Threatened Species Recovery Hub

National Environmental Science Programme

Conserving fauna in fire-prone landscapes: A review of fire-associated management actions that affect fauna conservation and recovery

Bendall, E. R.[1,2], Robinson, N.M.[1,2], Lindenmayer, D.B.[1,2], Morgain, R.[1,2], Legge, S.[1,2], Woinarski, J. C. Z.[1,3], Rumpff, L.[1,4], Maron, M.[1,5]

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Charles Darwin University Australia

The University of Melbourne

The University Of Queensland Australia

Authors: Bendall, E. R.[1,2], Robinson, N.M.[1,2], Lindenmayer, D.B.[1,2], Morgain, R.[1,2]., Legge, S.[1,2], Woinarski, J. C. Z.[1,3], Rumpff, L. [1,4], Maron, M.[1,5]

[1]The National Environmental Science Program, Threatened Species Recovery Hub, Australia

[2]Fenner School of Environment and Society, Australian Capital Territory, Australia 2600

[3]Charles Darwin University

[4]University of Melbourne

[5]University of Queensland

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Cover image: Reduced food and cover are key challenges for wildlife following an intense bushfire. Image: Nicolas Rakotopare

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Summary

Global change is modifying disturbance regimes and placing increased pressure on natural ecosystems and their fauna. Severe and unusually widespread fires create fauna management challenges, as the number of killed, injured and affected animals may number in the billions, many animal species may lose much of their population size, post-fire environments may be unsuitable for long periods for many species, and fire may exacerbate the impacts of other threats. There is an urgent need for effective strategies that minimise the impacts of fires on fauna, and enhance the recovery of affected species following fire.

This global systematic review assessed the global research literature on fire-associated management actions that impact fauna, alongside the publicly available Australian grey literature. Key findings include:

1. The intent of fire-associated actions varied widely, and included:
    - resource harvesting
    - ecological restoration
    - fauna conservation
2. The most commonly studied actions were post-fire salvage logging, ecological forest thinning and ecological grazing in association with fire, with the majority of these involving birds, invertebrates and mammals.
    - Post-fire salvage logging had an overwhelmingly negative impact
    - Pre-fire ecological thinning and grazing generally had positive impacts on most taxa

    In many cases there were species-specific responses to such actions - both 'winners' and 'losers'. These studies therefore suggest that:
    - mosaic-style approaches to land management that create environmental heterogeneity are more likely to achieve conservation aims across taxa.
    - spatio-temporal variation in disturbance severity and type is usually recommended to fulfil the ecological requirements of co-existing species in disturbance-prone terrestrial ecosystems.
3. There is little published evidence available to assess the potential effectiveness of a range of key fire-associated fauna management actions that have been proposed, or are implemented, by conservation practitioners within Australia. We found few studies that addressed the effectiveness of most post-fire fauna conservation actions, such as animal rescue, provision of artificial habitat or supplemental feeding. However, such actions were commonly mentioned in the Australian grey literature as post-fire strategies for managing fauna. Thus there is a significant gap between common practices and the available evidence to assess the effectiveness of those practices.

Introduction

Human activities are having profound effects on global ecosystems to the extent that current rates of species extinction are significantly higher than perceived background rates (IPBES 2019). The world is also likely to become uninhabitable for many species within the next hundred years (Urban 2015, IPBES 2019). Recently, unprecedented mega-fires swept across large parts of Australia, burning millions of hectares of vegetation (Boer *et al.* 2020, Lindenmayer and Taylor 2020) and leaving ecological devastation in their wake (Wintle *et al.* 2020). The effects of such substantial changes in the scale of wildfires on ecosystems are poorly understood, with management plans not designed to cope with the escalation in the scale of impacts being experienced (Kelly *et al.* 2020). There are likely to be widespread species declines if paradigms in ecological theory and consequent management strategies do not urgently address these changes, adapt and prepare for further potential changes in future (Ward *et al.* 2020).

Aims

This project aims to use a global systematic review of literature to ask: (i) What is the range of fire-associated management actions that impact fauna?; (ii) What are the responses of fauna to these actions (i.e. positive, neutral, negative)?; (iii) Which of these actions might be considered for further investigation in an Australian context, based on similarities between taxa and ecosystems?

The objectives of our study were to provide conservation practitioners and land managers with a body of evidence that can guide fauna management into the future, and to identify key knowledge gaps that merit further research such that the evidence base for management is more robustly established.

Background

What is being done?

In the Australian context, there is increasing awareness of the dire situation facing fauna following catastrophic wildfires. It has been estimated that close to three billion native vertebrates were killed or displaced during the recent 2019-2020 fire season (van Eeden *et al.* 2020). In the wake of these fires, detailed lists of priority species and potential management actions were developed by government agencies in collaboration with the scientific community (Australian Government 2020b, DELWP 2020, Legge *et al.* 2020). However, the effectiveness of the potential post-fire management actions for conserving fauna after such large-scale fires is largely unknown for many species within the Australian context.

Media articles often depict fauna management actions such as koalas being rescued, or animals being given supplementary food and water to assist survival in resource-depleted landscapes (e.g. Thomas 2019, Readfearn 2020). However, a broader range of fire-related actions are often undertaken as part of longer-term fauna conservation strategies and recovery programs, such as strategic fire exclusion, prescribed burning, post-fire habitat rehabilitation and feral predator control (NSW DECC 2008, ACT Government 2020).

More broadly, there is a range of fire-associated management actions reported in the scientific literature that are implemented for different objectives but have potential to impact fauna (Table 1). Some of these actions precede or are used in-between frequent prescribed fires, such as ecological vegetation thinning (as distinct from commercial forest thinning for timber harvest objectives) or grazing that aims to reverse changes in vegetation density and structure due to previous inappropriate management regimes (Winder *et al.* 2018, Roach *et al.* 2019, Latif *et al.* 2020). However, vegetation thinning or frequent prescribed fires within the context of some Australian ecosystems may increase fire severity or flammability in some ecosystems, which could be detrimental to some fauna (Zylstra 2018, Taylor *et al.* 2020). The potential for animals to perform far-reaching ecosystem engineering roles in relation to fire may also extend beyond grazers to those that turn over soil and litter, create trails and cycle nutrients, highlighting the need for better understanding of how overall ecosystem management might influence outcomes for fauna following fire (Foster *et al.* 2020, Ryan *et al.* 2020). Thus, the success of fire-associated actions in conserving fauna is likely to be context- and taxa-dependent. The potential for perverse outcomes from some practices justifies a systematic review of the available evidence base, and hence a more considered assessment of their applicability within the Australian context.

Table 1. Types of fire-associated management actions that can influence fauna conservation, and their use in relation to a fire.

Management objectives	Pre-fire	During fire	Post-fire
Resource preservation (e.g. identifying and maintaining refuges, protection of key habitat features)	X	X	X
Resource supplementation (e.g. provision of feed stations, nest boxes)			X
Habitat restoration (e.g. replanting, thinning, weeding)	X		X
Fauna conservation (e.g. animal rescue, translocation)	X	X	X
Predator management	X		X
Competitor management	X		X
Fire control (e.g. use of control lines, retardant)	X	X	
Resource harvesting or manipulation (e.g. salvage logging, grazing)	X		X

Some fire-associated actions are generally detrimental to fauna, such as post-fire salvage logging, which removes resources for hollow-dependent species and post-fire specialists (Thorn *et al.* 2018, Zmihorski *et al.* 2019, Georgiev *et al.* 2020). Similarly, intensive livestock grazing combined with fire can homogenise habitat complexity leading to a loss of fauna, but when livestock grazing is undertaken with fauna objectives in mind, ecosystems and their endemic fauna can be restored (Churchwell *et al.* 2008). However, livestock grazing may not be effective at reducing fire severity, and may have impacts on vegetation that undermine other conservation goals, such as habitat rehabilitation (Williams *et al.* 2006, Lindenmayer *et al.* 2018). Further, livestock grazing may assist feral predator movement, allowing predators easier access to native fauna (Legge *et al.* 2019).

Here, we seek to understand the range of fire-related management actions that are implemented globally, the circumstances and ecosystems in which they are used, and their impacts (positive, negative and neutral) on different types of fauna. This collation and analysis of evidence should allow for more informed decision making when developing and implementing fire-associated management actions for use in Australia and other fire-prone countries.

Types of actions and their potential effects

Fire-associated management actions that impact fauna can be grouped according to their intention, such as fauna conservation, ecological restoration or resource harvesting, and by their timing with regard to fire (e.g Table 1). Pre-fire management actions usually form part of structured management objectives, such as ecological restoration, long-term fauna conservation strategies or as part of attempts to balance multiple land-use needs, such as forestry, agriculture or fuel reduction. For example, in parts of North America, long-term fire exclusion and suppression has led to dramatic changes in ecosystems, converting historically open forests to densely vegetated forests (Waltz and Covington 2004, Nyoka 2010, Irwin *et al.* 2018). In particular, longleaf pine forests and oak savannahs have been subject to many decades of inappropriate fire regimes and have been largely deprived of the frequent low-intensity fires needed to maintain ecological balance (Steen *et al.* 2013). As a result, these altered ecosystems no longer support the needs of a range of open-habitat species and post-fire specialists (Weiss *et al.* 2019). Restoration efforts in these ecosystems often involves ecological thinning of the overstory and/or understory via mechanical and/or chemical means, followed by prescribed burning at frequent intervals to reduce fuels and hasten the return of a natural stable state (Kalies *et al.* 2010).

Management actions implemented during fire often aim to mitigate the impact of fire or fire-control activities on fauna or habitat, via methods such as strategic fire exclusion and direct protection of habitat trees and logs (Bluff 2016, NSW DPIE 2020a). However, some actions associated with fire control activities may be incidentally detrimental to fauna, such as destruction of habitat trees (Bluff 2016), contamination by firefighting chemicals (Calfee *et al.* 2003, Dietrich *et al.* 2013), or facilitating the movement of feral animals (Velamazn *et al.* 2018). These types of mitigating actions are often not the subject of scientific attention, testing or monitoring (but see Bluff 2016). As a result, little is known regarding the effects or effectiveness of these fire-associated management actions for conserving fauna. For example, despite the widespread use of firefighting chemicals, there are only a handful of studies that test their effects on fauna and these generally do not account for the interacting effects of fire or other environmental variables.

The objectives of post-fire management actions range from resource harvesting, including salvage logging and intensive stocking, to actions aimed at ecosystem recovery, such as habitat rehabilitation and erosion control. Additionally, some post-fire actions such as fauna rescue/translocation, supplemental feeding and targeted feral predator control are implemented directly to conserve fauna and minimise population declines, prevent extinction or to improve the chances of survival for individuals (Lunney *et al.* 2004, Bleicher *et al.* 2020).

