Fire disturbance favours exotic species at Kaituna Wetland, Bay of Plenty

Article *in* New Zealand Journal of Ecology · July 2019

DOI: 10.20417/nzjecol.43.23

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NEW ZEALAND JOURNAL OF ECOLOGY

RESEARCH

Fire disturbance favours exotic species at Kaituna Wetland, Bay of Plenty

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Published online: 24 April 2019

Abstract: Fires regularly occur in New Zealand wetlands, affecting ecological indicators and conservation values such as native plant species richness. Following a small fire at the Kaituna Wetland, Bay of Plenty, foliage cover was measured and biodiversity indices determined on eight occasions over 48 months. Visual percentage estimation of species cover in six height classes showed that grasses (especially naturalised exotic species) were early colonists, although plots were subsequently dominated by the exotic Japanese honeysuckle (*Lonicera japonica*) and the native common twig rush (*Machaerina rubiginosa*). At 48 months, there were 14 exotic vascular species in burnt plots compared to 10 in unburnt plots; conversely 10 native species were found in burnt plots, compared to 18 in unburnt plots. Mean species richness, Shannon-Weiner diversity, and total vegetation cover increased in the burnt quadrats over time, with exotic plant species having a greater relative increase in these measures than native species. Without proactive management, fire does not confer conservation benefits to the Kaituna Wetland. Disturbance events such as fires can be used as natural experiments to measure restoration and rehabilitation initiatives post-perturbation.

Keywords: Bay of Plenty, fire, Kaituna Wetland, vegetation response

Introduction

Fire brings ecological transformations, with important conservation and restoration challenges (Perry et al. 2014). These challenges, such as draining, weed invasion and fire are hastening the loss and degradation of wetlands (McGlone 2009). The palaeoenvironmental record indicates that prior to human settlement in New Zealand fire frequencies were low, except for those in lowland northern wetlands (McGlone et al. 1984; Perry et al. 2014; Battersby et al. 2017). Māori-firing of the landscape initiated new wetlands in New Zealand (McGlone 2009). Logging, fire and draining of both pristine forested wetlands and fire-transformed wetland systems by European settlers from the 19th century onwards, which greatly reduced the extent of wetlands (McGlone 2009). Most of the contemporary wildland, rural and forest fires in New Zealand occur in grassland and scrubland vegetation, and have averaged over 3000 in number, burning over 5000 ha annually (Anderson et al. 2008). Fires in wetlands now account for approximately one percent of total fires in New Zealand, both in terms of number of fires and area burned (BC unpubl. data).

Plant community succession following fire in New Zealand wetlands will often follow a predictable pattern with dominance by indigenous species maintained, though in some circumstances it can lead to alternative successional trajectories, with reduced indigenous biodiversity (Timmins 1992; Clarkson 1997; Johnson 2005). The investigation of multiple fires in West Coast wetland and scrub vegetation showed that fire did not confer any benefits to conservation values (indigenous biodiversity, recreation opportunities, historic heritage), ecological processes, or biota (Johnson 2005). While there has been considerable research on the impact of fires on wetland vegetation in New Zealand (Timmins 1992; Clarkson & Stanway 1994; Clarkson 1997; McQueen & Forester 2000; Hicks et al. 2001; Johnson 2001, 2005; Norton & de Lange 2003; Perry et al. 2014), nothing has been published on vegetation recovery following fires in the Bay of Plenty Region. Our study takes advantage of a recent fire event at the Lower Kaituna Wildlife Management Reserve (hereafter Kaituna Wetland), Bay of Plenty, to monitor changes in vegetation cover and species richness following a fire. It was expected that: (1) there would be an initial response from exotic grass species and rhizomatous species (whether of exotic or native origin), as moderate severity fire rarely destroys rhizomes (Neary et al. 2005); and (2) that exotic species would outcompete native species over the first 4 years post-fire, to the detriment of the wetland's conservation values, such as native species richness.

