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SHORT COMMUNICATION

Effect of a scrub fire on a population of Southern Alps geckos in the Mackenzie Basin

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Abstract: Little is known about the impacts of fire on New Zealand's lizard fauna. Anecdotal evidence suggests that the direct impact of fire and subsequent loss of habitat are drastically negative for arboreal and grassland species. The impact of fire on saxicolous (ground-dwelling) species is less understood and difficult to presume given we understand little about the protective nature of rocky refugia and species' reliance on fire-susceptible habitat. In September 2023 a large scrub fire burnt through Pukaki Scientific Reserve (Mackenzie Basin, South Island), which is home to a population of *Woodworthia* "Southern Alps" geckos. Having completed sampling for geckos in the reserve prior to the fire and at a similar nearby reserve that remained unburnt, we investigated the impact of the fire on the gecko population by conducting systematic searching pre- and post-event. We employed a simple Before After Control Impact study design to control for unmeasured variation. We report a decrease in the catch per unit effort of geckos at the fire-affected site and provide evidence of direct mortality from fire. More work is needed to fully quantify the lasting impacts of drastic habitat loss on the gecko population, especially considering projected increases in wildfire frequency.

Keywords: conservation, herpetofauna, Pukaki Scientific Reserve, saxicolous, Woodworthia

Introduction

Aotearoa New Zealand (NZ) is experiencing an increase in the frequency of severe wildfires, driven by a drying and warming climate (Melia et al. 2022). This trend is expected to worsen, with "very-extreme" conditions predicted to occur every 3–20 years in arid regions of the country (e.g. Mackenzie Country, Upper Otago, and Marlborough; Melia et al. 2022). In much of the world, fire contributes to ecosystem function (Pausas & Keeley 2019; McLauchlan et al. 2020); however, in systems that are already under pressure its frequency and impact on indigenous biodiversity can be accentuated (Perry et al. 2014; Perry et al. 2015; Lindenmayer & Sato 2018; Santos et al. 2022a; Santos et al. 2022b).

The impacts, both direct and indirect, of fire on NZ lizard species are poorly characterised, with only one formal study to date (Patterson 1984). Differences in the ecology of NZ species likely play a key role in determining their susceptibility to fire. Impacts may be greatest in species which rely on vegetation (e.g. arboreal species) for resources and protection. For example, jewelled geckos (*Naultinus gemmeus*) have undergone declines and potentially population extinctions in the Lammermoor Range following a large tussock fire in 2019 (C. Knox, Southern Scales, pers. comm.). Geckos were reported to survive the fire-event, but later declined, indicating a reliance on the destroyed tussock habitats (C. Knox, Southern Scales, pers. comm.). Ground-dwelling species may be less affected, either by better avoiding the direct threats of fire (e.g. burrowing species) or by being less reliant on destroyed habitat (Cano & Leynaud 2010; Costa et al. 2013). Patterson (1984) showed a 28% decline in a population of McCann's skinks (*Oligosoma maccanni*), a ground-dwelling species, following a controlled burn in tussock grass; this suggests that even low-intensity events can have significant impacts on lizard populations. Waitaha gecko (*Woodworthia* cf. *brunnea* Cope 1869) a common saxicolous (rock-dwelling) species, suffered major declines (one population to undetectable levels) in two Significant Natural Areas following a major (2075 ha) fire on the Port Hills in 2017 (M. Lettink, Fauna Finders, pers. comm.). Fire has been demonstrated to have negative impacts for some NZ lizard species, though the lack of formal studies, the variability in refuge availability and type, and lack of information on fire-avoidance behaviours makes presuming the impact on others difficult.

Woodworthia "Southern Alps" geckos (hereafter Southern Alps geckos; At Risk-Declining; Hitchmough et al. 2021) are relatively common and widespread throughout the Mackenzie Basin and are known to primarily use rockland habitats (e.g. rock outcrops and tors, scarps, scree and talus slopes, stable dry riverbeds) as refuge. Recently, the Mackenzie Basin has experienced a high incidence of fire, with three major wildfires occurring in the past five years (2020 Pukaki, 2020 Lake Ōhau, and 2023 Pukaki). It is largely unknown how these fires may have affected resident lizard fauna, due to a

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lack of species monitoring before and after the fire events. Fortuitously, we conducted surveys for Southern Alps geckos in Pukaki Scientific Reserve prior to the 2023 event, and in a nearby unburnt site, Mount Mary. Here we take advantage of these pre-fire surveys to investigate the impact of wildfire on a population of Southern Alps geckos.

