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High Resprouting of Plants Within 16 Months of Wildfire in a Dry Grassland in Aotearoa New Zealand

Shanta Budha-Magar[1,2] | Hannah L. Buckley[1] | Timothy J. Curran[3] | Nicola J. Day[4]

[1]School of Science, Auckland University of Technology, Auckland, New Zealand | [2]Environment Management, NorthTec, Whangārei, New Zealand | [3]Department of Pest-management and Conservation, Lincoln University, Lincoln, New Zealand | [4]School of Biological Sciences, Victoria University of Wellington, Wellington, New Zealand

Correspondence: Nicola J. Day (Nicola.Day@vuw.ac.nz)

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ABSTRACT

Wildfires are projected to increase in severity and frequency in dryland ecosystems due to climate change. To predict how plant communities will respond to these changes in wildfire patterns, it is vital to understand how plants establish following fire; such knowledge is limited in Aotearoa New Zealand. Individual plants regenerate after fire by resprouting or germinating from seeds. We aimed to quantify short-term community dynamics and regeneration strategies of plants after a wildfire in the eastern dryland zone in the Pukaki Scientific Reserve, Canterbury, Aotearoa New Zealand in August 2020. We established seven plots and recorded all vascular plant taxa present 1 and 4 months post-fire and again 16 months post-fire for two plots. Additionally, we used destructive sampling to determine whether individual plants had resprouted post-fire or germinated from seed. A total of 63 taxa were observed in the repeated surveys. Graminoids dominated at all times, particularly the exotic grasses *Anthoxanthum odoratum* and *Agrostis capillaris*. Species composition among the seven plots differed 1 month post-fire but tended to converge over 4–16 months. Woody species took longer to recover compared with forbs and graminoids. Of the 242 destructively sampled plants from 25 taxa, most individuals present after fire (215) had resprouted; six exotic taxa were the only ones to regenerate via seed. All six woody taxa resprouted. These results suggest that substantial changes in plant community structure occur 16 months after fire that is not evident in the first month, which has implications for management decisions. Further, while many native plants in this dryland zone can resprout post-fire, their lack of recruitment from seed may result in long-term shifts favoring exotic species under increased fire activity.

1 | Introduction

Globally, wildfire activity is shifting beyond historical norms, driven by changes in ignition sources, drought frequency and intensity, increases in fire weather, and land use (Bowman et al. 2020; Shen et al. 2025). Fire disturbance outside of historic norms can lead to dramatic changes in plant composition, particularly in dry parts of the landscape (Rogers et al. 2005; Day and White et al. 2020; Baltzer et al. 2021). Repeated measurements of plant communities in the initial stages after fire can facilitate understanding of future vegetation dynamics by capturing immediate responses such as prevalence of plant resprouting and changes in community structure. This fundamental knowledge is necessary to inform restoration decisions post-fire (Underwood et al. 2022).

Plant individuals or populations can recover from fire by resprouting or germinating via seed (Bellingham and Sparrow 2000; Bond and Midgley 2001; Pausas 2019); some species can recover using both methods. Additionally, some plants survive by experiencing minimal burning due to low flammability or being situated in areas of the landscape that do not burn (Pausas 2019). To successfully resprout post-fire, individual plants need to protect their buds

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and also have built up reserves to allow structures to regrow after fire (Clarke et al. 2013). For plants regenerating from seed, they must disperse from a nearby unburned area or have had sufficient time between fires to build up a fire-resistant seed bank in the soil or canopy (Enright et al. 2015; Nolan et al. 2021). If fires become too frequent outside of historical norms and exceed the ecological tolerances of the species, then this compromises the ability of plants to recover, known as interval squeeze or immaturity risk (Enright et al. 2015; Nolan et al. 2021). Similarly, fires that are more severe or intense than the historical fire regime can also cause dramatic changes in plant community composition and even widespread shifts in dominant species (Nolan et al. 2021; Baltzer et al. 2021). Thus, impacts of altered fire regimes on plant regeneration strategies could impact initial plant community structure that may be detectable for many decades and potentially through multiple fire cycles.

Species of different growth forms may differ in how they are impacted by fire and, therefore, their post-fire recovery. For instance, woody species may take longer to recover than grasses due to differences in growth rates. In the absence of fire, grassy ecosystems can be dominated by woody species over decadal timescales (Keeley et al. 2005). Exotic species, particularly those that become invasive, are often more tolerant to disturbances than native species in the same environments. For instance, invasion by low-growing forbs with low flammability has dramatically reduced community-level flammability in Aotearoa New Zealand native grasslands (Padullés Cubino et al. 2018), so this may help them to be dominant after fire; in many areas, native species in these grasslands may require semi-regular fire to maintain their distribution (Perry et al. 2014).