Alternative approaches to intensive stocking and frequent burning in grassy ecosystems such as 'patch-burn grazing' aim to create a mosaic of vegetation succession via relatively fine-scale rotation of livestock and prescribed fires across grasslands (Churchwell *et al.* 2008, Ricketts and Sandercock 2016). Such manipulation of landscapes may have feedbacks with consequences for biodiversity, nutrient cycling and trophic interactions via fire- and human-mediated pathways (Bowman *et al.* 2016, Bowman and Legge 2016). For example, patch-burn grazing can have positive impacts on ground-dwelling birds that require heterogeneity in vegetation structure to forage, avoid predators and successfully reproduce (McNew *et al.* 2015, Winder *et al.* 2017). Investigating and interpreting the nuances of such approaches will be required if these types of management options are to be considered, adapted and applied in an Australian context.

Following fire, the resources that animals need to survive may be in short supply across landscapes. This trend is likely exacerbated when severe fires cover large areas, leaving few unburnt refugia that fauna can utilise or recruit from (Robinson *et al.* 2013, Wintle *et al.* 2020). Additionally, competition from introduced herbivores may be heightened over the diminished resources, and predation by feral predators may intensify following fire, as burned areas facilitate easier access to prey (Hradsky 2020); although at least some predators may also have been killed in fires, resulting in post-fire declines in predator densities (Arthur *et al.* 2012). Some post-fire conservation actions are aimed at mitigating these impacts, via rescue and rehabilitation, translocation, installing artificial habitat, controlling introduced species or providing supplementary food/water. For example, rescue, rehabilitation and release of fire-injured koalas can achieve comparable long-term survival rates to uninjured koalas (Lunney *et al.* 2004). There is also evidence that some species with highly-specific nesting requirements may utilise artificial habitats when they are appropriately designed, correctly installed and properly maintained (Saunders *et al.* 2020). Further, intensive predator control following fire may be effective at temporarily reducing predation impacts on native fauna (Hradsky 2020).

Unfortunately, there have been few studies quantifying the effectiveness of many post-fire conservation actions, although many such actions are part of the operations of many land management agencies and resource managers (NSW Government 2014, VicForests 2018, DELWP 2020). In addition, many actions that are targeted towards fauna may have dual function: preservation of populations and species, but also welfare of individual animals. These different types of actions can ultimately result in achieving their stated objectives, but may not necessarily be effective for overall fauna conservation. Given the common application of the various approaches and the likely worsening future environmental conditions that many species will face, there is a pressing need for better assessment of global scientific evidence for the effectiveness of currently employed or proposed fire-associated fauna management actions across Australia. We did not investigate the cost-effectiveness of different actions, as there were differences in spatial scale, duration and objectives of studies, and budgets were rarely documented.

Methods

We conducted a global systematic review of fire-associated management actions; our search criteria included global peer-reviewed literature and Australian grey literature (i.e. publications created outside of academic institutions, by government agencies or other organisations). We followed the globally recognised guidelines and workflow outline in the PRISMA statement (Moher *et al.* 2009).

Searches

On 29/09/2020, we searched the bibliographic databases Scopus (https://www.scopus.com), Web of Science (https://www.webofknowledge.com) and ProQuest (https://www-proquest-com). We did not update any search results following this single round of searching. In addition, we searched federal- and state-level databases such as https://trove.nla.gov.au/. (Fig 1). Following these higher-level searches, web pages for individual agencies or organisations at all levels were manually searched using either keywords or using site maps/following internal links. We also searched within fire management or biodiversity/conservation agencies for guidance and/or procedures for responding to fauna needs in relation to fire, such as reviews, debriefs, responses to past wildfire events and how wildlife were managed. It is important to note that our grey literature search was not exhaustive and generally we did not search at local government/regional level. For example, the New South Wales National Parks and Wildlife Service has individual management plans for every reserve within their estate, but it was not feasible to assess each one of these documents within our project's timeframe and they were excluded. Between November 2020 to March 2021, we approached fire management and conservation practitioners within government agencies and the private sector with a survey to obtain knowledge and insights not covered by the literature. These survey results are provided in a supplementary report. For full details regarding search strategy and terms see Appendix 1.

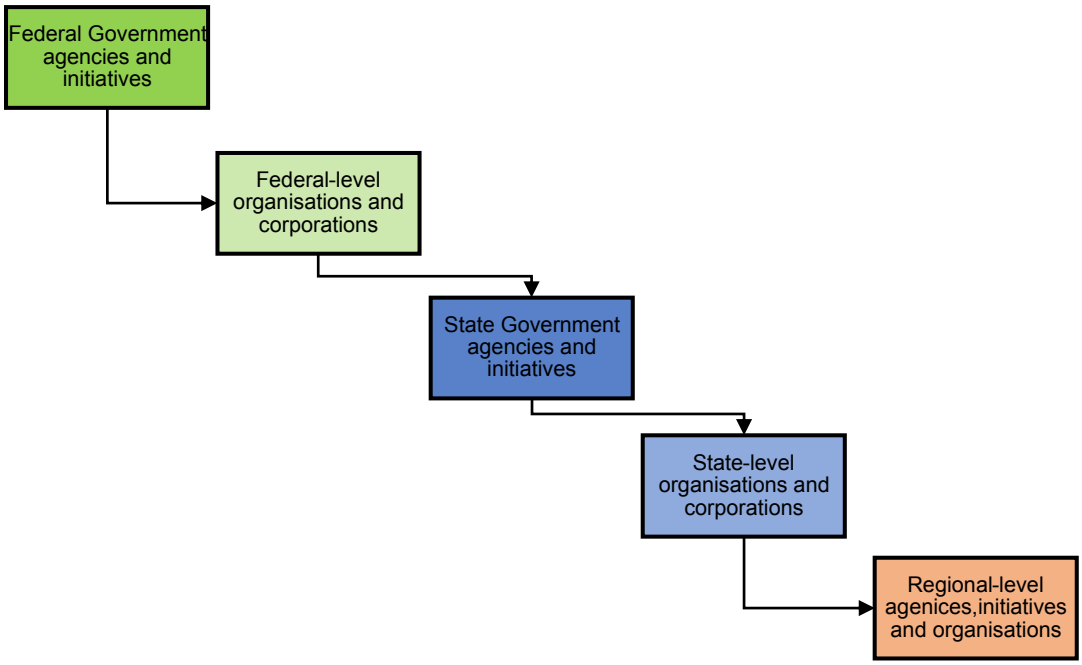


Figure 1. Diagram of tiered levels of organisation within Australian government agencies or organisations. Search workflow followed a top-down approach.

Eligibility criteria

We used clearly defined eligibility criteria when screening articles for inclusion (for full details regarding screening see Appendix 1). Eligible subjects were all global terrestrial and freshwater ecosystems that experience the effects of fire. Eligible interventions were any management action associated with fire that had an effect on fauna. Eligible comparators were biological and ecological outcomes. Eligible designs were all peer-reviewed studies that produced empirical quantitative and qualitative data related to fire-associated management actions involving both vertebrate and invertebrate fauna. In addition, we reviewed Australian grey literature, or non-peer reviewed reports, published internally by government and non-government agencies. We accepted articles that spanned the period 1991-2020. We only considered literature written in English. We did not impose any constraint on the types of fauna, the timescales of fire-associated management actions in relation to the fire event (pre/post/during), the type of fire (planned or wildfire), or the management action objective (i.e. fauna conservation or other objective).

Meta-data coding

For each article, we extracted data on action type, fauna type, vegetation type, management intent and other parameters (data available at https://github.com/eli-bendall/fauna_actions.git). We allowed for multiple responses for each category (e.g. >1 fauna group), and where possible assigned each response to a specific category. In some instances, actions could not be easily assigned a category, and some individual fauna group responses could not be determined and were thus treated as one category ("multiple"). We developed case studies for Australian ecosystems by analysing the regional literature and drawing contrasts and comparisons with relevant global literature.

Synthesis strategy

We presented our synthesised meta-data in the form of descriptive graphs, tables and heat maps where appropriate. Low numbers of studies with similar designs and objectives precluded meta-analysis. All data and R scripts used to manage data, deduplicate data and screen data are provided online in a data repository (https://github.com/eli-bendall/fauna_actions.git).

Results: Overview and range of actions addressed in the peer-reviewed literature

We accepted 227 peer-reviewed articles for use in our review, based on the eligibility criteria and following the screening process (see Appendix 1 for details on criteria and screening). 62% of articles were from the USA, 14% from Australia, 9% from Canada, with several other countries or studies that considered multiple regions representing minor contributions to the literature (Fig 2). We did not identify any articles from the central or southern Americas, central or sub-continental Asia, northern Africa or Russia, presumably at least in part because we specified English language publications (Fig 2).

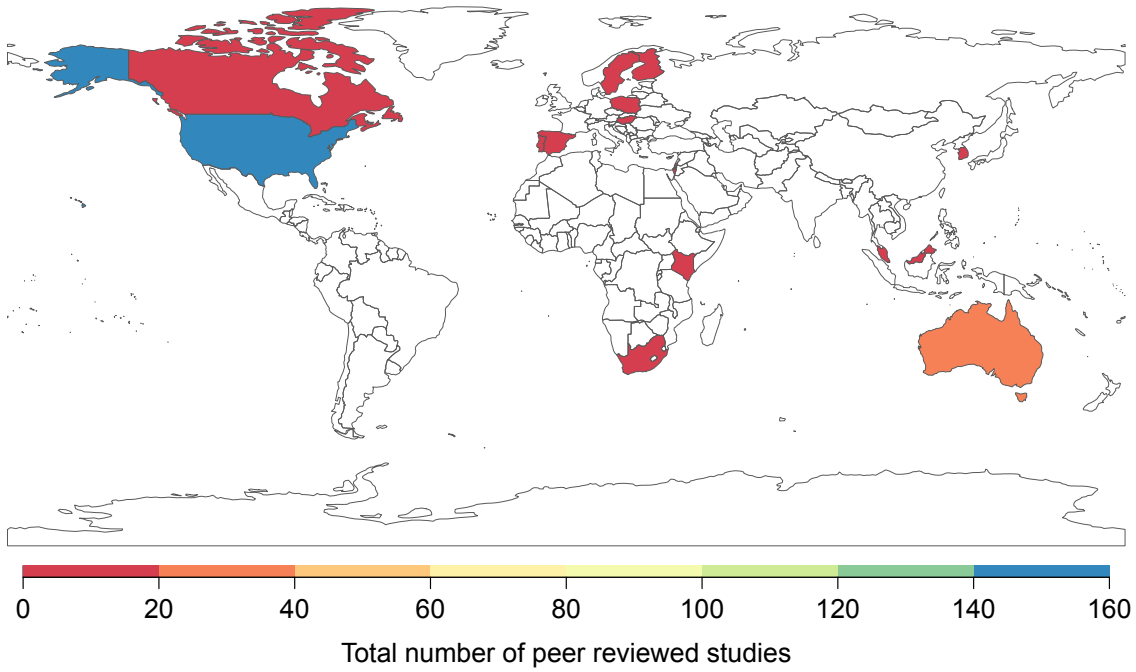


Figure 2. Global map showing the number of peer-reviewed studies per country related to fire-associated management actions that impact fauna.