DOI: https://dx.doi.org/10.20417/nzjecol.43.23

Methods

Study area and fire

The Kaituna Wetland (37º45′S, 176º22′E) is in the western Bay of Plenty Region, east coast of the North Island, New Zealand (Fig. 1). It is approximately 200 ha in area, with the wetland bounded on its northern side by the Kaituna River, and by drained farmland on the others. It is predominantly a cabbage tree (*Cordyline australis*) and grey willow (*Salix cinerea*) permanent swamp forest, in a basin form (Johnson & Gerbeaux 2004), with moderate water flow and a water and soil pH of 6 (BC unpubl. data).

During mid-March 2004, several fires were illegally lit, indicated as previous fires on Figure 1. On 5 April 2004, further fires were lit, which soon spread and merged. The fire was not fully extinguished by suppression actions, and on 6 April it reignited, with the wind strengthening from the southwest (225º) in the morning to over 9 km hr^{-1} from the west (270º), changing to a light breeze 2–6 km hr^{-1} (225º) for most of the afternoon. Further fire suppression efforts were made, with the burn extent ending primarily at surface water. The total area burnt was approximately 1.1 ha, with a perimeter of 1.6 km.

Monitoring

Between 20 April and 7 June 2004, twelve 2 × 2 m plots were established systematically, with six in the burnt area and six in the neighbouring unburnt, comparative vegetation community. Six plots in the burnt area were established within approximately one month after the fire on 20 April and 7 May 2004, and six control plots were placed in unburnt vegetation within 2 months of the fire. All plots were located at least 20 m apart unless barriers or obstacles such as open water precluded them. Each 2 × 2 m plot was divided into four 1 m^2 quadrats and were left *in-situ* for the study duration. Vegetative cover by species was estimated as a percentage at six height classes (<45 cm, 45–75 cm, 75–135 cm, 135 cm–2 m, 2–5 m, 5–12 m). The mean live plant vegetation cover was calculated as the sum of vegetation cover divided by total of height classes where live plants were present in the plots. Eight monitoring occasions occurred at 1–2, 4, 8, 12, 18, 24, 36, and 48 months after the fire.

Data analysis

At each monitoring period, we calculated the burnt and unburnt plot species origin (native or exotic) vegetation composition and foliage cover and four indices of diversity: species richness; Shannon-Weiner diversity; Shannon evenness; and Berger-Parker dominance (Magurran 1988). These measures were chosen as the use of multiple indices, both simple and complex offer improved understanding of biological interactions (Morris et al. 2014). We then assessed these differences between the initial and last monitoring periods