Knowledge of how plants recover from fire in Aotearoa New Zealand is limited, but specific adaptations to fire are thought to be rare in the native flora (Ogden et al. 1998; McGlone et al. 2014; Perry et al. 2014). One exception is *Leptospermum scoparium* (mānuka), which has serotinous capsules (Bond et al. 2004; Battersby et al. 2017). In addition, there are many flammable native plant species (Cui et al. 2020) and many woody and nonwoody native species resprout within months of fire (Calder and Wardle 1969; Burrows 1994; Espie and Barratt 2006; Teixeira et al. 2020). *Chionochloa* spp. (snow tussocks) rapidly resprout and flower after fire, but seeds produced after burns have lower viability rates than other grasses and unburned snow tussocks (Mark 1965; Mark 1969; Gitay et al. 1992). Other dryland species that can resprout after fire include *Celmisia* spp. (Allen and Partridge 1988), *Pteridium esculentum* (bracken fern; Stone and Langer 2015), and the woody species *Discaria toumatou* (matagouri; Daly 1969) and *Corokia cotoneaster* (Burrows, 1994). Research comparing plant communities in unburned areas to experimentally burned areas in tussock grasslands showed that diversity of native plants declined due to fire, but not necessarily in areas that burned in spring (Espie and Barratt 2006). If native species are less able to regenerate after fire, exotic invasion and dominance is a concern. Exotic graminoids, such as *Agrostis capillaris*, and *Anthoxanthum odoratum* are highly abundant after fire in grasslands and can impact germination of native woody shrubs (Sessions and Kelly 2000), but areas can return to being dominated by native species after a decade post-fire (Allen and Partridge 1988; Calder et al. 1992; but see Richardson et al. 2018). Some prostrate invasive exotic forbs, such as *Pilosella officinarum*, are less flammable than other species in dryland ecosystems, suggesting they could resprout and outcompete native species where fire disturbance is prevalent (Padullés Cubino et al. 2018).

Several studies showing changes in plant community structure and long-term succession decades after fire have been conducted in grasslands and woody ecosystems in Aotearoa New Zealand (Young et al. 2016; Burge et al. 2020). Repeated surveys after a fire in a dryland *Kunzea robusta* (kānuka) forest showed that vegetation cover in all life forms recovered rapidly from 6 to 12 months after fire, but cover of native woody species increased the most between 36 months and 15 years after fire (Richardson et al. 2018). The abundance of fine-fuels in grassland-shrubland drylands in other countries support fast-moving fires that may not be very hot or severe (Pausas et al. 2017), conditions that could promote survival. However, similar to other Aotearoa New Zealand ecosystems, such as forests (Teixeira et al. 2020), in general, there is little understanding of post-fire regeneration strategies and observations of recovery of plant communities in the initial years after fire, and how communities change, in increasingly fire-exposed dryland ecosystems. Assessing community composition at one time point after fire may not be representative of longer-term recovery. Knowing species' regeneration strategies and post-fire community dynamics informs post-fire management by informing us which species or areas could be most at risk of losses in diversity over time.

The eastern dryland zone (sensu Rogers et al. 2005) of the South Island of Aotearoa New Zealand represents areas with low precipitation and high evaporation. Parts of the eastern dryland zone currently occupied by native-dominated grasslands and shrublands in the eastern-central South Island are projected to experience the greatest increases in fire risk compared to other parts of the country (Pearce et al. 2011; Melia et al. 2022). In this study, we aimed to quantify and understand short-term plant community dynamics and plant regeneration strategies after a wildfire in early spring in Pukaki Scientific Reserve that falls within the eastern dryland zone. Prior to the wildfire in August 2020, this site had not burned since 1996 or earlier. We undertook repeated post-fire measures of vascular plant communities to investigate changes 1–16 months after fire and used destructive sampling to assess whether plants were regenerating from seed or had resprouted. We asked: (1) How did plant community composition change with time after fire? (2) Which species resprouted and which regenerated from seed? and (3) Were patterns in resprouting of plants related to origin or growth form?

2 | Materials and Methods

2.1 | Site Description and Field Sampling

Pukaki Scientific Reserve covers 32 ha and lies 620–650 m a.s.l. in Canterbury, Aotearoa New Zealand (Figure S1). In 1976, the site was recommended for status as a Scientific Reserve due to its unique potential contributions to science and education (Molloy and Hodder 1976). At that time, the vegetation was short-tussock grassland and mixed scrub and included the last remnant of primary dryland scrub in the Mackenzie Basin. Pukaki Scientific Reserve provides critical habitat for the nationally endangered lepidopteran *Izatha psychra* (Department of Conservation 2021). The reserve is managed by the New Zealand Department of Conservation and has not been burned or grazed by domesticated stock since it was established in 1996. Pukaki Scientific Reserve falls within one of Aotearoa New Zealand's eight dryland ecosystems (Rogers et al. 2005). Soils are alluvial in origin and the climate is characterized by low values for atmospheric water-holding deficits, annual temperatures, and solar radiation, as well as early winter frosts. Mean annual temperature and precipitation over 30 years from 1992 to 2022 was 8.9°C and 593.7 mm, respectively, and mean seasonal temperature amplitude was 13.84°C (Wratt et al. 2006; Etherington et al. 2022).

A wildfire began in early spring on 29 August 2020 and burned through the Pukaki Scientific Reserve over the subsequent few days. The fire was started accidentally and burned approximately 2,226 ha (Fire and Emergency New Zealand 2020). We established seven vegetation plots 1 month after fire in October 2020; three plots were in areas dominated by grasses and four were in areas dominated by shrubs. All plots were remeasured 4 months after fire in January 2021, and two grassland plots (Plots 1 and 6) were remeasured again 16 months after fire in January 2022 (Figures S2 and S3). Vegetation surveys were done using a modified Whittaker's plot design where, within each 20 × 20 m plot, we established a 1 × 1 m subplot at each corner then divided this into four, 0.5 × 0.5 m quadrats (Figure S4). Within each 0.5 × 0.5 m quadrat, we recorded the presence of all living vascular plant taxa, which we defined as plants with green leaves. Burned woody stems without green leaves were not recorded. The dataset comprised 256 0.5 × 0.5 m quadrats: 224 in seven plots at 1 and 4 months and 32 in two plots at 16 months after fire.