64% of articles involved forest ecosystems, 14.5% involved grassland ecosystems and 8.5% involved woodland ecosystems; articles involving other ecosystem types contributed less than a combined total of 14% to the literature (Fig 3). The majority of studies examined actions that were performed post-fire (39%) or pre-fire (36%), with 17% performed both pre- and post-fire (Fig 3). Few articles (3%) examined actions that were performed during fire, such as fire control activities, or did not have any timing specified in relation to fire (Fig 3). 32% of articles described actions related to birds, 28% related to invertebrates, 20% related to mammals, 9% related to herpetofauna (reptiles and amphibians), 8% related to multiple taxa and 2% related to fish (Fig 3).

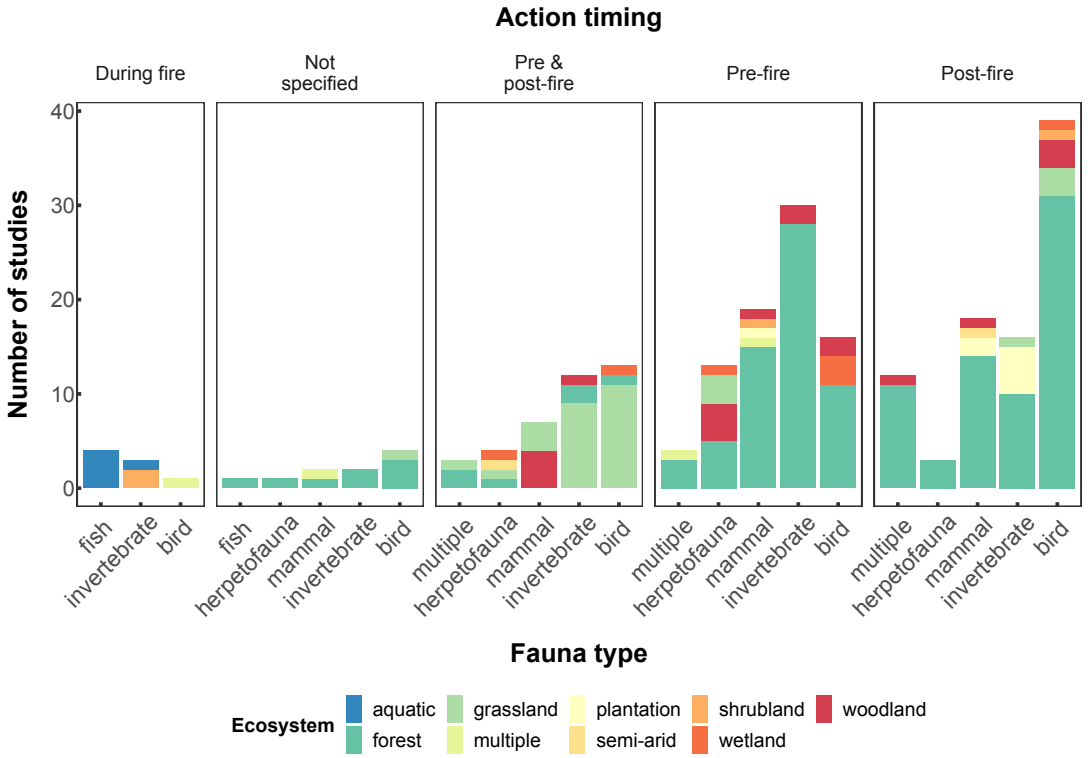


Figure 3. Total number of peer-reviewed studies (left y-axis) for each fauna type (bottom x-axis) performed at different times in relation to fire (panels left to right) among ecosystem types (stacked bars; colour legend defines ecosystem type).

Range of actions

We identified 12 'coarse groups' of fire-associated actions (coarse action groups) that were derived from a broader range of specific actions in the peer-reviewed literature (Fig 4; see Appendix 2 for details on how action groups were assigned). These actions ranged from those intended specifically for fauna conservation to those intended for fire control or resource harvesting but which have impacts for fauna, while some actions were part of multiple management objectives aimed at ecosystem restoration (Fig 4). We defined two forest logging categories: salvage logging, which was conducted post-wildfire, and other types of pre-fire logging, such as those conducted prior to prescribed burns (e.g. post-harvest regeneration burns). We also defined two mechanical forest thinning categories: mechanical ecological thinning and non-ecological mechanical thinning. The majority of studies examined actions that were intended for either resource harvesting (42%) or fauna conservation (37%; Fig 4). The coarse groups represented a larger range of specific actions that were often highly context-specific (see Appendix 2).

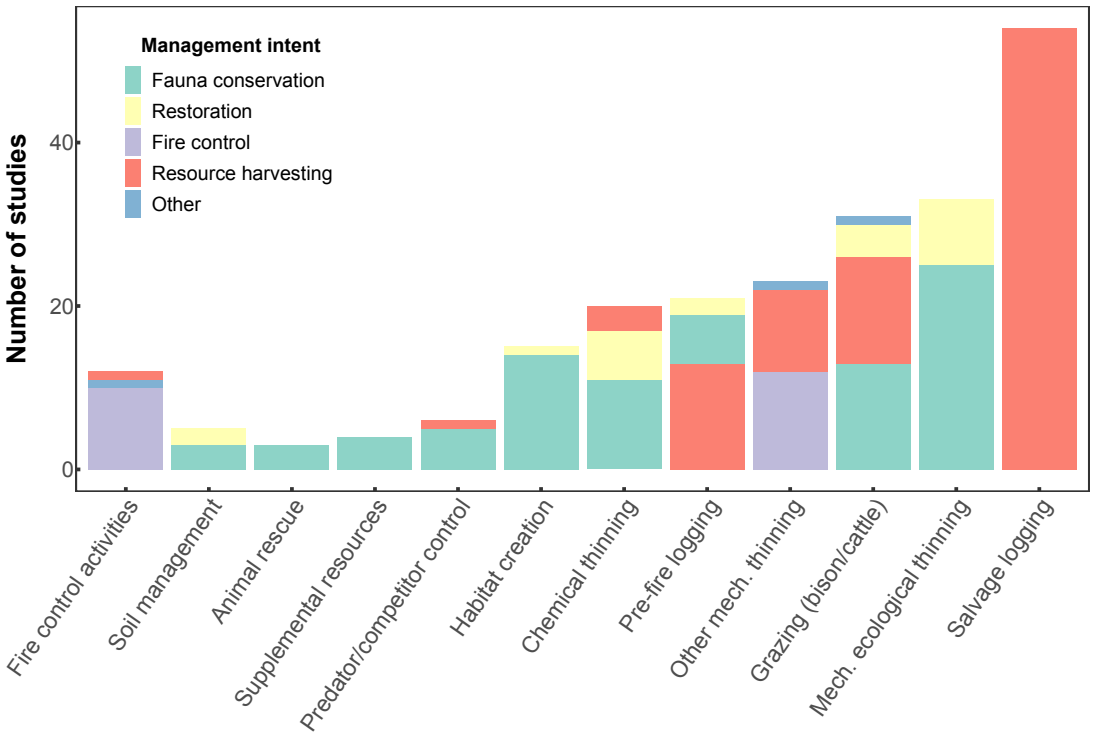


Figure 4. Total number of peer-reviewed studies (left x-axis) for each group of coarse action types (y-axis) in relation to the management intent of the action (stacked bars; colour legend defines management intent). Other = 'Management for research purposes' (n = 1), 'Inadvertant' (n = 1) and 'Unclear' (n =1).

The most commonly reported fire-associated actions, where there were more than two studies per action for a given fauna type in any ecosystem, were generally dominated by forestry practices, such as logging and mechanical thinning, or grazing practices (Fig 5). Studies of fire-associated grazing practices were most common in grassland ecosystems and mostly involved birds or invertebrates (Fig 5). Most studies in forest ecosystems involved some form of mechanical or chemical vegetation removal and also mostly involved birds and invertebrates, with a moderate number involving mammals or multiple taxa (Fig 5). Studies involving herpetofauna or fish were under-represented in the most common action groups (Fig 5). A large range of actions such as predator/competitor control or supplemental food/water were encountered only once or twice for each fauna type in the literature (data available at https://github.com/eli-bendall/fauna_actions.git).

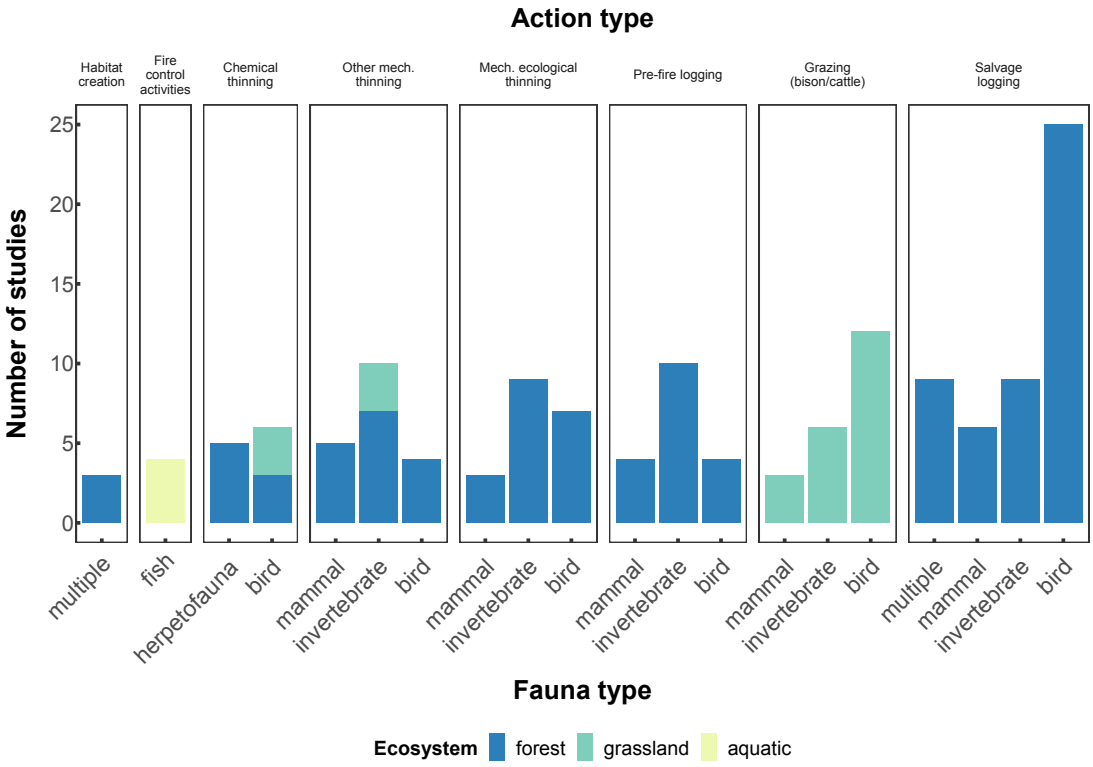


Figure 5. Total number of peer-reviewed studies (left y-axis) for each fauna type (bottom x-axis) in different fire-associated action groups (panels left to right) among ecosystem types (stacked bars; colour legend defines ecosystem type).