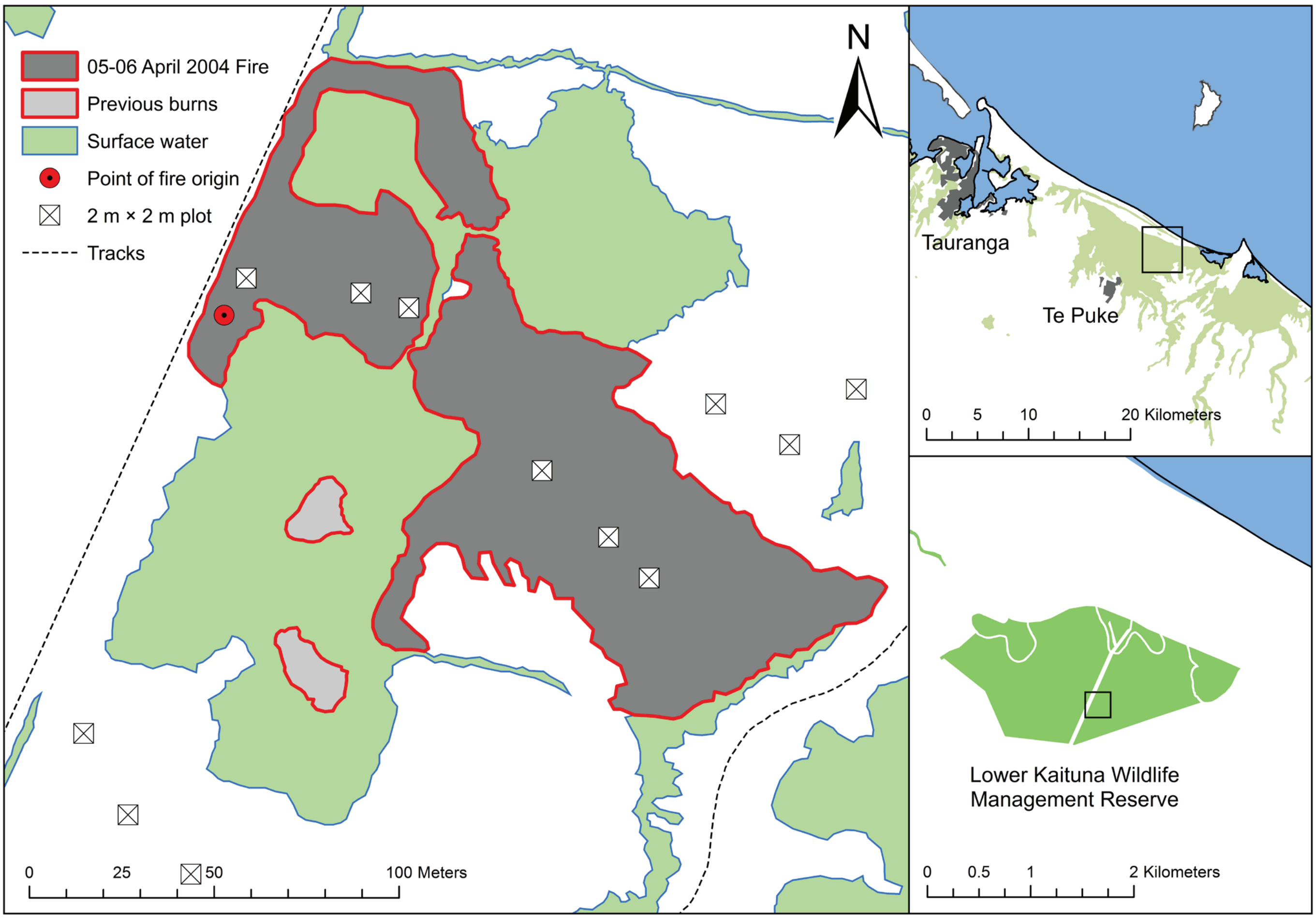

Figure 1. Fire extent 5–6 April 2004. Fires lit in March 2004 are listed as previous burns. The top insert shows the historic wetland extent (olive) within the coastal Bay of Plenty around Te Puke and Tauranga (grey urban areas), North Island, New Zealand. The bottom insert shows the Lower Kaituna Wildlife Management Reserve relative to the fire extent map.

using repeated-measures analysis of variance (ANOVA), using the statistical programme R version 3.2.5 (R Core Team 2016). The vegetation composition and foliage cover and the four indices of diversity were used as the response variables, and the burnt and unburnt comparison (the fire treatment) as the predictor variable. No multiple test corrections were applied. The relationships between these variables were also investigated. All data were tested for normality using the Shapiro-Wilk test.

Results

Immediate impacts of fire

The effects of the burn were examined the day after the fire, with further notes made at the time of the first monitoring occasion on 6 May 2004. Nearer the origin of the fire, the major effects were on sedge understorey species such as *Machaerina* spp. and *Carex* spp., which were burnt almost entirely to their leaf bases. The lower halves (2 m) of the canopy trees such as cabbage trees were burnt, with sub-canopy species such as *Phormium tenax* and *Coprosma propinqua* partially burnt (Fig. 2). The burn edges were still distinct after one month, extending to the open water edge. Fire fingers approx. 2–25 m in length were present on the fire's southern flank, indicating occasional and localized wind changes (22.5º–325º) (Viegas 2004).

