# The Impact of Ski Resort Disturbance on Bird Species Distribution in Kosciuszko National Park

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## Abstract

As alpine tourism expands, the disturbance of natural habitat creates substantial changes in the composition of vegetation communities and their dependent bird populations. This investigation was conducted to determine if ski resorts are negatively impacting bird species abundance and distribution within Kosciuszko National Park. Species presence was measured along six 2km transects from highly disturbed ski resorts out to less disturbed habitat. Birds were categorized by known species weight, feeding preferences and habitat choice simplified to Boolean classes (large > 100g < small) and generalist category; combined sum of suitable food and habitat types (generalist > 4 < specialist). The conclusions of the study found that total bird abundance and species richness was higher in close proximity to ski resorts and that both generalist and larger bird species were favoured in high disturbance locations. This could imply that small specialist species are the most susceptible to the effects of environmental disturbance caused by ski resorts. Future studies may consider the negative impact that ski resort disturbance has on small specialist bird species and may include the impacts of indirect disturbances such as dieback events and global warming induced habitat fragmentation.

## Introduction

Alpine-subalpine environments comprise sensitive ecological niches that nurture large numbers of endemic fauna and flora (Sato et al. 2013b). One of two alpine environments within Australia, Kosciuszko National Park (KNP) is a critical biological hotspot. Species within KNP are affected by the extreme conditions that are characteristic of alpine environments; high elevation, snowfall, strong winds, cold temperatures, minimal shelter and poor soils (Rolando et al. 2007). Due to these adverse conditions, only flora and fauna resilient enough to survive in the harsh environment are found within the Alps, leading to unique and minimised species diversity and delicate community structures, easily impinged by human disturbance (Ohler et al. 2020).

Increased seasonal recreation in Australia's subalpine areas are creating intensely disturbed locations. The expansion of ski resorts has caused habitat modification and fragmentation, disrupting the connectivity between habitats, and impacting species populations (Laurance et al. 2011). Human disturbances alter the natural balance of ecosystems, and the distribution of niches animals seek within them. These points of disturbance alter when and where species can survive in the area, increase introduced species' abundance, as well as reducing and altering available natural habitats. All of which alters the distribution of available niches for native bird species (Laiolo and Rolando 2005). The deforestation needed to expand ski resorts has a significant impact on biodiversity and ecological processes (Haddad et al. 2015). Furthermore, the expansion of resorts exacerbates light, noise, and chemical pollution and creates urban heat islands from carparks and roofing, disturbing biotic communities in these remote regions (Pickering et al. 2003). This disturbance can cause lasting damage to native plants and jeopardising long-term survival of wildlife. Despite these risks, ski tourism plays a significant role in the economies of many countries (Sato et al. 2013a). As a result, there is a global inclination to expand development in alpine-subalpine areas to meet the demands of visitors. However, this expansion could lead to the disappearance of species, especially those already in danger and unique to these environments. To prevent such losses, it is vital to establish ecological management plans grounded in solid empirical research.

The impact of ski resorts on bird abundance and richness in alpine and subalpine fauna is well documented within Europe and America but is notably lacking in Australian alpine research, exposing a major knowledge gap. The inspiration for this study was taken from Sato et al.'s (2013b) research on the impact of disturbance on reptiles in KNP. This demonstrated reduced abundance and habitability in disturbed spaces with diminished habitat complexity (ski runs). Sato's meta-analysis reported both negative and positive effects of human-generated disturbance on fauna diversity in alpine and subalpine areas (Sato et al. 2013a). The impact of anthropogenic changes on bird populations are dependent on bird species life history traits including size, habitats, feeding habits, and opportunism. Larger birds with generalist habits tended to benefit from the established fringe habitats, open spaces, and regular edible human waste, with larger species (with fewer predators) being more abundant than smaller generalists in these spaces (Samia et al. 2015; Nordberg and Schwarzkopf 2019). Specialist feeders and smaller birds tend to retreat into regions with denser habitat, optimal for predator evasion and with less disturbed food sources (Morelli et al. 2019; Noe et al. 2022), leading to anthropogenic distribution selection pressures. Generalist species are often opportunistic, and able to make use of an array of habitat and food resources, while specialists tend to have closer mutualistic relationships and be more dependent on specific resources for their needs (Morelli et al. 2019). Both groups, however, have important functional roles within alpine ecosystems within pollination, seed dispersal, and trophic systems (Dehling et al. 2021).