Key results on the impact of actions from peer-reviewed literature

64% of studies that reported actions with an overall positive impact on fauna were from the USA, 16% were from Australia, 7.5% were from Finland, while others represented minor contributions (Fig 6a). The total number of different types of coarse-group actions identified that were reported to have an overall positive impact on fauna was highest for the USA (9) and Australia (8), and low in all other regions (<2 per region; Fig 6b).

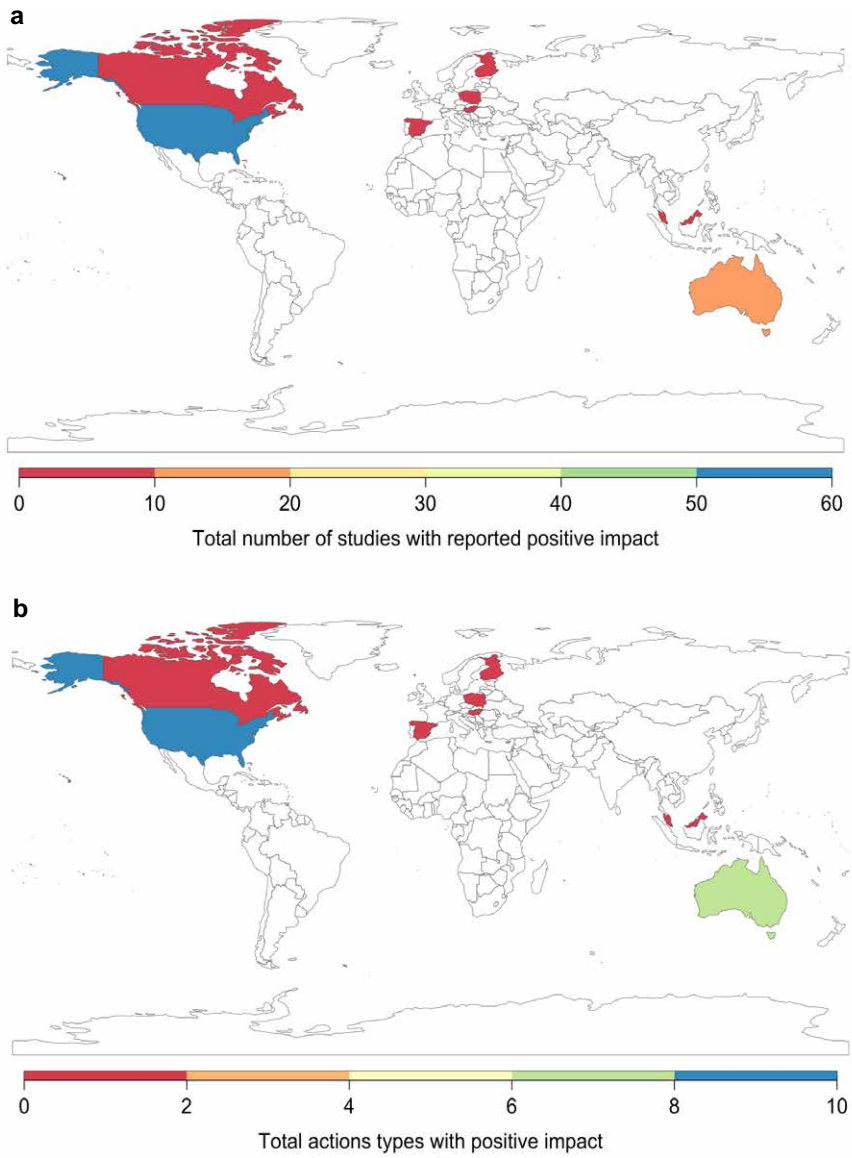


Figure 6. Global map showing the number of peer-reviewed studies per country related to fire-associated management actions that reported an overall positive impact on fauna (panel a) and the number of different types of actions reported to have an overall positive impact on fauna (panel b).

Intent

The majority of studies reported an overall positive impact on fauna when the management intent was fauna conservation (Fig 7). When the management intent was resource harvesting, the majority of studies reported an overall negative impact on fauna (Fig 7).

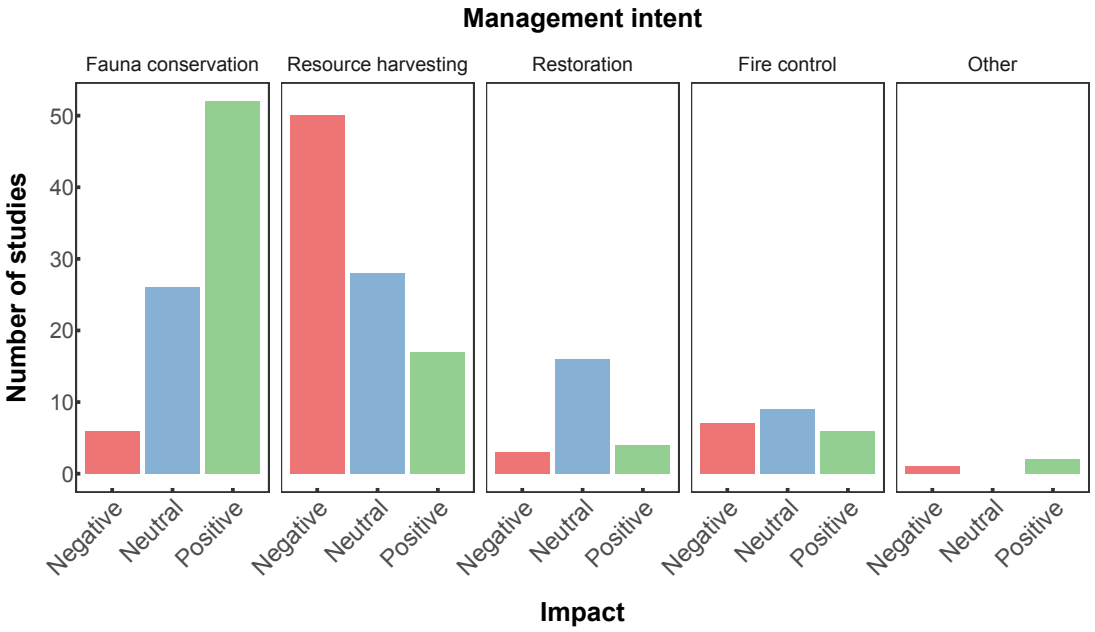


Figure 7. Total number of peer-reviewed studies (y-axis) reported to have positive (green bar), neutral (blue bar) or negative (red bar) overall impacts on fauna, in relation to management intent of the action (panels left to right).

Birds

Fire-associated actions that had an overall positive impact on birds in >50% of studies included all types of vegetation thinning and habitat creation (e.g. artificial nest boxes; Fig 8) – although we note that the number of studies in many action types was low. Post-fire salvage logging had an overall negative impact on forest birds in >75% studies, while other types of pre-fire logging had either negative or neutral impacts (Fig 8). Various types of ecological grazing practices (e.g. patch-burn grazing) had an overall positive impact on grassland birds in >50% of studies (Fig 8).

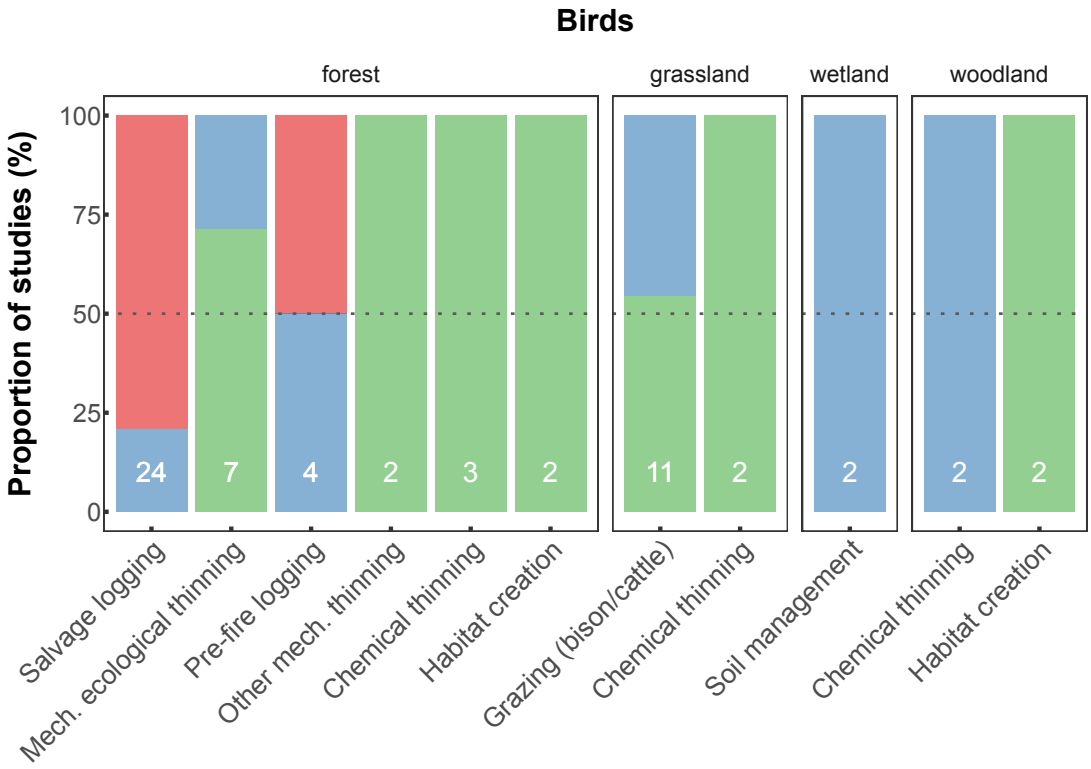


Figure 8. The proportion of bird-related studies (x-axis) within each fire-associated action (coarse group; left y-axis) reported to have positive (green stacked bar), neutral (blue stacked bar) or negative (red stacked bar) overall impacts on fauna in different ecosystem types (panels left to right). White numerals = number of studies for each action.