To assess whether individual plants were recovering from seed or resprouted after the fire, we undertook destructive sampling at two locations adjacent to the seven vegetation survey plots 1 month after fire (Figure S4). We excavated plant root systems within two 2 × 2 m plots at each end of a 10 m long transect, aiming to collect at least five individuals with green leaves for each taxon present within each plot. Our constrained sampling area was designed to minimize disturbance in this scientific reserve, but this led to low sample sizes for some taxa. For each individual excavated, we recorded whether it had resprouted, evidenced by an extensive root system, or whether it had recently germinated from seed since fire, evidenced by having a small root system and often a seed still attached, following established methods

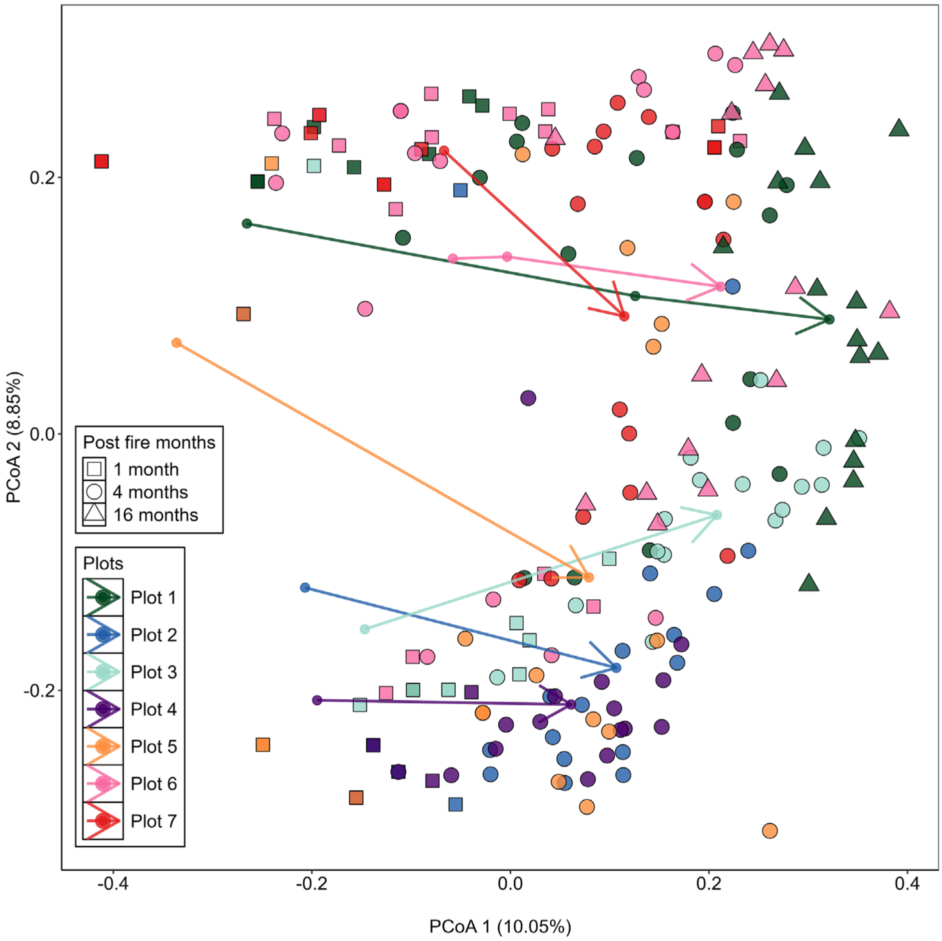

FIGURE 1 | Site scores from Principal Coordinate Analysis (PCoA) of post-fire plant composition in 254 0.5 × 0.5 m quadrats within seven 400 m^2 plots and their trajectories over time in Pukaki Scientific Reserve, Aotearoa New Zealand ($n = 63$ taxa). The variation explained by each PCoA axis is in parentheses. The start, middle, and end points of the trajectory arrows are the compositional centroids for each plot at the sampling time points measured one and 4 months (all seven plots), and 16 months (two plots only) post-fire. See Figure S5 for species scores.

(Day and White et al. 2020). Destructive sampling was repeated 4 months after fire in a different location from the 1 month location, but still adjacent to each vegetation survey plot. For most individuals, it was too difficult to differentiate between these regeneration strategies at 16 months after fire.

Most individuals were able to be identified to species level, but some could only be identified to genus (Table S1). For all taxa, we collated plant trait data from existing data sources and the literature (Breitwieser et al. 2010; Padullés Cubino et al. 2018; New Zealand Plant Conservation Network 2022). Each taxon was categorized by origin (native or exotic) and growth form (forb, graminoid, woody) (Table S1). Nomenclature follows The Flora of New Zealand (https://www.nzflora.info). Two dominant exotic grasses, *Agrostis capillaris* and *Anthoxanthum odoratum*, were difficult to differentiate 1 month after the fire, so these two species were grouped together for all analyses and are referred to as *Agrostis-Anthoxanthum*.