Further research would enable a deeper understanding of how Australian subalpine bird abundance and species richness is impacted by hotspots of human activity and would help to articulate the extent of human impacts on bird distribution. This could be used as a proxy for how other endotherms in the park may be impacted by the expansion of resorts and the implications of climate change and the linked *Eucalyptus pauciflora* dieback, altering ecological niches, habitat types, and distribution of flora communities (Zhu et al. 2020; Byrant et al. 2023).

Due to the lack of bird specific research into disturbance implications in subalpine Australia, this study aimed to monitor bird abundance and richness in and around ski resorts in KNP. We aimed to determine whether the distribution of bird species changes across disturbed and non-disturbed sites in Australia's subalpine region, and if specific bird life history traits are disadvantaged by human activity in Australia. In areas with development and land cleared for seasonal tourism such as ski runs and resorts, bird abundance and species richness are hypothesised to be lower than in the surrounding minimally disturbed areas. Consistent with observations made in other systems (Nordberg and Schwarzkopf 2019), we predicted that bird species richness within KNP would increase with distance away from directly disturbed spaces. Further, we hypothesised that generalist and larger species would be more abundant closer to ski resorts and specialist and smaller species would be more abundant further away from disturbed sites.

# Methods

*Study Site*

Alongside its ecological importance, KNP has cultural, economic, and recreational significance within Australia. Humans have had an impact on the Snowy Mountains area since First Nations People first inhabited the region tens of thousands of years ago (Slattery 2015). However, no permanent anthropogenic disturbance was made until European Settlers exploited the landscape to farm cattle in the 1800s. Although the area is now a protected national park, human impact on the environment has continued to grow as KNP is now the largest ski tourism destination in Australia, attracting over 2.1 million visitors each year (Office of Environment and Heritage 2023).

This study investigates the effect of human disturbed regions (fragmented or non-natural habitats such as ski fields) on bird species abundance, richness, and distribution in Kosciuszko National Park, New South Wales, Australia. Habitat alteration and fragmentation caused by ski resorts provides both opportunities and challenges for varying bird functional traits, potentially changing the distribution of species on a gradient of disturbance (meters from disturbed areas). Accordingly, transects were selected, starting at a centre of disturbance (e.g. resort car park) and ending in relatively undisturbed ecosystems.

The three resort sites were selected based on their high levels of disturbance, their adjacency to the National Park and their comparable levels of altitude (1680m ±50m). Sites were also selected based on their proximity to each other, which reduced commute times between sites and minimized differences in the time-of-day actively spent monitoring and the effect this has on bird abundance (Robbins 1981). Surveying was conducted during spring in November 2023.

*Data Collection*

Field surveys were conducted from three resort sites; Perisher Valley (-36.40575, 148.41201), Smiggins Hole (-36.39166, 148.42695), and Guthega Village (-36.38012, 148.37367). Transects were selected using the application Gaia GPS (Johnson 2009), which allowed transect paths to be found from the resorts out to non-disturbed regions

(in any direction or elevation gradient). The app found walking paths, 4WD trails, and cross-country ski tracks which have been considered relatively low disturbance for this study. Two replicate continuous transects two kilometres in length were walked at each site in only one direction (due to the disturbance caused by walking), counts of bird abundance and species richness (within 15m of the path) were documented by sight without visual aids and their location recorded using Gaia GPS (Johnson 2009). Every 200m along the transect a separate point measurement was documented with the addition of temperature and time. This allowed bird abundance and richness to be blocked into increasing sets of 200-meter distances from the point of disturbance. Additional data such as weather, presence of bird calls, bird activity, landcover changes, and increasing elevation were also noted. To increase sample size observations from the three resort sites were pooled together for analysis. The equipment used for data collection was kept consistent across transects, elevation (m) and time (AEST) were recorded using the Gaia app (Johnson 2009), and temperature (˚C) was measured with a kestrel or an inferred surface thermometer (aimed at organic objects).