General trends and diversity indices

The fire reduced the native species richness count as compared to the exotic species (Fig. 3). At 48 months: the exotic species numbers in the burnt area (14) was 140% of the comparative unburnt plots (10); the native species numbers in the burnt area (10) was 56% of the comparative unburnt plots (18). Species richness, evenness and diversity of native species origin, and total live foliage cover (sum of cover over all height classes) showed significant interactions between the fire treatment (burnt and unburnt areas) and time (Table 1). Mean species richness (± standard error) in the burnt quadrats increased by 2 ± 0.35, and 5.17 ± 0.41 for native and exotic species respectively, whereas there was little change in mean species richness within the unburnt quadrats. Evenness and diversity of exotics showed a statistically significant interaction between the fire treatment and time. Mean evenness in the burnt quadrats decreased for both native and exotic species, whereas the decrease in mean evenness within the unburnt quadrats was minimal. Mean diversity (± standard error)

Figure 2. Photograph (07/04/2004) of wildfire effect on vegetation, showing burnt bases of cabbage trees (*Cordyline australis*).

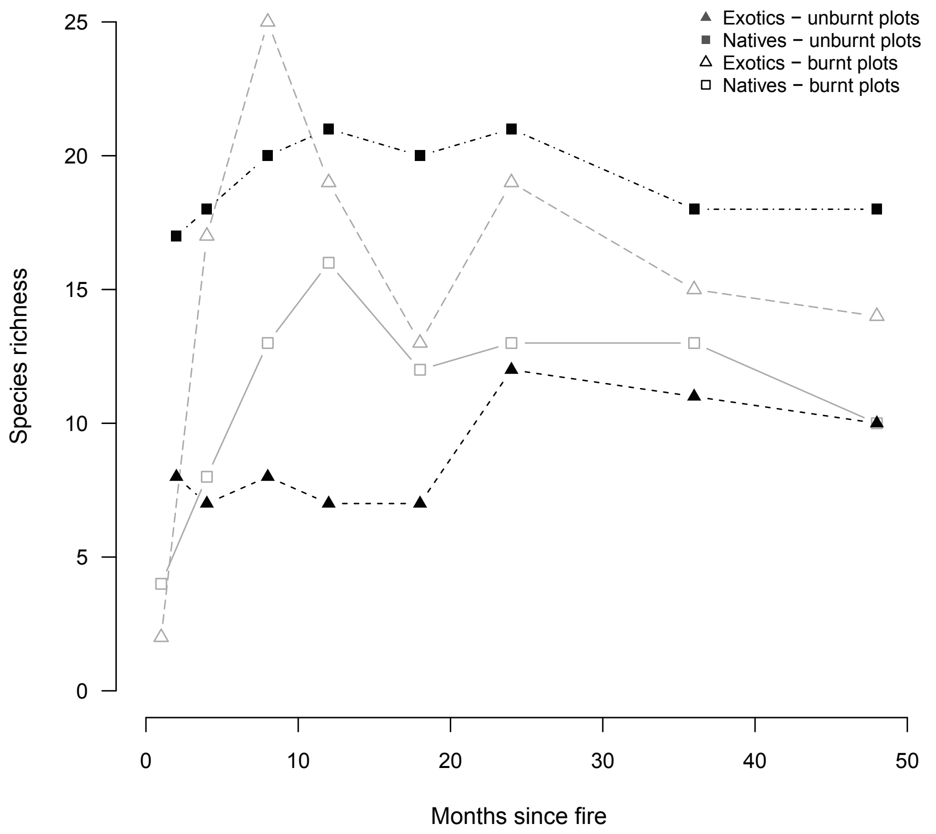

Figure 3. Exotic and native plant species richness at eight intervals over 48 months after fire at the Kaituna Wetland.

Table 1. Mean diversity indices and vegetation cover (± standard error) at 1st measure and last measure (8th) after fire, with repeated-measures ANOVA *p* values.