2.2 | Data Analysis

All analyses were conducted in R v. 4.3.2 (R Core Team 2024) using the packages "readxl" (Wickham et al. 2023a), "readr" (Wickham et al. 2024), "stringr" (Wickham 2023), "tibble" (Müller et al. 2023), "purr" (Wickham and Henry 2023), "tidyr" (Wickham 2017), "dplyr" (Wickham et al. 2023b), "ggreppel" (Slowikowski et al. 2021), "gghighlight" (Yutani 2022), "ggh4x" (Brand 2024), and "tidytext" (Silge and Robinson 2016) for data manipulation and visualization. Libraries used for more specific procedures are indicated below.

2.2.1 | Post-Fire Changes in Plant Community Composition

To investigate changes in post-fire plant taxon composition, we used taxon presence within each 0.5 × 0.5 m quadrat at every plot at each time. We performed a principal coordinate analysis

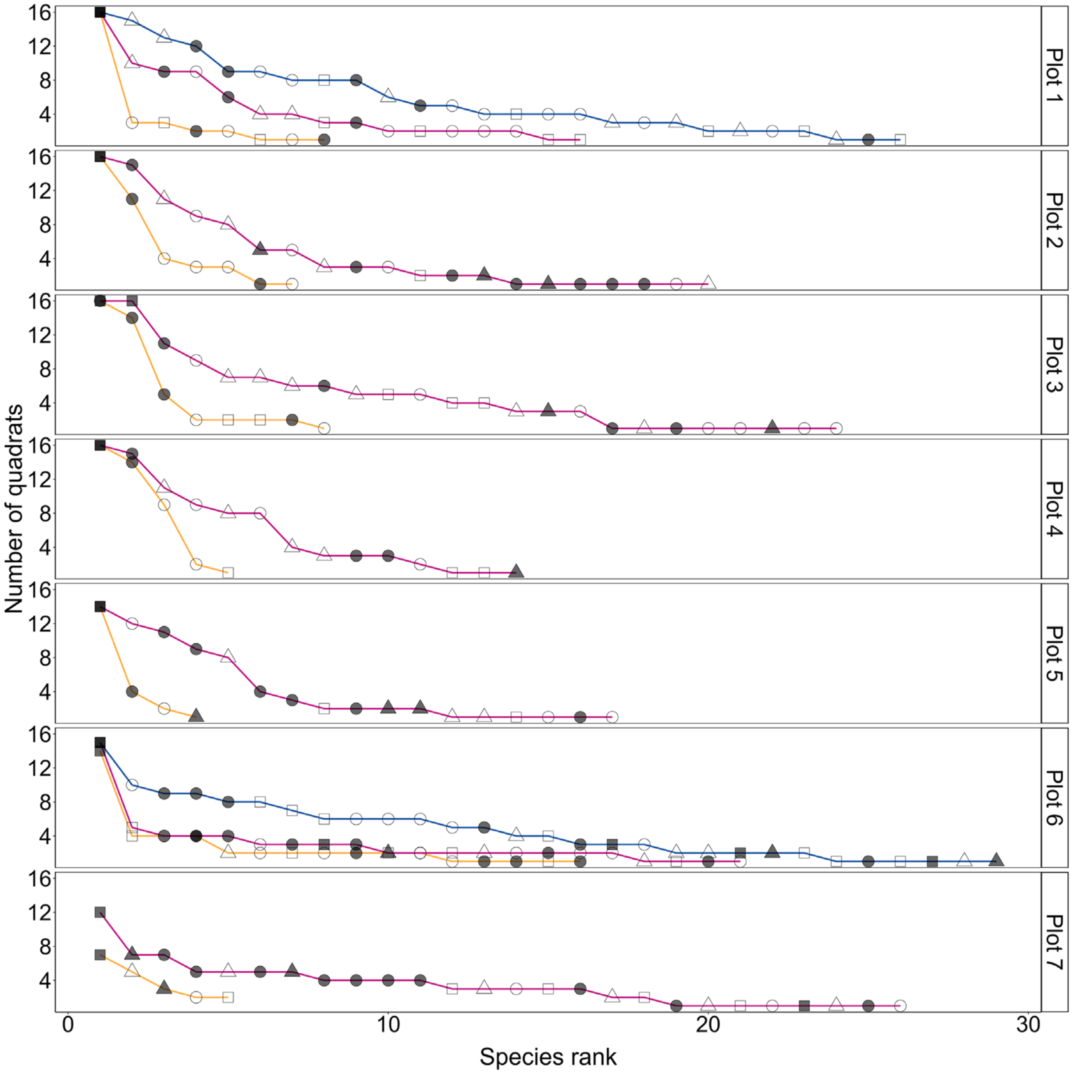

FIGURE 2 | Rank abundance curves for 63 taxa, based on the number of 0.5 × 0.5-m quadrats in which each taxon occurred across 254 quadrats located within seven 400-m2 plots in Pukaki Scientific Reserve, Aotearoa New Zealand. These plots were surveyed two or three times. Ferns ($n = 2$ species) were grouped with forbs. Open symbols were used for natives and filled symbols for exotics. Line colors represent the time after fire: 1 month (orange), 4 months (purple), and 16 months (blue; only plots 1 and 6). Point shapes represent growth forms: forbs (circle), graminoids (rectangle), and woody (triangle). See Figure S6 for taxon labels.