Bird abundance changes with temperature and time of day, with birds most abundant in the morning and late afternoon (Robbins 1981). Due to this factor the Perisher and Guthega transects were both walked between 08:30am and 10:30am (on separate days), however the Smiggins Hole transects were walked at a later time (12:30- 14:00). As a metric for disturbance, meters from the starting ski resort (disturbed location) were used, this avoids complications within categorising levels of habitat change and fragmentation.

*Statistical Analysis*

Data was recorded by hand while walking transects and later transcribed into Excel (Microsoft 2023). Bird species were separated into body mass categories, large (>100g) and small (<100g) (IUCN 2023), and a generalism score was created for each bird species by calculating the number of habitat types each species inhabit, and the number of food types they consume, from IUCN red list data (IUCN 2023). A sum of these values created a generalism score for each species of bird observed. In our statistical analysis, birds with a generalist score of five or above were considered generalists and below five were considered specialist species.

RStudio (RStudio Team 2023) was used for statistical analysis. To explore the relationship between abundance (number of individuals) and disturbance (meters from ski resort), as well as species richness (number of species) and disturbance, a linear mixed effects model was used. This model was selected to control for differences in relative bird abundance between transects and this data was normalised using a square root function. The distribution trends observed within each transect were similar, and random variation between individual site abundances were accounted for through the independent analysis of this model, with a fixed variable of distance from disturbance. A linear model analysis was used for determining the significance of the relationship between generalism category and species mass relative to distance from disturbance and this data was log transformed.

# Results

In total our field surveys recorded 19 bird species across our transects. These species ranged in abundance from 1 to 55, in average mass from 7.0g to 822.5g, and in generalist score from 3.5 to 9.5 (Table 1). Bird abundance declined with distance from resorts ($P < 0.001$; $t = 4.932$; Figure 1). Similarly, species richness decreased with increasing distance from resorts ($P<0.001$; $t = -3.487$). No significant relationship was found between size and the distance from the resorts. Finally, we observed an interaction between distance from resorts, generalism and bird size ($P<0.001$; $Z = -3.859$) (Figure 2). Generalism negatively correlated with distance from the resorts in small birds, however this did not apply to large species.

Table 1: 233 birds from 19 species observed across three sites within Kosciuszko National Park, NSW, Australia and their corresponding bird mass, relative abundance, and specialisation ratings.

| **Scientific name** | **Species name** | **Abundance** | **Average Bird Mass (g)** | **Generalism Score** | **Generalism Rating** |
|---|---|---|---|---|---|
| *Petroica phoenicea & P. boodang* | Flame Robin & Scarlett Robin | 26 | 12.25 | 3.5 | Sm-Spec |
| *Rhipidura albiscapa* | Grey Fantail | 11 | 8.5 | 4 | Sm-Spec |
| *Anthus novaeseelandiae* | Australasian Pipit | 20 | 25 | 4 | Sm-Spec |
| *Acanthiza lineata & A. reguloides* | Striated Thornbill & Buff-rumped Thornbill | 61 | 7 | 4 | Sm-Spec |
| *Caligavis chrysops* | Yellow-faced Honeyeater | 8 | 17.5 | 4 | Sm-Spec |
| *Phalacrocorax sulcirostris* | Little Black Cormorant | 2 | 787.5 | 4 | Lg-Spec |
| *Vanellus miles* | Masked Lapwing | 1 | 33 | 4 | Sm-Spec |
| *Sericornis frontalis* | White-browed Scrubwren | 4 | 14.5 | 4 | Sm-Spec |
| *Chenonetta jubata* | Wood Duck/Maned Duck | 8 | 822.5 | 5 | Lg-Gen |
| *Elanus axillaris* | Black-shouldered Kite | 2 | 275 | 5 | Lg-Gen |