					p		
Index	**Species origin**	**Comparison**	**1st measure**	**8th measure**	**fire**	**time**	**time*fire**
Species richness	Native	Burnt	0.958 ± 0.165	2.958 ± 0.310	<0.001	<0.001	0.004
		Unburnt	3.875 ± 0.331	3.957 ± 0.451			
	Exotic	Burnt	0.083 ± 0.058	5.250 ± 0.404	<0.001	<0.001	<0.001
		Unburnt	2.167 ± 0.222	2.957 ± 0.204			
Evenness	Native	Burnt	0.918 ± 0.038	0.519 ± 0.052	<0.001	<0.001	<0.001
		Unburnt	0.686 ± 0.044	0.601 ± 0.062			
	Exotic	Burnt	1.000 ± 0.000	0.488 ± 0.042	0.001	<0.001	0.060
		Unburnt	0.743 ± 0.056	0.456 ± 0.057			
Dominance	Native	Burnt	0.859 ± 0.038	0.743 ± 0.040	<0.001	0.169	0.201
		Unburnt	0.571 ± 0.036	0.583 ± 0.047			
	Exotic	Burnt	0.833 ± 0.059	0.606 ± 0.048	<0.001	0.325	0.563
		Unburnt	0.770 ± 0.044	0.743 ± 0.032			
Diversity	Native	Burnt	0.248 ± 0.060	0.613 ± 0.075	<0.001	0.017	0.008
		Unburnt	0.987 ± 0.084	0.901 ± 0.101			
	Exotic	Burnt	0.000 ± 0.000	1.040 ± 0.217	<0.001	0.008	0.647
		Unburnt	0.482 ± 0.084	0.611 ± 0.063			
Total cover	Native	Burnt	2.729 ± 0.848	122.5 ± 21.93	<0.001	0.002	<0.001
		Unburnt	169.1 ± 15.82	125.3 ± 25.26			
	Exotic	Burnt	0.625 ± 0.458	87.17 ± 8.773	0.004	<0.001	<0.001
		Unburnt	112.0 ± 9.114	95.65 ± 10.73			

increased in the burnt quadrats by 0.41 ± 0.10, and 1.04 ± 0.11 for native and exotic species respectively. Dominance showed a statistically significant fire effect for both native and exotic species, although not over time. Total live foliage cover (i.e. summed for all height classes, ± standard error) increased in the burnt quadrats: 120 ± 22.4, and 86.5 ± 9.12 for native and exotic species respectively, whereas the decrease in total live foliage cover in the unburnt quadrats was small: 49.1 ± 30.0, and 16.3 ± 14.1 for native and exotic species, respectively. Mean live vegetation foliage cover across all height classes in the burnt area steadily rose from one percent to 100% relative to the comparative unburnt areas, becoming similar across treatments at 24 months onwards (Fig. 4).

Vegetation response and comparison

There was a steady increase in the native species vegetation cover, and a relatively quick recovery in exotic vegetation cover over the 48 months (Fig. 5). Key differences found in the exotic vegetation cover for all height classes between the two sets of plots were: the large initial growth of Yorkshire fog (*Holcus lanatus*), and then its decline; the decrease in grey willow (*Salix cinerea*); and the increase in sallow sedge (*Carex lurida*) and Japanese honeysuckle (*Lonicera japonica*). Differences in native vegetation cover for all height classes were: an increase in common twig rush (*Machaerina rubiginosa*); towards the end of the study an increase in cover of *Coprosma propinqua*; and a steady increase in cabbage tree (*Cordyline australis*) and kiokio (*Parablechnum novae-zelandiae*).

Discussion

There are around 4000 rural fires per year in New Zealand (Christensen 2014), with 546 fires burning over 2000 ha in wetlands between 2000 and 2016 (BC unpubl. data). Despite the number of fires occurring in wetlands, the scientific literature on wetland vegetation response to fire is limited. Even more limited is research on the impact of fire on swamp forest such as that at the Kaituna Wetland. Our study has helped fill this knowledge gap by showing that grasses (especially naturalized exotic species) were early colonists following the fire, and that the burnt area became dominated by Japanese honeysuckle (*Lonicera japonica*) and common twig rush (*Machaerina rubiginosa*), with the relative exotic species richness and diversity having a greater increase than that of the native species by 48 months post-fire.