(PCoA) on the taxon presence matrix using Jaccard dissimilarity in "vegan" (Oksanen et al. 2022) to visualize temporal changes in post-fire taxon composition in the seven, nondestructively sampled vegetation survey plots. We then calculated the weighted average scores for each taxon using function "wascores" and overlaid those on the PCoA to visualize the variation in community composition among quadrats of plots. Following Avolio et al. (2019), we used taxon rank changes and reordering in relative abundance to determine how the frequency of taxa within each of the two origin categories and three growth forms changed after fire.

2.2.2 | Regeneration Strategies of Plants

To determine the regeneration strategies of plant taxa, we calculated the number of individuals of each taxon from the destructive sampling that resprouted or germinated from seed after the fire. We calculated the number of resprouting and seeding individuals in each plot across the seven plots within levels of two categorical variables: (a) origin (native and exotic species) and (b) growth form (forb, graminoid, and woody); these classifications allowed us to understand relationships between post-fire recovery strategies and these two factors, without performing formal statistical tests, because of the relatively low sample sizes.

3 | Results

3.1 | Post-Fire Changes in Plant Community Composition

We observed a total of 63 vascular plant taxa in the repeated measures of plots across the three times taken between one and 16 months after wildfire (Table S1). More of the observed taxa were native ($n=39$) than exotic ($n=24$). While plant composition within plots changed over time, the recovery was in the same direction (Figures 1 and S5). The directional change in composition was likely related to the increase in the number of taxa with time since fire (Figure 2). Similar taxa were present in each plot (Figures S5 and S6). The exotic graminoid taxon group *Agrostis-Anthoxanthum* was consistently the most frequently occurring taxon at 1, 4, and 16 months (Figure S6). Forbs were the most frequently occurring growth form 1 month after fire (Figure 2). Five of the seven plots (Plots 2, 3, 4, 5, and 7) showed a high degree of change in taxon ranks at 4 months compared with 1 month after fire, largely due to recovery of woody species. The two plots that were measured 16 months after fire showed further changes in taxon ranks (Figure 2), suggesting that recovery of plants in the community was still occurring over the course of the study.

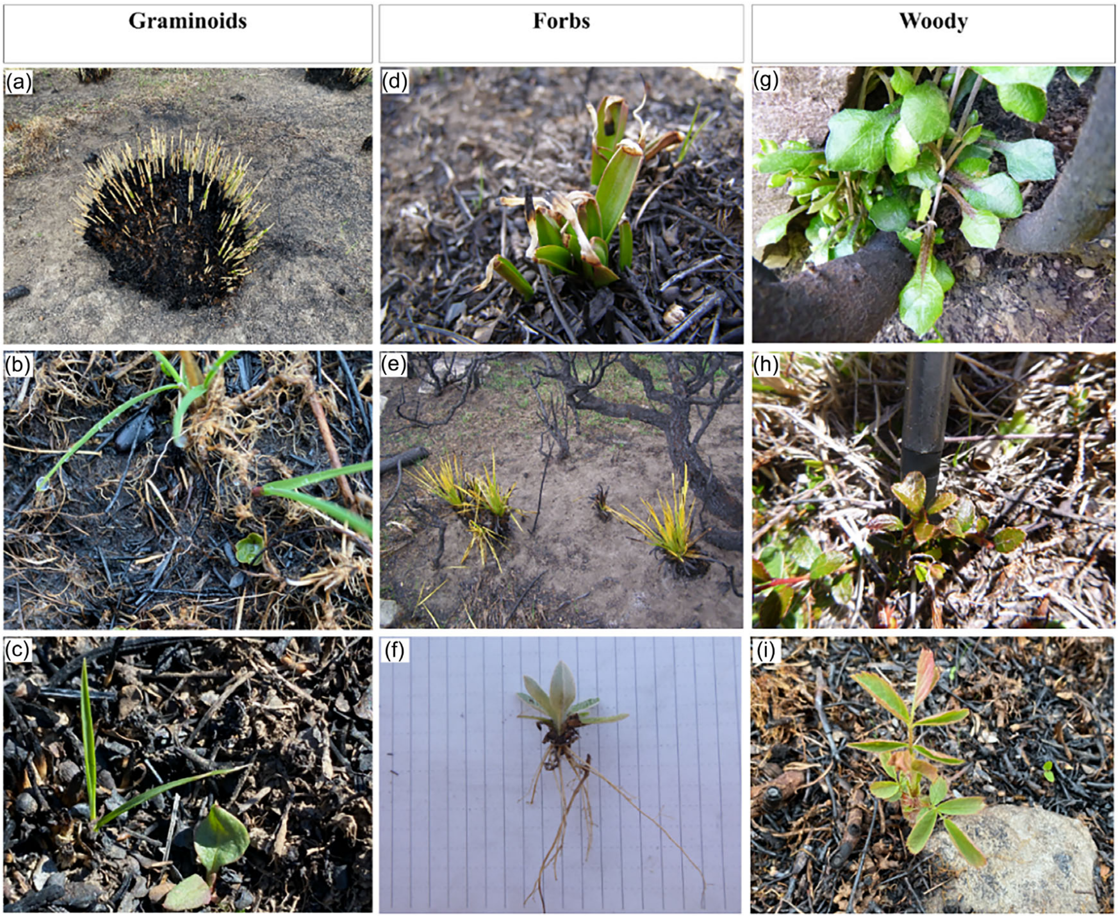

FIGURE 3 | Photos of plants post-fire at Pukaki Scientific Reserve, Aotearoa New Zealand. Columns represent plants within the three different growth forms (graminoids, forbs and woody). Taxa are: *Chionochloa rigida*, Poaceae (a); *Anthoxanthum-Agrostis*, Poaceae (b,c); *Thelymitra longifolia*, Orchidaceae (d); *Aciphylla aurea*, Apiaceae (e); *Pilosella officinarum*, Asteraceae (f); *Corokia cotoneaster*, Argophyllaceae (g); *Gaultheria depressa*, Ericaceae (h); and *Rosa rubiginosa*, Rosaceae (i).

