease the identification of these areas by tourists (http://www.respektiere-deine-grenzen.ch).

The final decisive question, however, is how to make sure that these winter refuges are truly respected by people practicing winter sports. Information and education is of course the first prerequisite. We imagine both traditional information media (signs, leaflets, brochures) but also target-group specific education in collaboration with schools, sport organizations, tour or nature guides. Yet, given that information will never reach and/or convince the minor, but crucial proportion of ignorant persons, a policy including controls and fines may be necessary. Within and near ski resorts, this requests regular checks by the people in charge of managing the pistes. Outside ski resorts, the job could be done by game keepers employed by the regional administration. Generally, however, one should avoid resorting too often to a policy of sanctions that may erode public acceptance in the long run. Assessments of visitor behaviour [32] and inquiries inquiries of sportspeople and stake-holders, recognizing their preferences and needs, may assist in implementing the best strategies for rendering the visitor management concepts attractive, and encouraging the public to respect the refuges. Optimally, this aspect should be an integrative part of any planning programme.

CONCLUSIONS AND OUTLOOK

As illustrated here by the situation of the black grouse in the European Alps, outdoor winter recreation can significantly impact the physiology, behaviour and demography of wildlife. Conservation biologists thus need to provide targeted, evidence-based solutions to mitigate these effects through the designation of spatially and temporally optimised wildlife refuges, as successfully attempted in some areas of the Alps, at the example of the Bavarian Alps ([29], A. Zeitler, pers. comm.). Yet, to even better anticipate the effects of future tourism developments and to further refine conservation strategies, it will now be crucial to link the observed disturbance effects (stress and behavioural responses, population decline) to measurements of quantitative fitness costs. This would enable the identification of the demographic mechanisms at play. The example

given above for Bavaria suggests that wildlife can habituate if not adapt to human presence once direct confrontation to sportspeople is avoidable [29]. The recognition of the specific environmental and species-specific preconditions for habituation and adaptation will be a further essential element to increase – *e.g.,* by a set of finely adjusted measures - the tolerance of wildlife towards human presence. If such measures could be adopted all over the Alps, the future of black grouse in winter recreation areas could be brighter than currently believed: to some extent, successful human wildlife coexistence may be mostly a question of fine tuning of spatio-temporal land use by humans and wildlife as demonstrated for the Bavarian black grouse [29]. Finally, we are confident that the creation of winter refuges, once enforced on wide areas, would deliver beneficial outcomes for the preservation not only of black grouse but also of other related Alpine wildlife threatened by the rapid expansion of outdoor snow sports.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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