| | | | | | |
|---|---|---|---|---|---|
| *Anthochaera carunculata* | Red Wattlebird | 1 | 107 | 5 | Lg-Gen |
| *Platycercus elegans* | Crimson Rosella | 5 | 135 | 6 | Lg-Gen |
| *Strepera graculina* | Pied Currawong | 1 | 410 | 6 | Lg-Gen |
| *Gymnorhina tibicen* | Australian Magpie | 5 | 290 | 8 | Lg-Gen |
| *Hirundo neoxena* | Welcome Swallow | 23 | 77.5 | 8 | Sm-Gen |
| *Corvus mellori & C. corronoides* | Little Raven & Australian Raven | 55 | 539 | 9.5 | Lg-Gen |
| Total | | 233 | μ =222.57 | Spec-Gen ratio (16 > 4 < 16) | |

*Note.* Lg-Gen = Large Generalist; Lg-Spec = Large Specialist; Sm-Gen = Small Generalist; Sm-Spec = Small Specialist. Categorisation of bird size split into small or large (small < 100g > large). Generalist ratings were formed from the sum of suitable diet and habitat types a bird ate/habituated (generalist > 4 < specialist). Average mass, diet, and habitat preference from IUCN (2023). *Petroica, Corvus* and *Acanthiza* genera are grouped together for simplicity and to reduce misidentification between similar species.