Invertebrates

Post-fire salvage logging, types of mechanical thinning and grazing practices generally had mixed impacts on invertebrates, while other types of pre-fire forest logging generally had positive impacts (Fig 9). Other types of actions generally had neutral impacts on invertebrates (Fig 9).

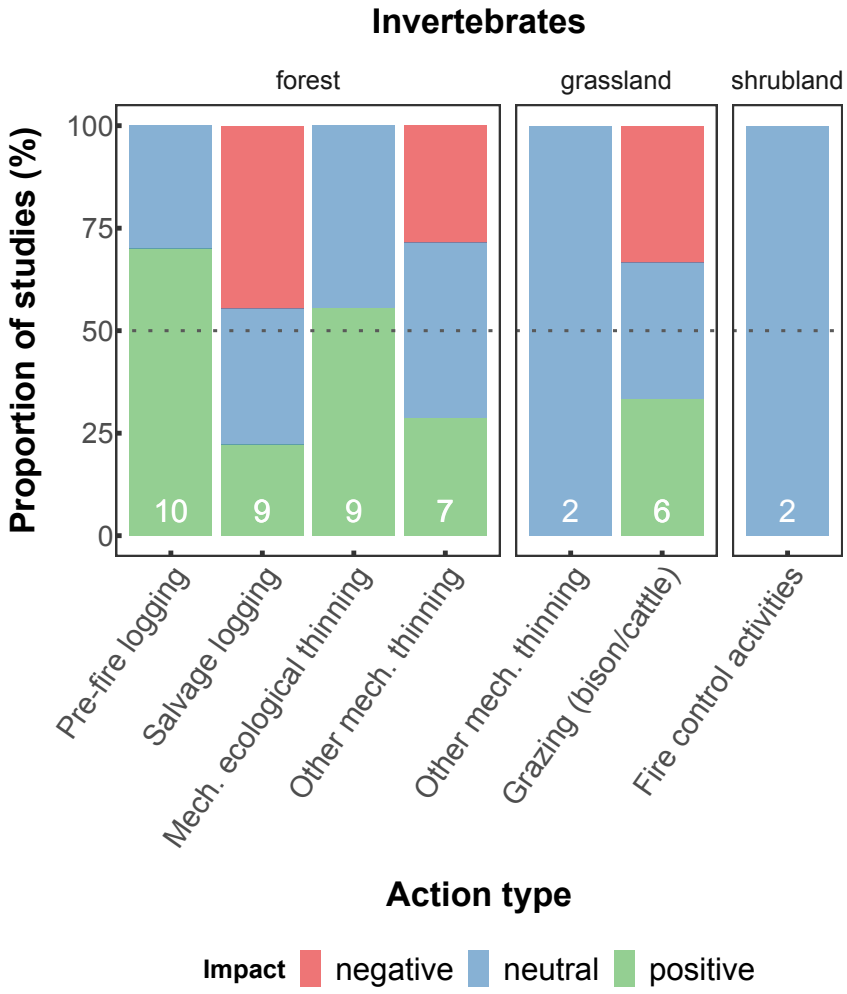


Figure 9. The proportion of invertebrate-related studies (x-axis) within each fire-associated action (coarse group; left y-axis) reported to have positive (green stacked bar), neutral (blue stacked bar) or negative (red stacked bar) overall impacts on fauna in different ecosystem types (panels left to right). White numerals = number of studies for each action.

Mammals

Fire-associated mechanical ecological vegetation thinning in forests and grazing practices in grasslands had an overall positive impact on mammals in >50% of studies, while post-fire salvage logging generally had a negative impact (Fig 10). Other types of pre-fire forest logging had both positive and negative impacts in equal proportions, while non-ecological vegetation thinning generally had neutral or positive impacts (Fig 10). Note that we found few or no studies reporting on the responses of mammals to some action types (e.g., habitat creation).

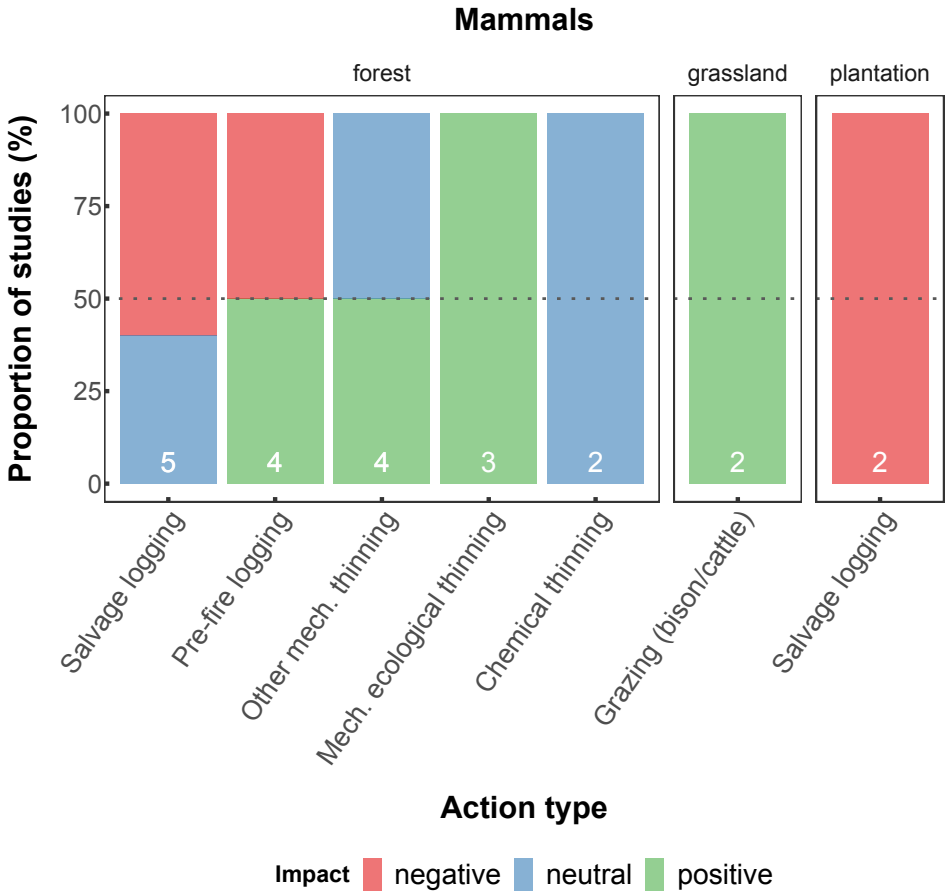


Figure 10. The proportion of mammal-related studies (x-axis) within each fire-associated action (coarse group; left y-axis) reported to have positive (green stacked bar), neutral (blue stacked bar) or negative (red stacked bar) overall impacts on fauna in different ecosystem types (panels left to right). White numerals = number of studies for each action.

Other taxa

There were very few studies reporting on any fire-associated actions related to herpetofauna (2 studies per action) or fish (n = 5). Types of vegetation thinning and forest logging had a neutral impact on forest-dwelling herpetofauna in both cases. For fish, most studies examined the effects of fire-retardant chemicals, which were reported to have negative impacts in all cases. For studies that examined multiple taxa (n = 12), salvage logging had an overall negative impact in all cases (n = 8). Other studies that examined the effects of types of vegetation thinning and habitat creation reported positive impacts on multiple taxa in all cases (n = 4).

Overview and range of actions identified in the Australian grey literature

We accepted 68 grey literature articles for use in our review, based on the eligibility criteria and following the screening process (see Appendix 1 for details on criteria and screening). 28% of articles were from New South Wales, 14.5% each were from Queensland, South Australia or were country-wide, while Tasmania, Western Australia, Victoria and Northern Territory contributed the remainder (Fig 11).

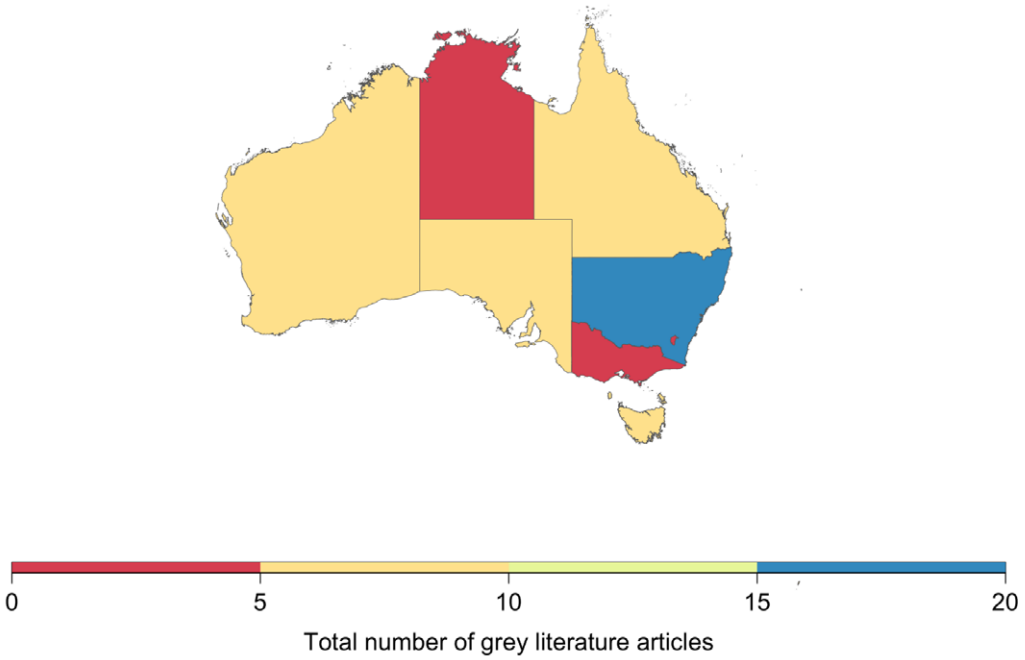


Figure 11. Map of Australia showing the total number of grey literature articles found per state/terrtory that mentioned fire-associated actions that impact fauna.