Methods

We carried out a Before After Control Impact study, where Pukaki Scientific Reserve (Fig. 1; 44°7′40.93″ S, 170°7′16.42″ E) was our treatment site, and the nearby Mount Mary (c. 12 km to the east; 44°5′56.84″ S, 170°16′11.01″ E) our unburned control site. Pukaki Scientific Reserve has been affected by two different fire events. The first fire was in September 2020 when 95% of the 31 ha reserve was burnt, leaving only a central stand of mature scrub (1.4 ha; Fig. 1b). The latest fire was in September 2023, which removed the remaining scrub (Fig. 1c). Here we investigate the effect of the latter. Before-fire surveys were conducted between November 2022 and March 2023, and after-fire surveys were completed between February and March of 2024 (Table 1). Surveys in Pukaki Scientific Reserve were conducted in a boulder field which originally had mature native scrub and vine cover consisting primarily of *Coprosma propinqua* (mingimingi), *Corokia cotoneaster* (korokio), *Muehlenbeckia complexa* (wire-netting bush), *Discaria toumatou* (matagouri), and *Rubus* sp. (bush lawyer) (Fig. 2). Post-fire vegetation consisted primarily of emergent *Verbascum thapsus* (woolly mullein) and *Pteridium esculentum* (bracken fern), the former of which prefers disturbed habitat (Gross & Werner 1978) and the latter of which is a known fire adapted species (Perry et al. 2014). Surviving or newly emergent native scrub plants were rare and the majority of the formerly-vegetated boulder field was barren with only burnt scrub trunks remaining (Fig. 2e). At Mount Mary, surveys were carried out primarily in grasslands, though on the lower slopes vegetation is a combination of *D. toumatou*, *Sophora prostrata*, and *Rosa rubiginosa*. In terms of gecko habitat structure, the primary difference between Pukaki Scientific Reserve and Mount Mary is the connectivity of rocky habitat; the former has contiguous habitat while Mount Mary has tors or single boulders separated by 50–200 m.

Surveys were conducted between 9:00 a.m. and 12:00 p.m., when cryptic basking behaviour has been reported to be most frequent in *Woodworthia* "Otago/Southland large" gecko, a closely related species (Gibson 2014; Gibson et al. 2015). Ambient air temperatures during surveys were between 18–24°C, measured with a Kestrel 3000 weather meter (Kestrel Meters, U.S.A).