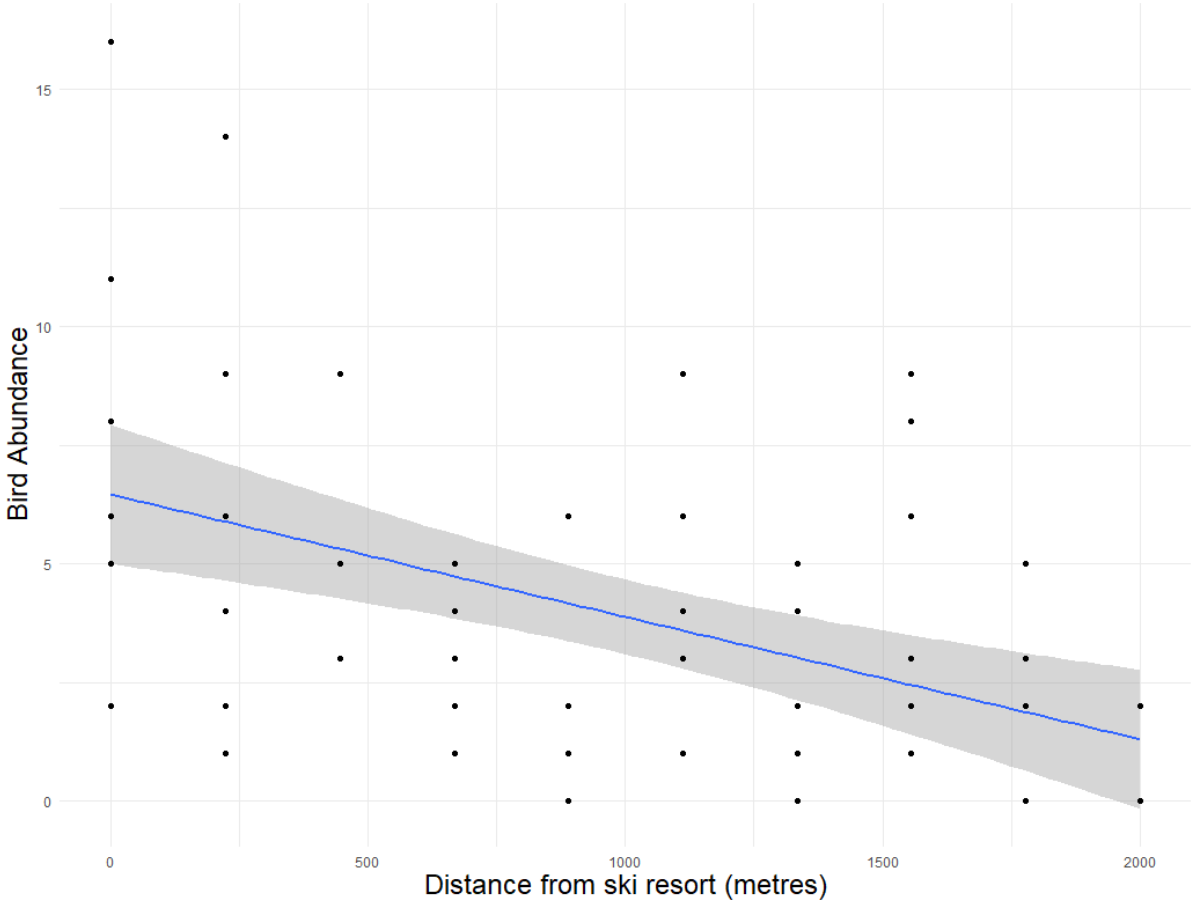


Figure 1: Bird abundance (total counts of individuals) observed by distance from disturbed sites (m) pooled from six transects within Kosciuszko National Park, NSW, Australia.

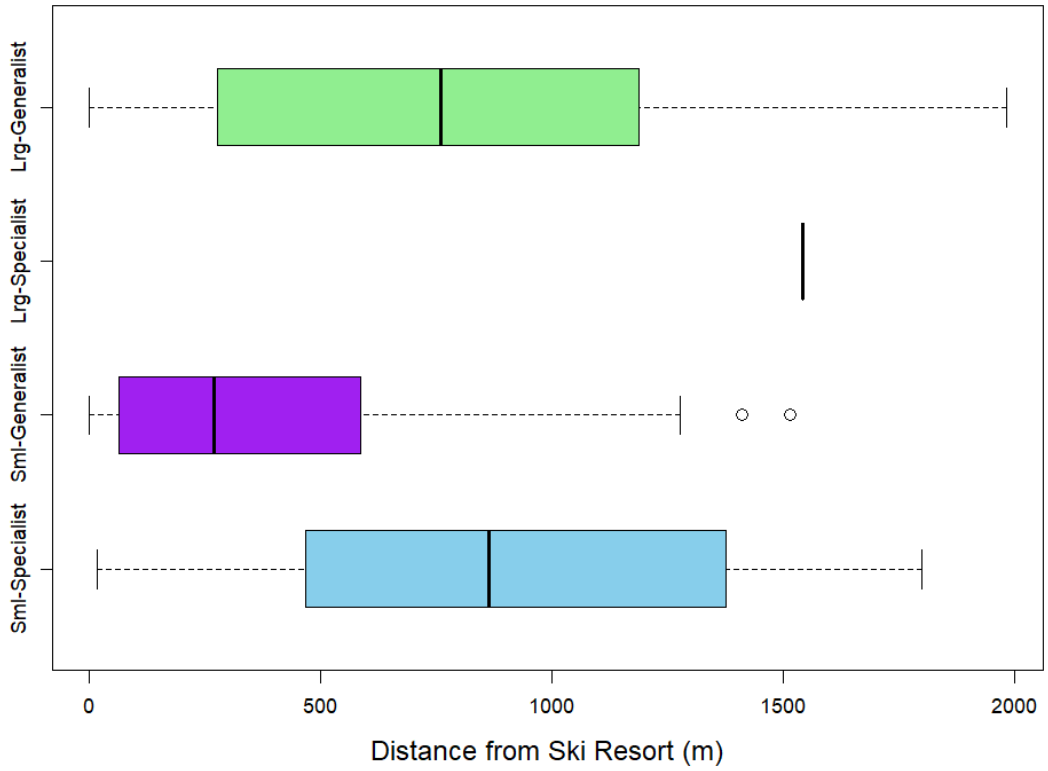


Figure 2: Bird abundance (total counts of individuals) by distance (m) from disturbed sites for large generalist, large specialist, small specialist, and small generalist species pooled from six transects across three sites within Kosciuszko National Park, NSW, Australia. Note. Lrg = Large; Sml = Small

# Discussion

In this study, we sought to determine whether the impacts of human activities in subalpine Australia alter the distribution of bird life on a gradient of disturbance and whether specific traits in birds such as size, feeding habits, and plasticity of habitat preference cause them to be disproportionately affected by disturbance. We found that birds were more abundant closer to resorts than in less disturbed habitats, bird diversity was greater around disturbed sites, and generalist species (particularly small species) were most abundant around resorts.