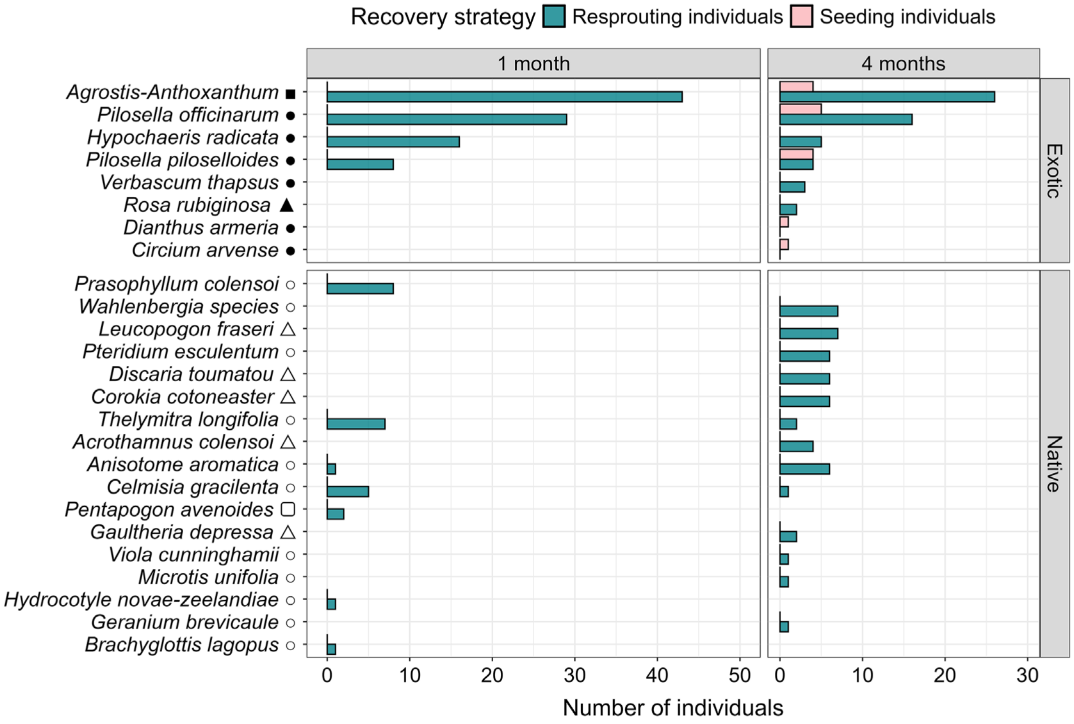

FIGURE 4 | Post-fire recovery strategies of 242 destructively-sampled individual plants in 25 taxa by origin at 1 and 4 months after fire in Pukaki Scientific Reserve, Aotearoa New Zealand. Open symbols were used for natives and filled symbols for exotics. Shapes of the taxa represent growth forms: graminoids (rectangle), forbs and ferns (circle), and woody (triangle).

3.2 | Regeneration Strategies of Plants

We excavated 242 individual plants from 25 taxa: 121 individuals in 11 taxa were excavated 1 month post-fire and a further 121 individuals in 21 taxa 4 months post-fire (Figure 3). Most individuals excavated had resprouted ($n = 215$), and most taxa were native ($n = 17$; Figure 4). The 27 individuals that germinated from seed only occurred 4 months post-fire; all of these were nonwoody, exotic species. Most individuals excavated were from exotic taxa ($n = 167$), which showed a high proportion of resprouting, particularly in the cases of *Agrostis-Anthoxanthum* (94.5% of 73 individuals), *Pilosella officinarum* (90% of 50 individuals), and *Hypochaeris radicata* (100% of 21 individuals; Figure 4).

3.3 | Post-Fire Plant Regeneration in Relation to Origin and Growth Form

All 50 individuals of excavated native forbs resprouted as well as most individuals of exotic forbs (88% of 92 individuals). The only taxa that regenerated from seed were the exotic forbs *Pilosella officinarum*, *Pilosella piloselloides*, *Dianthus armeria*, and *Circium arvense* and the *Agrostis-Anthoxanthum* grass group. Among the six woody taxa, all 27 individuals regenerated by resprouting (Figure 4). Most of the excavated woody taxa were native (92.59% of 27 individuals) except two individuals of *Rosa rubiginosa*.