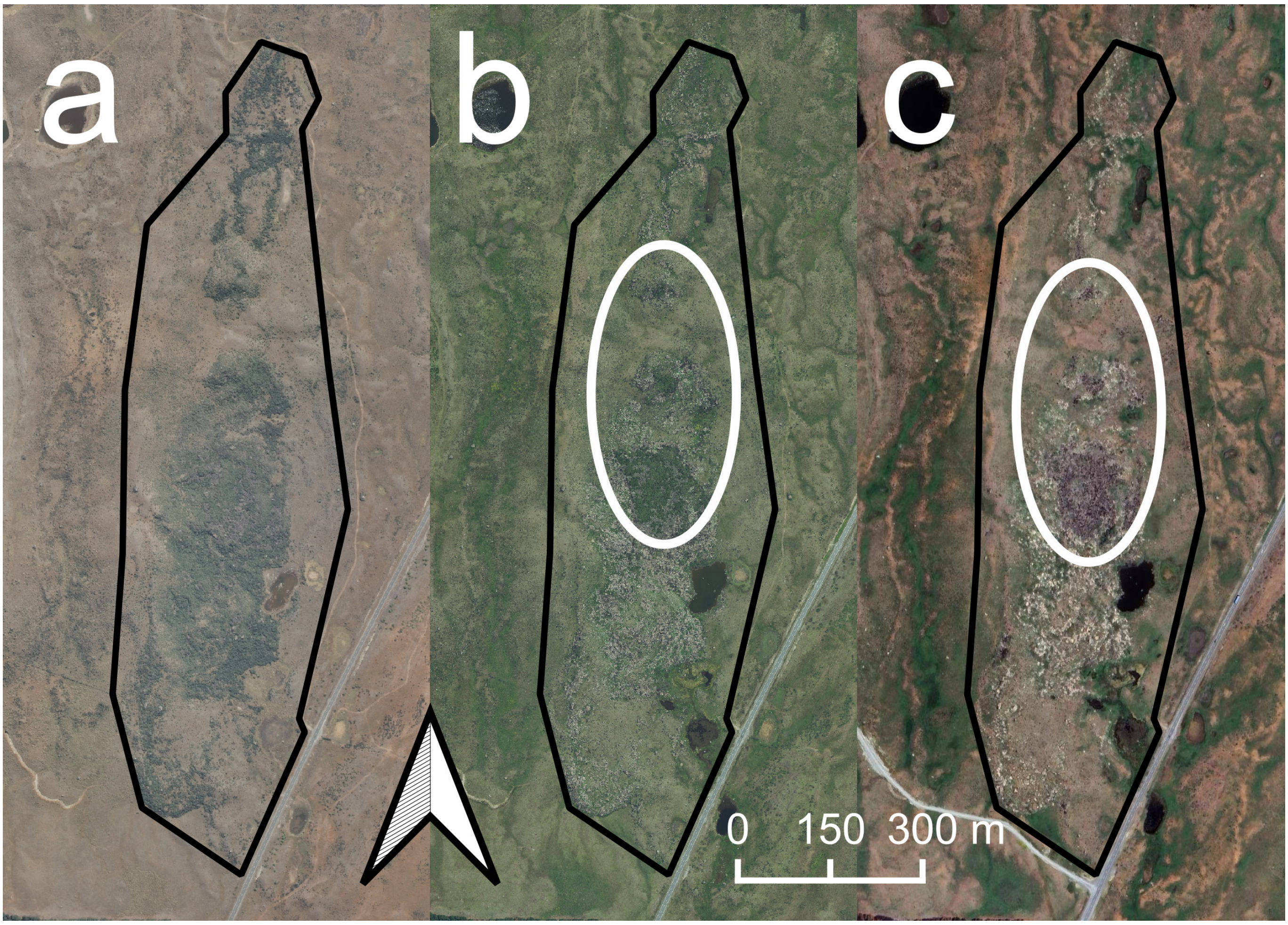

Figure 1. Pukaki Scientific Reserve (black border) prior to the 2019 fire (a; 2017/18), between fires (b; 2021) and post-fire (c; 2024). White ellipses show the area of remaining dense vegetation where survey effort was conducted in 2022/23 (c. 1.4 ha; b) that was subsequently burnt in the 2023 fire (c). Maps sourced from LINZ data service (a & b) and Google maps (c).

Table 1. Summary of search effort, *Woodworthia* "Southern Alps" gecko sightings, and sightings per unit effort in Pukaki Scientific Reserve and Mount Mary in both 2022/23 and 2023/24. The numbers in brackets are those from down-sampled and standardised data (first 3.5 hours of search effort by a single observer, SB), used in statistical analysis. The fire of interest occurred in September of 2023, affecting Pukaki Scientific Reserve but not Mount Mary.

Site	Season	Fire status	Effort (person hrs)	Geckos sighted	Geckos per hour of effort
Pukaki Scientific Reserve	2022/23 (Nov–Feb)	Before fire	3.5	37 (37)	10.57
	2024 (Feb–March)	After fire	7.5	30 (19)	4.00
Mount Mary	2022/23 (Nov–Feb)	No fire	3.5	38 (38)	10.86
	2024 (Feb–March)	No fire	4.5	43 (43)	9.56