Grey literature articles were different in structure, approach, intent and purpose compared with the published literature. Rather than formal studies, experiments and reviews, the grey literature mainly consisted of government agency or organisation operations manuals, management plans or policies (51.5%), agency technical reports (19%), government agency or other organisation website articles (12%), with other article types contributing a minor proportion to the grey literature (Fig 12). The majority of articles described an adopted action and its implementation (59%), with most of these found within manuals, management plans or policies (Fig 12). 31% of articles described a potential action, while few articles described the implementation of an action and how/whether the action was monitored (7.5%) or reported on the effectiveness of an action for conserving fauna (n articles = 1). Overall, the grey literature was skewed toward actions that had perceived conservation benefit, rather than describing actions that may have negative consequences for fauna.

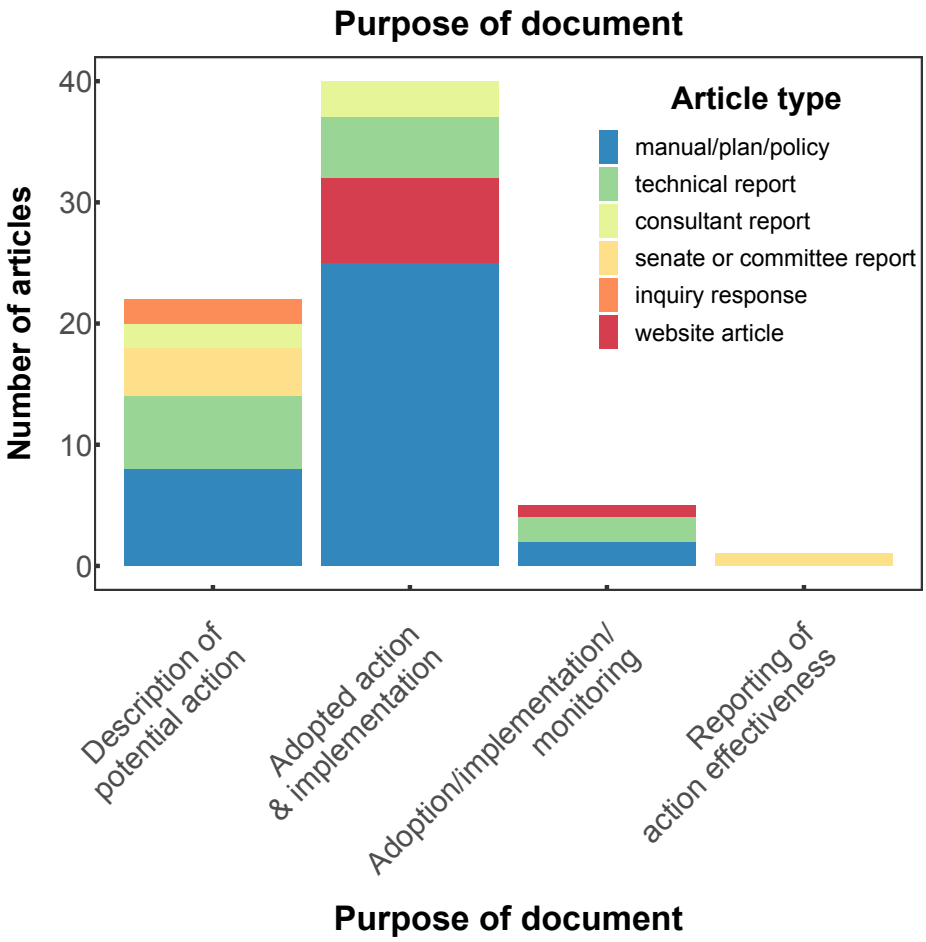


Figure 12. Total number of grey literature articles (x-axis) among document purpose categories (x-axis), article type (colour legend defines article type).

A substantial number of grey literature articles mentioned different actions multiple times for different fauna and ecosystem types. Thus, we pooled the articles and summarised at the level of the coarse action group, rather than at the level of the article. We found 325 mentions of fire-associated actions across the grey literature articles, with 27.5% of actions described at the federal level, largely due to several documents with large lists of actions for priority species following the 2019-2020 fire season (see Australian Government 2020; Legge *et al.* 2020). 18.5% of actions were mentioned for New South Wales, 12.5% for Queensland, 11% for South Australia, ~9% each for both South Australia and Western Australia, with other state and territories contributing the remainder (Fig 13).

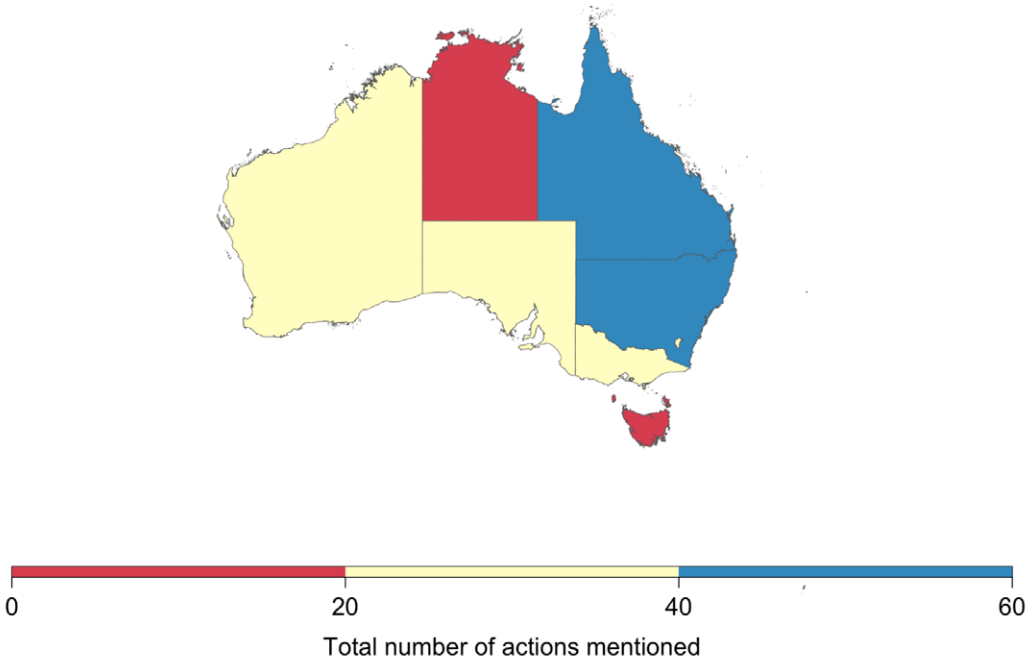


Figure 13. Map of Australia showing the total number of mentions of fire-associated actions across grey literature articles.

Many actions described in the Australian grey literature were highly general in nature and 13.5% did not pertain to specific ecosystems (Fig 14). 29% of actions applied in forest ecosystems, 19.5% applied across most southern temperate ecosystems, 17.5% applied in woodlands, 9% applied in aquatic ecosystems and 6% applied in alpine ecosystems, while actions for other ecosystem types contributed minor proportions (Fig 14). The majority of actions were intended for use post-fire (59.5%), while a smaller number of actions were intended for use pre-fire (15.5%) or did not have specified timing with relation to fire (15%; Fig 14). Some actions were intended for use both pre- and post-fire (7%), or during fire (5.5%; Fig 14). 27% of actions did not relate to any specific taxa, 26% related to mammals, 17% related to birds, 14% related to herpetofauna, 10% related to invertebrates and 5.5% related to fish (Fig 14).

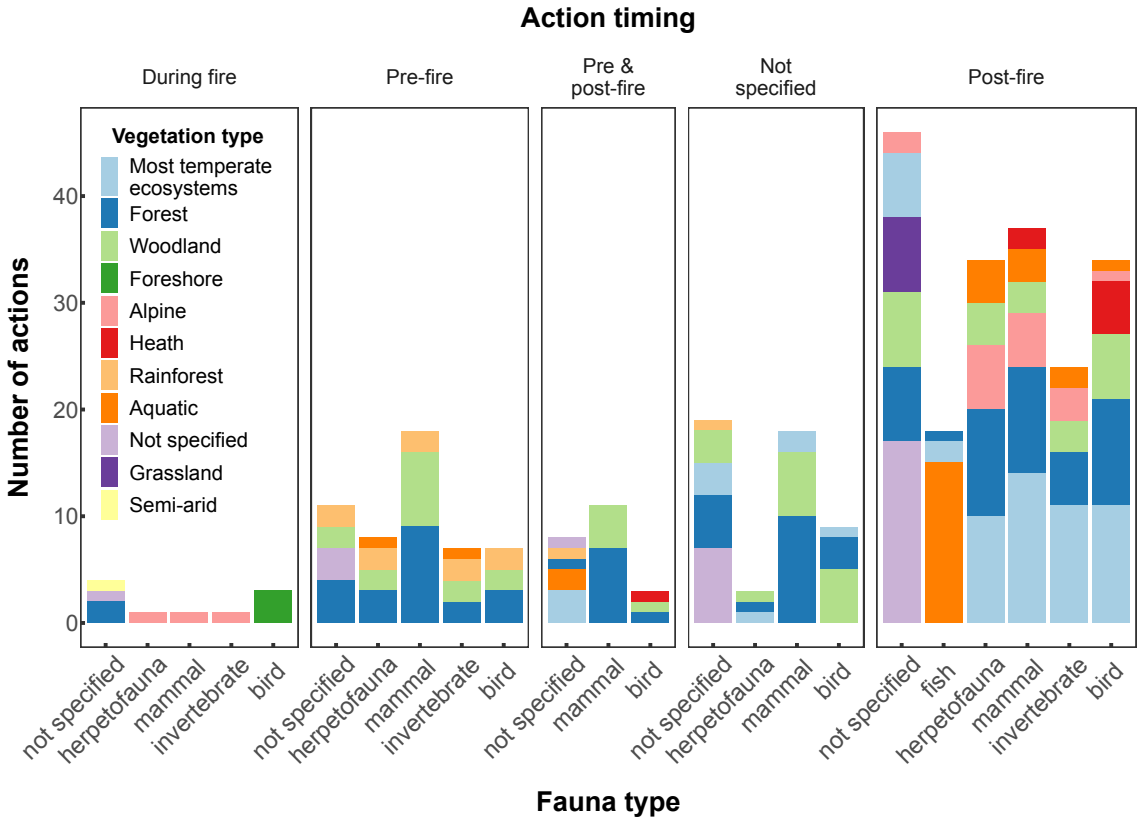


Figure 14. Total number of fire-associated actions that impact fauna mentioned across all grey literature articles (left y-axis) for each fauna type (bottom x-axis) performed at different times in relation to fire (panels left to right) among ecosystem types (stacked bars; colour legend defines ecosystem type).