The rapid recovery of *Machaerina* spp. is a common occurrence following fires in wetlands and bogs (Perry et al. 2014), and in this study *Machaerina rubiginosa* (a rhizomatous sedge) reached its peak cover (>19%) at the last measure 48 months, and was greater than the unburnt comparison area from 24 months onwards. Rhizomatous and exotic species responded early, and in terms of total species numbers, exotic species outcompeted native species by the end of the monitoring programme. Similar to the study of Johnson (2005) of wetland and scrub vegetation in Southland, Otago, and Westland, this study of Kaituna Wetland indicates that fire did not confer benefits to the wetland's botanical conservation values, i.e. the native flora, within 48 months after the fire, apart from the increase in *Machaerina rubiginosa*, and the decrease of the *Salix cinerea* numbers and cover. Monitoring the change of native and exotic plant species is of conservation interest, particularly ongoing observations of any exotic pests and (threatened) native populations, although further studies in the ecological integrity and history of the wetland would be of general scientific value. Because of the limited spatial scope of this study, we are unable to extrapolate our specific results beyond the Kaituna Wetland. However, some general management implications can be applied to the wider issue of wetland fires in terms of conservation.

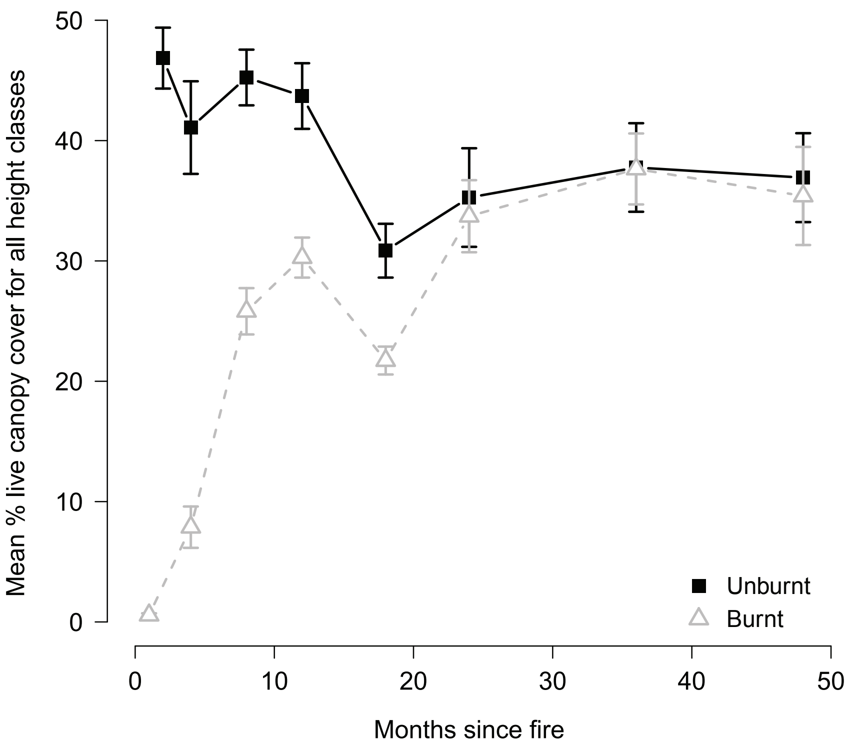

Figure 4. Mean live percentage foliage cover (with standard error bars) for all height classes and all species in vegetation plots for both burnt and unburnt areas over 48 months at the Kaituna Wetland.