The elevated bird abundance we observed closer to disturbed sites opposed our hypothesised outcome. Bird abundance was initially assumed to be greater in non-disturbed habitats due to higher concentrations of natural food resources, greater habitat complexity, niche abundance, protection from exposure and predator evasion, increasing population carrying capacity and species abundance (Smith et al. 2014). However, the observed higher abundance in disturbed sites could be due to a range of opportunities presented by altered habitats, such as edge habitats, open foraging areas, anthropogenic food resources, introduced or synthetic habitats, or reduced competition for resources available to opportunistic and resilient species such as generalists (Nordberg and Schwarzkopf 2019; Banks-Leite et al. 2010).

The high total diversity (specialist and generalist) found around disturbed sites was also unexpected as generalist diversity was predicted to be relatively greater in these locations due to a lack of specialist species competition (Morelli et al. 2019). Generalist diversity was expected to be evenly distributed across the gradient of disturbance and similar to specialists in less disturbed environments (1:1 ratio of generalist and specialist species were observed). Due to a particularly small sample size of large specialist species (only one species (P. sulcirostris) present in our survey) the comparison between specialisation, distance from disturbance, and size requires further observations to enable an informed outcome on the role of size, however, small generalist species tended to be more concentrated in disturbed sites relative to larger generalists and small specialist species (Figure 2). The uneven distribution of generalist and specialist species across gradients of disturbance suggests that disturbance may favour generalist traits, and therefore increases competition from these species as well as reduces suitable habitat for specialists, impacting specialist abundance greatly (Morelli et al. 2019; Nordberg and Schwarzkopf 2019)

Larger and omnivorous bird species were expected to be the most advantaged of generalist species in disturbed habitats, due to their size and hunting advantage (Morelli et al. 2019) however, anthropogenic clearing (ski fields) reduces habitat complexity and reduces small prey abundance (Rolando et al. 2007). This is intriguing considering that small generalist where the most abundant category close to resorts. This could be attributed to reduced specialist predator abundance, potential increased insect abundance, urban heat, or increased shrub density around fragmented habitat and regrowth areas bordering ski fields and lodges (Sato 2013b). This result provides a path for further research in determining the influence of bird size on distribution relative to disturbance and how this relates to species specialisation and their interactive and functional role within the ecosystem.

Generalist species are often more successful within changing environments due to redundance and diversity in their diet and habitat preferences, creating resilience. While specialist species can be just as successful in favourable conditions tend to suffer with habitat disturbance (Figure 2.) (Morelli et al. 2019; dos Anjos et al. 2019; Newbold et al. 2015). This study drew inspiration from reptile research on ski field disturbance in Kosciuszko by Sato et al. (2013b) which found reduced habitat complexity (cleared ski fields) led to lower abundance and increased predation for alpine reptiles. Similarly, a study by Laiolo and Rolando (2005) in Italy found bird abundance along anthropogenic edge habitats (edge of ski runs) where reduced compared to forested environments. These studies provided an opening and knowledge gap for similar research in the Australian subalpine region. The contrasting results found in this study (greater abundance close to resorts) demonstrate the novel interactive disturbance ecology of Australia's alpine bird communities and the need for further research into the intricacies of Australian alpine bird species, their functional needs, and their interactions with the environment.