Range of actions

We identified 13 'coarse groups' of fire-associated actions in the Australian grey literature (Table 2). Some of these action groups were more ambiguous in meaning than those presented in the peer-reviewed literature and so a table is presented for clarification (Table 2). The coarse groups represented a larger range of specific actions that were often highly context-specific (see Appendix 2). Most actions we encountered had fauna conservation objectives. Many represented some form of administrative changes or funding allocation in response to concerns about fauna survival or welfare in post-fire landscapes, while others represented some form of environmental mitigation during or following fire control activities or commercial forestry. For example, some documents (e.g. Bradshaw 2015, VicForests 2018, NSW DPIE 2020a) were comprehensive management plans for natural areas that contained policy and procedures for many aspects of management including but not limited to: personnel and public safety, legal requirements, rules and regulations applying to protected areas and fire management plans, and sections that applied to fauna conservation. Sometimes, these sections were brief and contained general, non-specific information such as excluding sensitive areas such as critical habitat for endangered species or riparian areas from burn perimeters or mechanical disturbance (Bradshaw 2015, NSW DPIE 2020a). In contrast, some articles contained detailed actions for a large number of species (VicForests 2018) . Sometimes, these documents referred to specific site-management or park/reserve operational plans that may apply where an activity is to take place. These may be contained within other agency documentation but were not covered in depth by our review.

Table 2. Table of 13 coarse groups of fire-associated actions that impact or potentially impact fauna described in Australian grey literature.

Fire-associated coarse action group	Description
Admin/funding	Plans, policies and reports that describe the allocation of/need for additional funding and/or resources for fauna conservation/welfare
Predator/competitor control	Exclusion fencing, poison baiting, shooting, weed removal
Mitigating harm from fire	Strategic exclusion zones for fauna habitat or sensitive areas during prescribed fire activities or wildfire control activities; Raking/removal of fuels around habitat features
Monitoring/research/consultation/education	Plans, policies and reports that describe the implementation/need for population monitoring, surveys, scientific research, expert/industry consultation and practitioner/public education around practices
Post-fire environmental. rehabilitation	Post-fire habitat rehabilitation, e.g. replanting, repairing damaged infrastructure/enclosures; Rehabilitation of areas degraded by fire control activities
Animal rescue	Animal rescue and rehabilitation/release, emergency translocation, emergency salvage for ex-situ conservation
Supplementary resources	Supplementary food, water or shelter
Logging/land clearing	Forest harvesting activities or land clearing for development or agriculture
Pollution prevention	Preventing post-fire chemical, nutrient or sediment pollution in waterways or swamps; erosion control infrastructure
Ecological grazing	Grazing practices designed to reduce fuel loads and strategically modify habitat
Restriction of public access	Closure of natural areas to protect fauna/refugia and/or allow regeneration. Can be administrative closure or use of physical barriers
Prevention of poaching	Methods not described; preventing illegal collection of animals from the wild
Fire control activities	Damage to natural areas due to creation of fire breaks, control lines, backburning, fire retardant use, residential or commercial vegetation clearing

Key results from the Australian grey literature

Birds

The majority of fire-associated actions that related to birds applied specifically in forests and woodlands, or applied more broadly across most southern temperate ecosystems (Fig 15). Actions for heathland birds had moderate representation (e.g. at least 5 mentions) while actions for alpine, aquatic, rainforest and foreshore birds were under-represented (<1 mention per action; Fig 15). The most common actions mentioned for birds were habitat creation (e.g. artificial nest boxes), mitigating harm from fire (e.g. exclusion zones, habitat tree protection), supplementary food or water, some form of scientific investigation and predator control (Fig 15). Moderately common actions included some form of environmental rehabilitation (e.g. plantings, remediating degraded areas; n = 5) and animal rescue or translocation (n = 3; Fig 15).

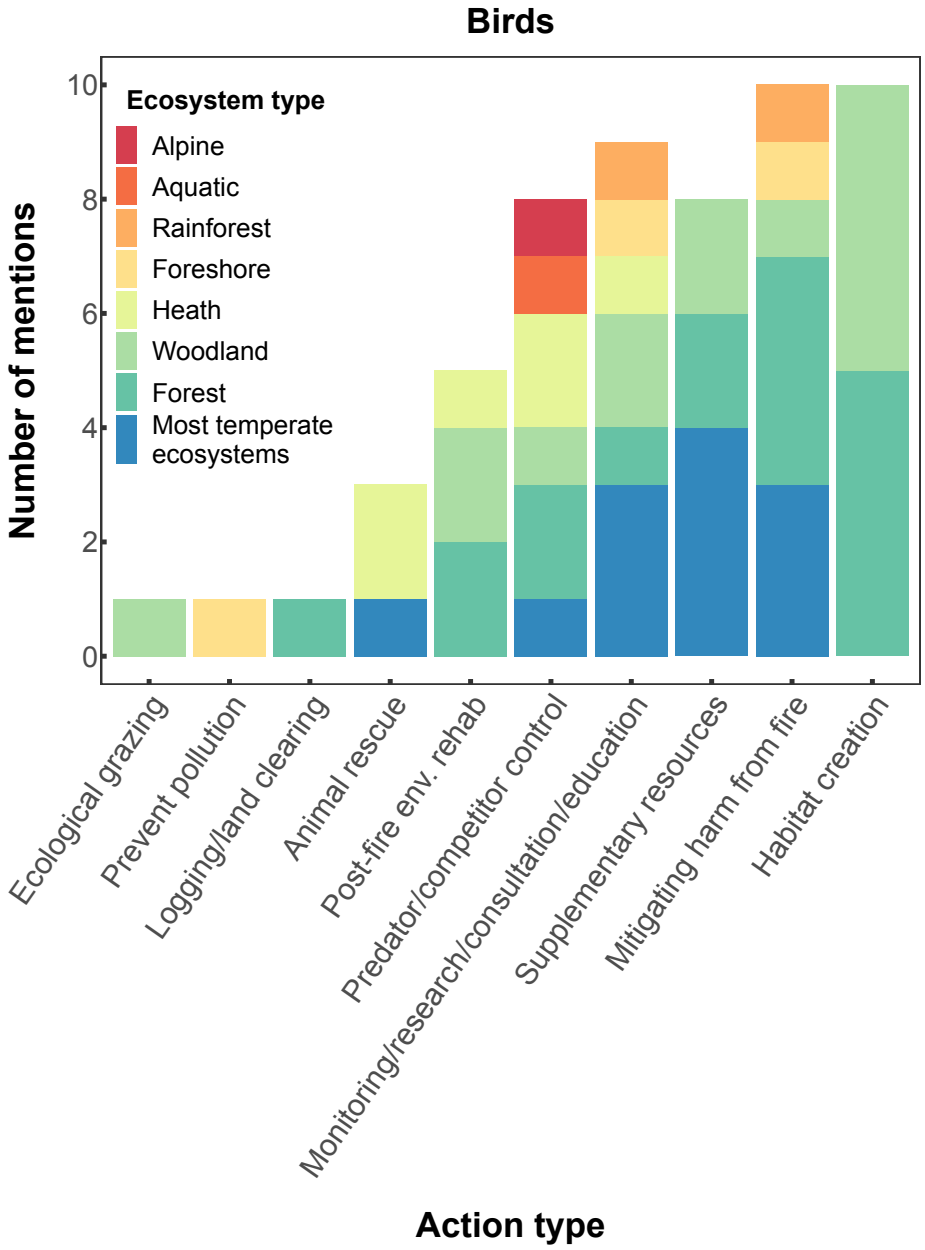


Figure 15. Total number of mentions of fire-associated actions involving birds among all grey literature articles (y-axis), within each fire-associated action (x-axis) in different ecosystem types (stacked bars; colour legend defines ecosystem type).

Mammals

The majority of fire-associated actions that related to mammals applied specifically to forests and woodlands, or applied more broadly across most southern temperate ecosystems (Fig 16). Actions for mammals in all other ecosystems were under-represented (Fig 16). The most common actions mentioned for mammals were mitigating harm from fire (e.g. exclusion zones, habitat tree protection), some form of scientific investigation, supplementary food or water, habitat creation (e.g. artificial nest boxes) and fauna rescue or translocation (Fig 16). Predator/competitor control was moderately common (n = 5) while all other actions were mentioned a few times (Fig 16).