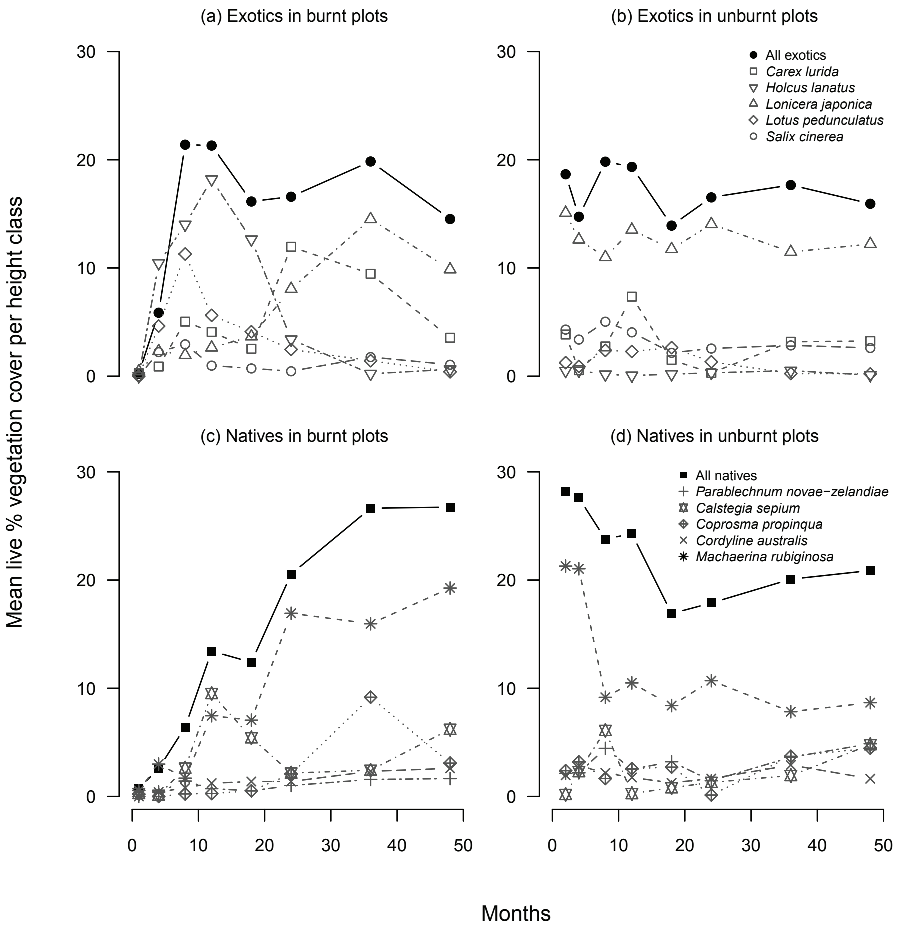

Figure 5. Mean live percentage vegetation cover for the 10 most abundant plant species over 48 months after fire at the Kaituna Wetland.

Management implications

After fires in Northland gumland wetlands, weeds increased and were considered likely to remain (McQueen & Forester 2000), though Clarkson et al. (2011) note that rare species such as light-requiring orchids also established and survived because of the newly opened habitat. Post-fire dynamics at the Kaituna Wetland suggest that fire is not beneficial for the native vegetation assemblage present in the 4 years post-fire. While no specific restoration objectives are currently published for the Kaituna Wetland, it is recommended that unsupervised fires in this location should be prevented, responded to and controlled as quickly as possible, as per Johnson's (2001, 2005) recommendations for wetlands and scrub sites in Southland, Otago, and Westland.

In addition, an important question arises: what is the long-term post-fire vegetation response following fires? For the Kaituna Wetland, as there is no ongoing monitoring, we suggest that DOC, Eastern Region Fish & Game, and the Bay of Plenty Regional Council consider establishment of permanent vegetation monitoring plots (ideally with fire-proof plot markers) throughout the wetland. In addition, we support the incorporation of Driscoll et al.'s (2010) recommendation of building implementation capacity for natural experiments following such wildfire events. Such activities may include the testing of active rehabilitation (e.g. planting, seeding, transplanting; Clarkson et al. 2017) vs natural i.e. passive restoration. Local native seeds could be stored to speed up ecosystem recovery following other major disturbances in the future.

Acknowledgements

We gratefully acknowledge Chris Hodder who suggested this investigation, and Toni Twyford who managed the initial DOC fire response and kept records of actions and site conditions. Chris Hodder, Alissa Woods, Kate McKnutt, and David Hunt accompanied and helped the monitoring team on individual days over the duration of this study. This work was improved by useful comments and suggestions from David Havell, Toni Twyford, Tim Curran, and two anonymous reviewers.

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Editorial board member: Tim Curran
Received 13 October 2017; accepted 27 March 2019

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