4 | Discussion

Together, our results suggest that the wildfire in this dryland area caused short-term changes in plant community composition because plants lost foliage and appeared dead 1 month after fire, but plants recovered over the first two growing seasons. Most plants present after fire, including native taxa, recovered by resprouting. No native species were observed to have regenerated from seed within 4 months of fire. Plant community composition differed among plots immediately after the fire but changed towards similar composition as vegetation recovered, suggesting a degree of convergence. Our results support the idea that while exotic grasses can be abundant after fires in these ecosystems, native species are also present and can recover over the longer term (Allen and Partridge 1988; Calder et al. 1992), particularly woody species. Although we do not have information on pre-fire vegetation, we speculate that because plants of most taxa present after fire had resprouted and there were similar taxa present over time, plant communities recovered to be similar to that of pre-fire. Based on our results, we suggest that active plantings after fire are not necessarily needed for plant community structure to recover, but pre- and post-fire monitoring would aid these types of management decisions. Fires of this type may not cause long-term changes in community composition in the eastern dryland zone of Aotearoa New Zealand, but this resilience may be eroded as fire activity increases. Indeed, this site experienced another wildfire as early as September 2023, just 3 years after the 2020 wildfire.

Our study is one of few assessments of plant regeneration strategies after fire in the eastern dryland zone of Aotearoa New Zealand, a dominant habitat type in many parts of the eastern South Island. Some of the native taxa have been shown to resprout from other studies, including *Chionochloa* spp. (Mark 1965), *Pteridium esculentum* (Stone and Langer 2015), and the woody species *Discaria toumatou* (Daly 1969), *Gaultheria* *macrostigma* (Teixeira et al. 2020), and *Corokia cotoneaster* (Burrows 1994). For some taxa, we provide the first records in Aotearoa New Zealand showing that they can resprout after fire, specifically our multiple observations of the small forbs *Wahlenbergia* sp. and *Anisotome aromatica* and the woody species *Leucopogon fraseri* and *Acrothamnus colensoi*. The orchids *Prasophyllum colensoi*, *Thelymitra longifolia*, and *Microtis uniflora* likely resprouted from underground bulbs. The prevalence of resprouting in native taxa indicates a degree of ecological tolerance to wildfires in this system, at least those at this frequency and severity, although we are not suggesting that this resprouting ability evolved directly due to fire. A notable exception to this is *Discaria toumatou*, which is considered one of few fire-adapted species in Aotearoa New Zealand, likely because of retention of traits from its ancestral lineage in fire-prone environments in Australia. Due to having very thick bark, *Discaria toumatou* can resprout epicormically following fire, though in Aotearoa New Zealand flora thick bark is most common in cool, dry environments and potentially aids with moisture retention (Richardson et al. 2015).

Only a few taxa germinated from seed and they were all exotic: the graminoids *Anthoxanthum odoratum* and *Agrostis capillaris*, and the forbs *Pilosella officinarum* and *Pilosella piloselloides* (*Dianthus armeria*, and *Cirsium arvense* also germinated from seeds, but their sample sizes were small). These species were able to recover by both germinating from seed and resprouting, possibly because their meristems are close to the ground where heat impact of fire would be lower. Further, we suggest that some exotic species that were frequent in the nondestructively sampled plots post-fire resprouted because they have low flammability, such as *Pilosella officinarum* and *Pilosella pilloselloides* (Padullés Cubino et al. 2018). Exotic sward-forming grasses had consistently high ground cover up to 15 years after fire in a dryland forest (Richardson et al. 2018). Despite the high proportion of native taxa that resprouted, we may see a long-term increase in cover of exotic grasses with increased frequency of wildfires given their ability to rapidly colonize post-disturbance sites by both resprouting and regenerating from seed.

While many native species resprouted after the fire, none were observed to have regenerated via seed. However, we had very low sample sizes for many native taxa in our destructive sampling, so we suggest further studies on this topic are worthwhile. Seed regeneration was likely hindered by sparse seed sources of native species from which dispersal could occur and a lack of on-site fire-resistant seed banks. Further, if there had been seed sources available nearby, the timeframe between the fire and our sampling may have been insufficient for these species to establish. It is also possible that native seed dispersed into our sampling area but was outcompeted or germination was prevented, as shown for sward-forming grasses on germinating seeds of native woody taxa (Sessions and Kelly 2000). We are not aware of any native species in this dryland ecosystem that form persistent seed banks to germinate after fire, but this is a common mechanism in fire-prone systems (Nolan et al. 2021). Further investigation of seed ecology, including seed banks, dispersal capacity, seed germination, and other aspects of recruitment limitation in the eastern dryland zone will aid understanding of the mechanisms underlying how these systems recover after disturbances.

In our study, plant species composition differed among plots 1 month after the fire, but composition tended toward convergence as recovery occurred over time. This is likely because there were many individuals that appeared dead 1 month after fire and required longer to resprout, so were detected in subsequent remeasurements. Exotic grasses were dominant in all plots at all times. While our results provide information on species frequencies and not abundance, another study in a dryland *Kunzea robusta* forest showed that non-native taxa accounted for 85% of total cover from 6 to 15 years after fire (Richardson et al. 2018); as with our study, there were no pre-fire survey data to compare with. The high proportion of excavated plants that resprouted suggest that composition at 4–16 months after fire was similar to pre-fire composition, although it is possible that some species did not recover at all and we could not detect these without pre-fire surveys.