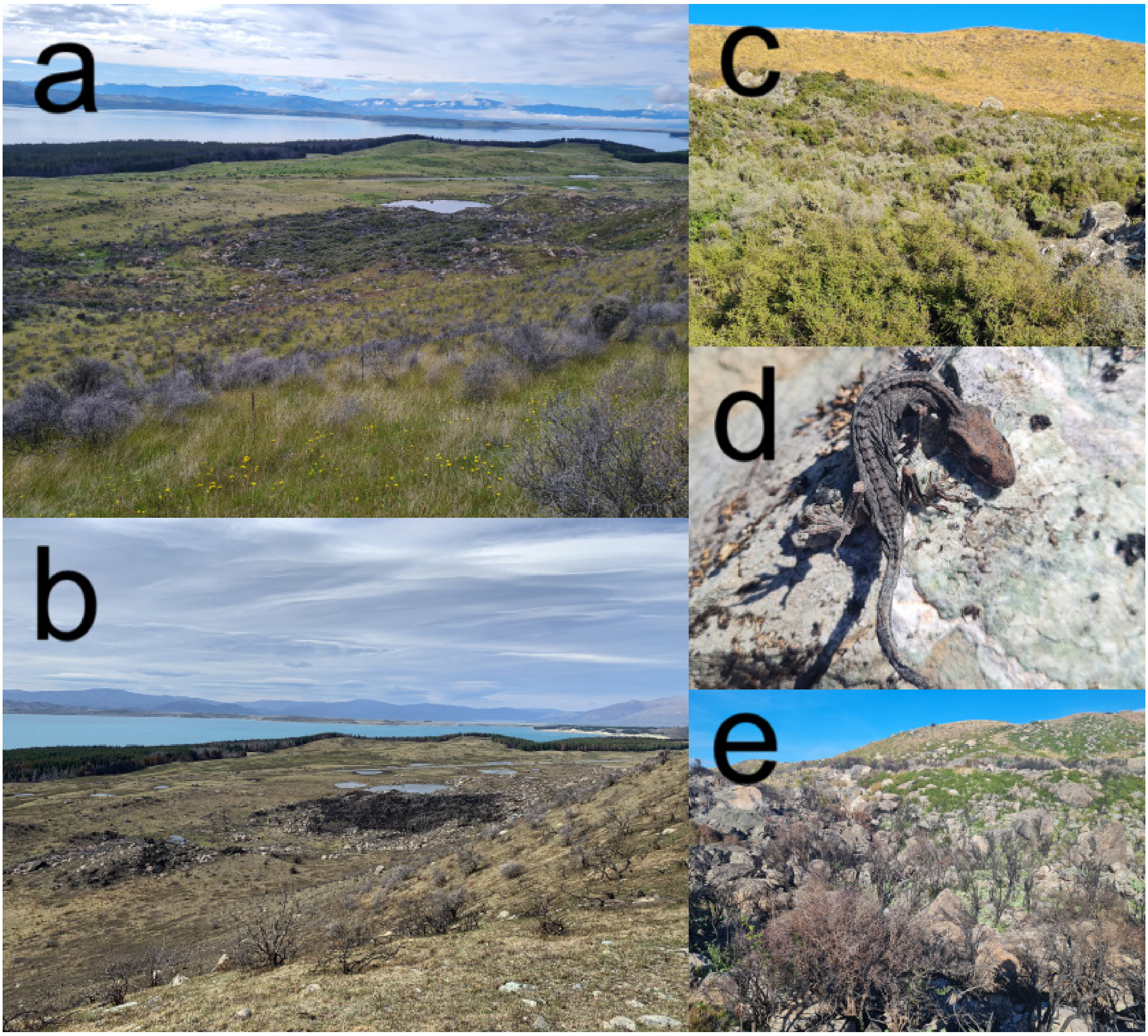

Figure 2. Images showing habitat in Pukaki Scientific Reserve before (a) and after (b; photo: Tom Goodman) the 2023 fire. Views are from approximately the same location, looking at the central boulder and mature scrub habitat. (c) Mature scrub (*Coprosma propinqua*, *Corokia cotoneaster*, *Muehlenbeckia axillaris*, *Discaria toumatou*) present in the central area; (d) shows a desiccated carcass of a *Woodworthia* "Southern Alps" gecko, found in burnt habitat; and (e) shows burnt skeletons of scrub with fire recovery species *Verbascum thapsus* and *Pteridium esculentum* visible. Photos (a) and (c) were taken in November 2022, (b) in October 2023, and (d) and (e) in February 2024.

Southern Alps geckos are usually found in or under rocks. To survey for the species we used systematic searching comprising a combination of rock lifting and visual searching (Hare 2012; Lettink & Monks 2016). The former involved lifting appropriate rocks to see if geckos were using the habitat beneath. Regardless of whether a lifted rock resulted in a gecko detection, care was taken to replace the rock in the exact position to preserve the habitat beneath. If the faithful replacement of the rock was dubious, the rock was not lifted. Visual searching involved inspecting crevices, without additional lighting, to locate geckos within. Time spent actively searching for geckos was recorded, not including time spent shifting between potential refugia. In both years crevices and rocks were selected for sampling on the basis that they looked most suitable for this species of geckos. We used Global Positioning System (GPS) tracks to avoid sampling the same refugia within season. As refugia were not physically marked in 2022/23 and GPS error was often > 5 m we were not able to replicate survey tracks between seasons. Regardless, many of the same refuges were rechecked in 2023/24, especially at Mount Mary, where rocky habitat is more limited. When geckos were uncovered or sighted during systematic searching the number of geckos seen was recorded. Gecko sightings in this study may include recaptures of individuals, as geckos were not marked for recapture.