Variation across transects has high potential for unaccounted variables within this research. The transects began in highly disturbed areas and ended in relatively undisturbed habitats, resulting in difficulty staying on route as the path became more vegetated and difficult to navigate. Avoiding the abundance of disturbed locations surrounding ski fields meant elevation and habitat type traversed became unaccounted

for and not kept constant across each transect. This likely effected observed bird abundance, as would the direction of travel (disturbed to non-disturbed) as later hours are known to reduce bird foraging abundance (Robbins 1981). While bird surveys were supervised by a bird expert, they were predominantly conducted by amateur bird watchers, which may have contributed to error in bird sightings. For this reason, we grouped the *Petroica*, *Corvus* and *Acanthiza* species because students were unable to reliably differentiate between the species. Furthermore, time constraints on the study meant that surveys were only conducted over one day, as on the second allocated day of surveying it rained, preventing further surveys and resulting in a small sample size.

Further studies will need to consider abundance and species richness in different habitat types occurring at different elevations. This is particularly important as the alpine landscape structure (hills and valleys) meant most transects started in a valley and increased in altitude with distance to avoid further disturbances concentrated in the sheltered valleys, potentially reducing abundance due to elevation and exposure rather than disturbance. The slope, aspect, habitat type, time, and elevation changed within and between transects, also likely effecting the observed distribution of bird species. Ski resorts are situated commonly on cooler aspects in sheltered valleys providing a microclimate and economic advantage (Silberman and Rees 2010), often interfering with native species who inhabit this niche. The setting of resorts themselves as disturbance sites may potentially have impacted the abundance of bird species observed as the transects leave this niche habitat. Further studies would need additional transects along constant elevations and habitat types to control for this and to better observe the effect of disturbance on abundance. If increasing altitude and changing habitat structure (most heathlands occurred further away) has an inverse effect on abundance and species richness, more intricate surveying is encouraged to confirm the findings of this study.

Future studies could be extended to non-direct disturbances on birds. The intimate relationship between climate and the alpine environment is causing rapid changes in community composition, and therefore niche distribution as alpine climates and seasonal patterns are altered by anthropogenic climate change (Zhu et al. 2020). Several indicators would also provide a clearer insight into the relationship between alpine bird species and their environment. This data could be used as an indicator or proxy for other endotherm species to better understand ecosystem wide interactions with rapid environmental changes from both urbanisation and climate change in alpine regions.

# Conclusions

These results on the functional and behavioural interactions of birds with direct disturbance in Kosciuszko National Park have important implications for management across resorts and Australian alpine National Parks, and importantly build on the limited knowledge pool of biotic interactions with alpine disturbances. The increased abundance of species around disturbed areas (primarily small generalists) provides an opportunity for prioritization of conservation measures. Specialist species (primarily small) with less resilient habits will need to be prioritised as urban expansion continues in these areas, for both the loss of habitat and the additional competition from favoured generalist species (Morelli et al. 2019). Much like the expansion of clearing and infrastructure, observed habitat alteration and fragmentation due to anthropogenic forcings such as climate change in alpine environments will likely also favour generalist species. This

study itself importantly raises awareness of this potential pattern of disturbance selection in subalpine Australia, and the clear impact disturbance has on bird distribution, providing opportunities for further study into the intricacies of bird disturbance behaviours and the future of avian diversity in Australian alpine national parks.

## Acknowledgements

We would like to acknowledge the traditional owners and custodians of the land on which this study was conducted and pay our respects to Indigenous elders and communities past and present of the Monaro Ngarigo, Walgalu, Wiradjuri and Ngunnawal peoples and all First Nations peoples and clans who have associations with the Snowy Mountains and the surrounding region.

The authors would like to thank those involved in conducting the research for this project; Harry Whittiker, Noah Tan, Ishbel Burns, Anita Ipalawatte, Monique White, Jesse Hill and Judy Qingyang. We would like to give special thanks to Lucy Aplin who helped design and guide the project and supervised all aspects of the research.

Thank you to the conveners of BIOL2203 Field Studies in Functional Ecology (ANU), who enabled this project: Adrienne Nicotra, and Megan Head, who helped facilitate and further inform the research. And finally, thank you to Tony and Matthew from the Southern Alps Ski Club for their hospitality during our stay in the mountains.

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