Our results suggest that plant surveys at only one time point recently after a fire are not representative of which plants resprouted or future plant community composition in this system, particularly when considering recovery of woody plants. Woody species took longer to be recorded in the surveys, probably because they are slower growing compared with forbs and graminoids. Indeed, woody species were still recovering 15 years after fire in a dryland forest in Marlborough (Richardson et al. 2018). Active restoration after fires like the one described in our study may be necessary to aid recovery of native plant diversity, but fundamental knowledge of the recovery strategies of plants in the system is needed in order to more fully understand its impact and the appropriate course for targeted restoration or other management (Underwood et al. 2022). In particular, if many individuals can resprout after fire, then this suggests a degree of ecological memory in the system that promotes resilience in plant species composition (Johnstone et al. 2016).

The observed vegetation patterns were likely impacted by herbivory: we observed a large number of rabbit burrows at the site and evidence of herbivory on pine seedlings. Herbivory is known to reduce recovery of *Chionochloa*, and likely other species, after fire (Mark 1965; Gitay et al. 1992). Fire also likely impacted fauna at the site, such as lizards, which are critical dispersers of seeds of native plants (Wotton et al. 2016). Populations of the Southern Alps gecko (*Woodworthia*) declined after the 2023 fire in the Pukaki Scientific Reserve, and native shrubs are thought to be important refuges for this lizard (Bourke et al. 2024). The endangered lepidopteran, *Izatha psychra*, that was key for the formation of the Reserve, were present after fire (Department of Conservation 2021). The recovery of many native woody species after fire in our study suggests relatively rapid recovery of critical habitat for native fauna.

Our study enhances knowledge of post-fire plant community recovery in this unique ecosystem in the eastern dryland zone of Aotearoa New Zealand. Our destructive sampling in the immediate months after fire showed which taxa resprouted, providing critical information to understand how future fire activity could impact this important ecosystem and restoration needs. Overall, our results suggest that many native plant species can resprout after fires, but so can many exotic species. The exotic species *Anthoxanthum odoratum*, *Agrostis capillaris*, *Pilosella officinarum*, and *Pilosella piloselloides* could both resprout but also successfully regenerate from seed; no native species used both regeneration strategies. More studies assessing fundamental impacts of fires on the flora of Aotearoa New Zealand will aid management decisions, particularly where regeneration of native species is the aim under increased wildfire activity.

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Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

Data have been deposited to the New Zealand Vegetation Survey (NVS) database. No custom code was used in data analyses. R code for statistical analyses is available from the authors upon request, and R packages used are cited in the Methods.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Map of study area showing location of burn in dryland ecosystem at Pukaki Scientific Reserve, Aotearoa New Zealand. (*Source*: Google satellite for baseline map, Land Information New Zealand for reserve). **Figure S2:** Photos of two, 400 m^2 non-destructive vegetation survey plots measured one, four, and 16 months post-fire in Pukaki Scientific Reserve, Aotearoa New Zealand. Note that photos were not always taken from the same location each time. **Figure S3:** Photos of five, 400-m^2 non-destructive vegetation survey plots taken at one and four months post-fire measured in Pukaki Scientific Reserve, Aotearoa New Zealand. Note that photos were not always taken from the same location each time. **Figure S4:** Sampling design for a) non-destructive sampling for vegetation measurements in 254, 0.5 × 0.5 m quadrats within seven 400-m^2 plots, and b) destructive sampling for excavation of individual plants in a 4-m^2 plot at each end of a 10-m long transect adjacent to each of the seven plots in Pukaki Scientific Reserve, Aotearoa New Zealand. **Figure S5:** Ordination plot showing species scores, which are weighted averages scores overlaid onto the Principal Coordinate Analysis (PCoA) space from 254, 0.5 × 0.5 m quadrats within seven, 400-m^2 plots in Pukaki Scientific Reserve, Aotearoa New Zealand. The variation explained by each PCoA axis is in parentheses. The color of the species codes represents each taxon's origin, where natives are purple and exotics are green. See Table S1 for definitions of species codes. See Figure 3 for the site scores. **Figure S6:** Rank abundance curves for 63 taxa, based on the number of 0.5 × 0.5-m quadrats in which each species occurred across 254 quadrats located within seven 400-m2 plots in Pukaki Scientific Reserve, Aotearoa New Zealand. These plots were surveyed two or three times. Ferns ($n = 2$ species) were grouped with forbs. Open symbols were used for natives and filled symbols for exotics. Line colors represent the time after fire: one month (orange), 4 months (purple) and 16 months (blue; only plots 1 and 6). Point shapes represent growth forms: forbs (circle), graminoids (rectangle) and woody (triangle). See Table S1 for definitions of species codes. **Table S1:** Taxa recorded in 254, 0.5 × 0.5 m quadrats within seven plots over 16 months after the August 2020 wildfire in Pukaki Scientific Reserve, Aotearoa New Zealand. Nomenclature follows The Flora of New Zealand (https://www.nzflora.info). Two dominant exotic grasses, *Agrostis capillaris* and *Anthoxanthum odoratum*, were difficult to differentiate one month after the fire, so these two species were grouped together for all analyses and are referred to as *Agrostis-Anthoxanthum*. Species names and origin (native or exotic) were taken from Flora of New Zealand the (https://www.nzflora.info). Code represents the first three letters each from genus and species epithet and were taken from New Zealand National Vegetation Survey Databank (except *Agrostis-Anthoxanthum*; https://nvs.landcareresearch.co.nz/Resources/NVSNames). Growth form data were collated from Padullés Cubino et al. (2018) and Flora of New Zealand (https://www.nzflora.info). Asterisks (*) represent taxa that were excavated at one month and/or four months post-fire to assess regeneration strategy.