Searching was conducted by a single observer (SB) in 2022/23 and by two observers in 2023/24 (SB and ST), and was broken into three sampling periods for Pukaki Scientific Reserve and two for Mount Mary. Total effort was roughly even between years and site, but slightly elevated for Pukaki Scientific Reserve in 2023/24 (Table 1).

Pearson's Chi-squared test with Yates' continuity correction was used to explore the relationship between season (2022/23 and 2023/24) and site (Pukaki Scientific Reserve and Mount Mary) for geckos sighted. Gecko numbers were down-sampled and standardised to 3.5 hours of survey effort to equalise sampling across all periods. This involved first removing effort completed by the secondary observer (ST), to control for observer bias, and then removing sightings after 3.5 hours of effort. All analysis was completed in RStudio (version 2023.12.1; Posit team 2023) using R (version 4.3.1; R Core Team 2023).

Results

We sighted 158 geckos over 19 hours of survey effort in two sites across the 2022/23 and 2023/24 season (Table 1). We sighted more lizards at Mount Mary than Pukaki Scientific Reserve in both years, 38 and 43 compared to 37 and 30 respectively. Gecko sightings per hour of effort dropped at both sites between 2022/23 and 2023/24, slightly at Mount Mary from 10.86 to 9.56, and drastically at Pukaki Scientific Reserve, from 10.57 to 4.00 (Table 1). We found a statistically significant deviation in the expected frequency of gecko sightings between site and season ($\chi^2 = 4.16$, p-value = 0.0413). This relationship is driven by the low sightings at Pukaki Scientific Reserve post-fire (37 vs. 19 in the first 3.5 hours of search effort by SB; Table 1).

Anecdotally, observers noticed that many of the locations occupied by geckos in 2022/23 were unoccupied following the fire. Further, six completely desiccated gecko carcasses (Fig. 2d) were found in post-fire surveys at Pukaki Scientific Reserve compared with none in pre-fire surveys. Five of the carcasses were found within rock crevices, while one was found on top of a boulder, near to a known basking rock. None of the carcasses had obvious evidence of burning (i.e. charred, or singed limbs), however, four of the five carcasses could not be extracted from their crevices. No carcasses were found at Mount Mary in either survey period, though similar carcasses are occasionally found in the Mackenzie Basin outside of the context of fire.

Discussion

We provide evidence of a short-term decline in a population of Southern Alps geckos following a major wildfire that burnt through the population's habitat. We report a reduction in gecko sightings per hour of effort and also show an apparent increase in the death rate of the population, evidenced by an unusually large number of gecko carcasses.

The decrease in relative abundance of geckos is most simply explained by the direct impact of the wildfire, though we acknowledge that the limitations of this study prevent causal links being defined. Other possible reasons for decline, such as increase in predation pressure and/or collapse of food supply are unlikely given the stability of the Mount Mary population. However, due to the paucity of control sites, the relative decline in abundance could be confounded by site specific factors. Disease and illegal collection cannot be completely ruled out as agents of decline, though we consider the latter unlikely given the relatively drab appearance of Southern Alps geckos compared to species at greater risk of poaching (Towns et al. 2016). Emigration from the site following the fire is also unlikely given high site fidelity and limited movement of other *Woodworthia* gecko species (Whitaker 1982). If individuals did emigrate following the event they would have moved into habitat considered atypical for the species (e.g. east: road, south: lavender farm, west and north: grazed farmland with few rocky refugia). Degraded grassland in particular is not considered suitable habitat for Southern Alps geckos and sampling of such habitat in Pukaki Scientific Reserve in 2022/23 with Gee's Minnow traps (56 trap nights) resulted in no gecko captures.

If fire is considered the agent of decline, this may suggest that available refugia were insufficient to prevent direct impacts. Lizards are able to escape from fire in several different ways, including moving away, climbing trees, or entering refugia (e.g. surface objects, burrows; Russell et al. 1999; Smith et al. 2012). Individuals may have attempted to escape the burning, but were unlikely to be successful given the distances required to remain unaffected by fire (c. 500 m). Instead, we assume that individuals would remain in the refugia they are often sighted in, though they may move deeper if able. If this is the case, then refugia within Pukaki Scientific Reserve were likely insufficient to prevent the death of some individuals, despite crevices often being 1–2 m deep. Interestingly, refugia in Pukaki Scientific Reserve differ markedly from where Southern Alps geckos are frequently found in the Mackenzie Basin. Commonly, the geckos use rockland habitats (e.g. rock outcrops and tors, scarps, scree and talus slopes, stable dry riverbeds), though they can also be present in grassland, whereas habitat in Pukaki Scientific Reserve is complex boulder fields. It is difficult to know whether refugia in other habitats would serve better or worse in a wildfire. It is concerning that even in a site with apparently ample refugia, the impact on geckos is still high.

Post-fire effort was conducted roughly five to six months after the event itself. As such, the decrease in gecko sightings could be driven by a reduction in resource availability e.g. food sources, shelter, and protection from introduced mammalian predators. It is largely unknown what role mature scrub plays for Southern Alps geckos, though members of the *Woodworthia* genus have been suggested as important dispersers of seeds for many native plant species (Whitaker 1987; Wotton et al. 2016). Further, Southern Alps geckos are often seen using arboreal habitats at night that are similar to those in Pukaki Scientific Reserve (*Coprosma propinqua* and *Discaria toumatou* scrub; C. Knox, Southern Scales, pers. comm.). It seems, however, that this species is able to persist despite the complete burning of surrounding scrub, indicating that habitat within retreats or surrounding fire-modified areas may be sufficient to support the surviving population. In other systems, habitat destruction by fire can have an important impact on lizard populations, leading to loss of body condition (Fenner & Bull 2007), and ultimately population decline (C. Knox, Southern Scales, pers. comm.). It is likely that the fire also altered invertebrate communities. For example, the Nationally Critical moth *Izatha psychra* has not been resighted in Pukaki Scientific Reserve following the 2023 fire, despite surviving the 2020 Pukaki fire (J. Schori, Project River Recovery, pers. comm.; Griffiths & Christian 1996; Hoare et al. 2017). Understanding the full impact of habitat loss and subsequent invertebrate community changes on this gecko species will require ongoing population monitoring.

Cree (1994) reports relatively low reproductive rates for *Woodworthia* geckos compared to lizards globally, linking low outputs to cool environmental temperatures. At Pukaki Scientific Reserve, which experiences harsh winters but hot summers, it is possible that gecko reproduction is biennial; a gestation period of up to 14 months has been observed in *Woodworthia* geckos from similar elevations at Macraes Flat in Otago; Cree 1994. Consequently, population recovery following fire events would likely be slow. If fires continue occurring at their current frequency (e.g. Pukaki 2020 and 2023) it is unlikely that gecko populations would be able to recover completely between burns.

Previous survey effort in Pukaki Scientific Reserve (April 2012) encountered 30 Southern Alps geckos, 17.14 geckos per hour of effort (M. Lettink, Fauna Finders, pers. comm.). This rate is considerably higher than the before-fire encounter rate (10.57) presented here, suggesting that the cumulative effect of both fires at Pukaki Scientific Reserve (2019 and 2023) may have had a larger impact on this gecko population than is reported in this study.

Wildfire, by nature, cannot be acutely predicted. Therefore, it is often difficult to design studies robustly to investigate the impact of fire (except in the case of controlled burns). Regardless, we believe that data presented here contribute compelling evidence for the significant adverse effect of fire on NZ's lizard species, at least in the short term. We acknowledge that much more work is required in this space to fully understand the impacts of fire on NZ lizard fauna. Future work is particularly important in light of the increasing intensity and frequency of fire regimes locally. Short of recommending controlled burns of lizard habitat, work could include more robust and widespread baseline monitoring in fire prone habitats, perhaps taking advantage of pre-existing or ongoing fire studies. We also recommend investigations of how habitat loss affects resource availability for lizards (e.g. Pianka & Goodyear 2012) and how refugia loss alters species' interactions with mammalian predators (e.g. loss of cover, riskier foraging; Doherty et al. 2022).

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Additional information and declarations

Author contributions: SB and JM conceptualised the project. SB and ST collected the data in the field. SB analysed the data and wrote the original draft of this manuscript All authors contributed to review and revision of the manuscript.

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Data and code availability: all data presented in this study are provided in the manuscript. As such, there is no code associated with this manuscript. No GPS locations of gecko capture are provided to reduce the risk of poaching. If readers wish to learn more about the gecko populations in sites mentioned in this study, please contact the corresponding author.

Ethics: all work was conducted under University of Otago Animal Use Protocol 22-72.

Conflicts of interest: the authors declare no conflicts of interest.

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