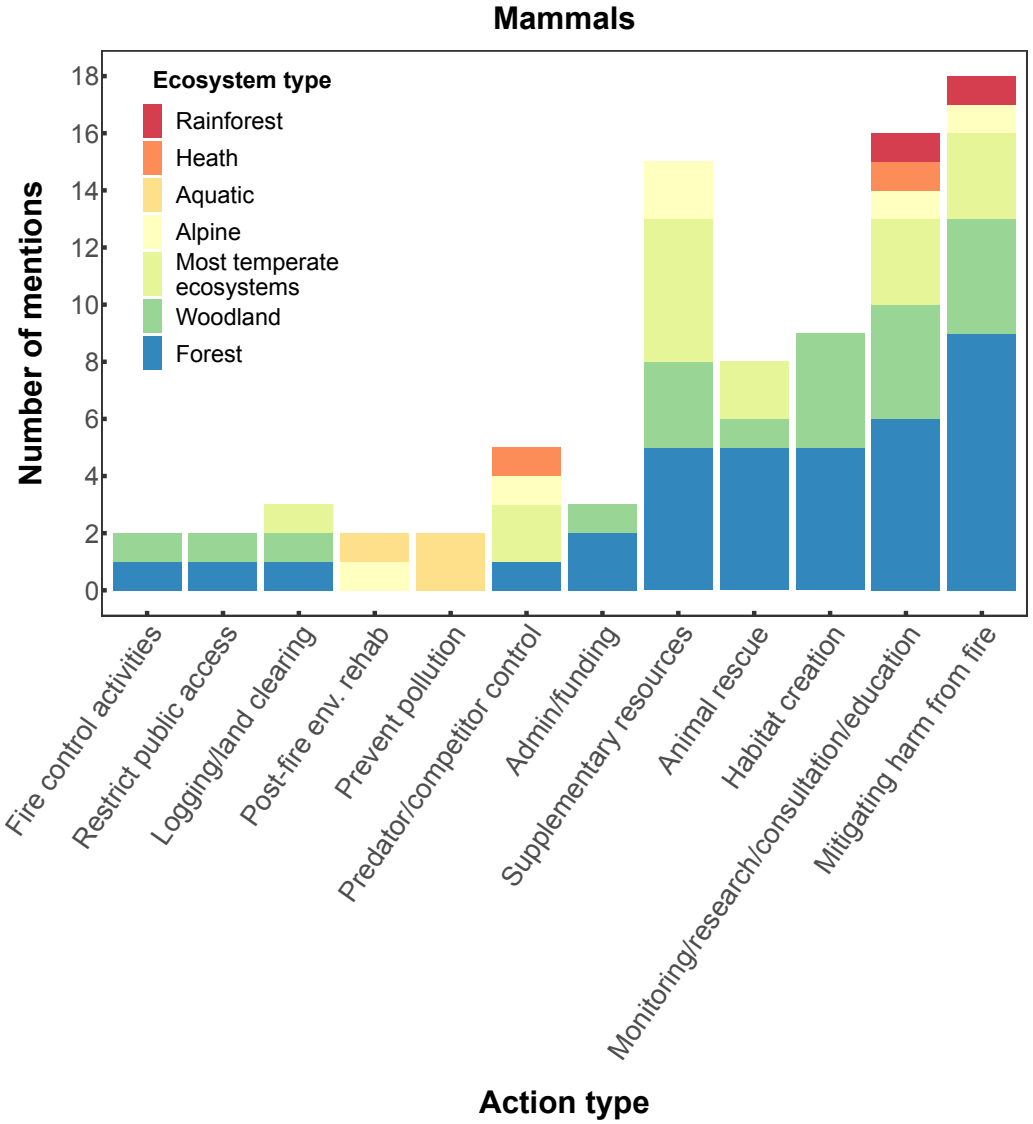


Figure 16. Total number of mentions of fire-associated actions involving mammals among all grey literature articles (y-axis), within each fire-associated action (x-axis) in different ecosystem types (stacked bars; colour legend defines ecosystem type).

Herpetofauna

Fire-associated actions that related to herpetofauna had moderate representation (e.g. at least 5 mentions) across most southern temperate ecosystems, and specifically in forests, woodlands, alpine and aquatic ecosystems (Fig 17). Actions for herpetofauna in rainforest ecosystems were under-represented (<1 mention per action; Fig 17). The most common actions mentioned for herpetofauna were mitigating harm from fire (e.g. exclusion zones, habitat protection), some form of scientific investigation, supplementary food or water, habitat creation (e.g. artificial shelters), animal rescue or translocation and predator/competitor control (Fig 17). All other actions were mentioned less than 2 times (Fig 17).

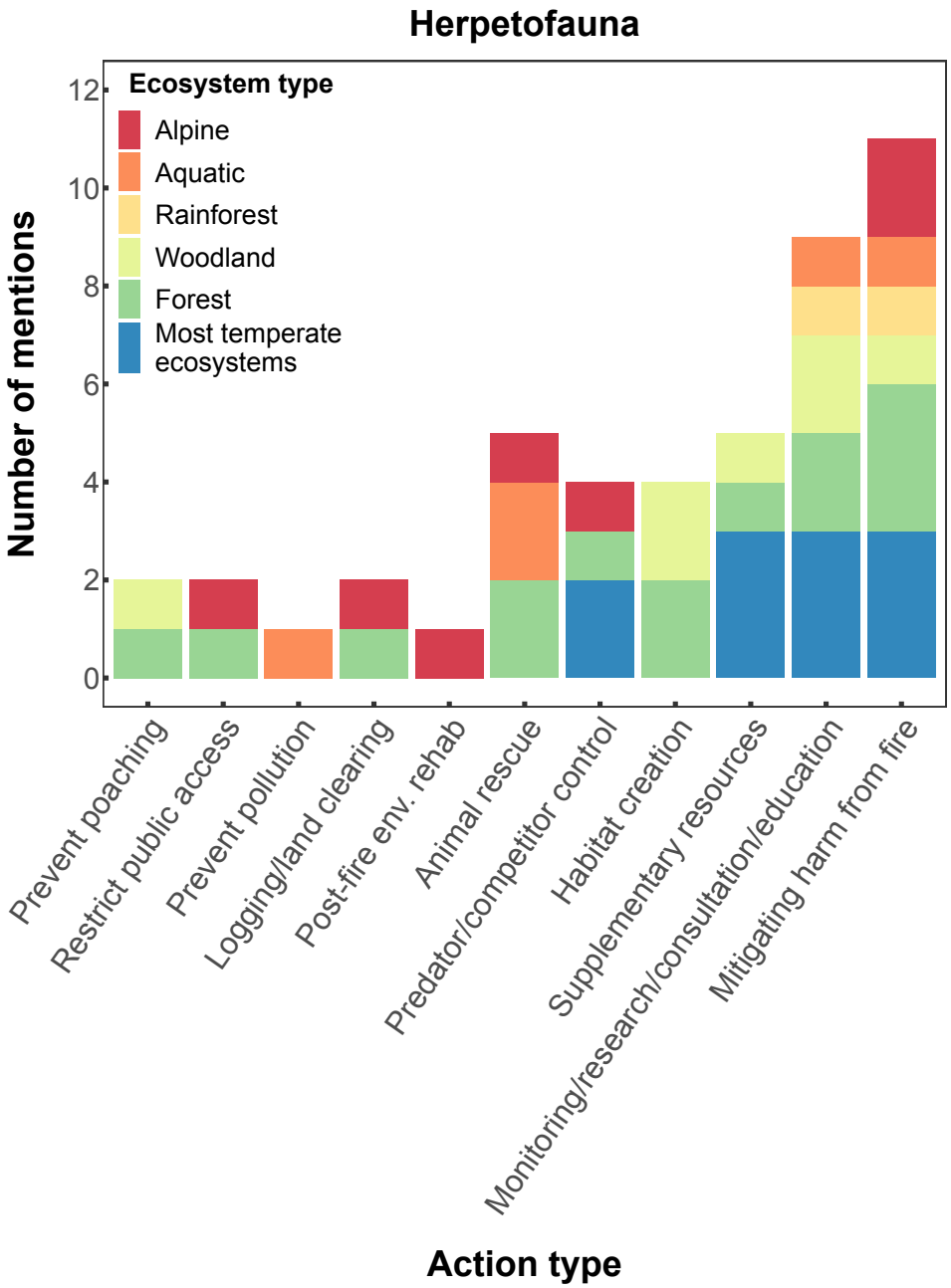


Figure 17. Total number of mentions of fire-associated actions involving herpetofauna among all grey literature articles (y-axis), within each fire-associated action (x-axis) in different ecosystem types (stacked bars; colour legend defines ecosystem type).

Fish

The most common fire-associated actions mentioned for fish in aquatic ecosystems were scientific investigation, fauna rescue or translocation and mitigating harm from fire (e.g. exclusion zones, habitat protection; Fig 18). A number of other actions were mentioned only once each (Fig 18).

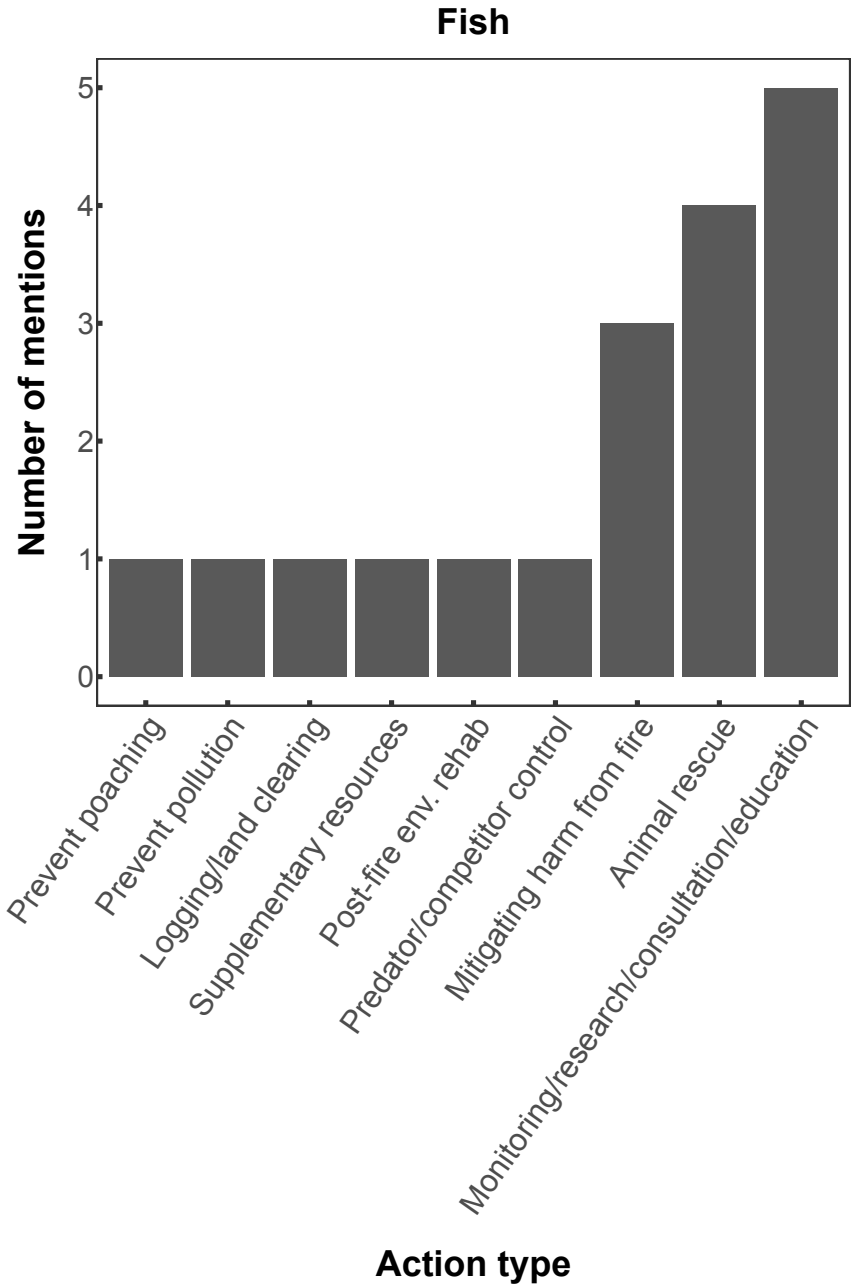


Figure 18. Total number of mentions of fire-associated actions involving fish among all grey literature articles (y-axis), within each fire-associated action (x-axis) in aquatic ecosystems.

Invertebrates

Fire-associated actions that related to invertebrates had low (e.g. 1-2) mentions across most ecosystems (Fig 19). The two most common actions mentioned for invertebrates were mitigating harm from fire (e.g. exclusion zones, habitat protection) and some form of scientific investigation (Fig 19). Predator/competitor control, animal rescue or translocation and supplementary food or water were mentioned a few times each (Fig 19).

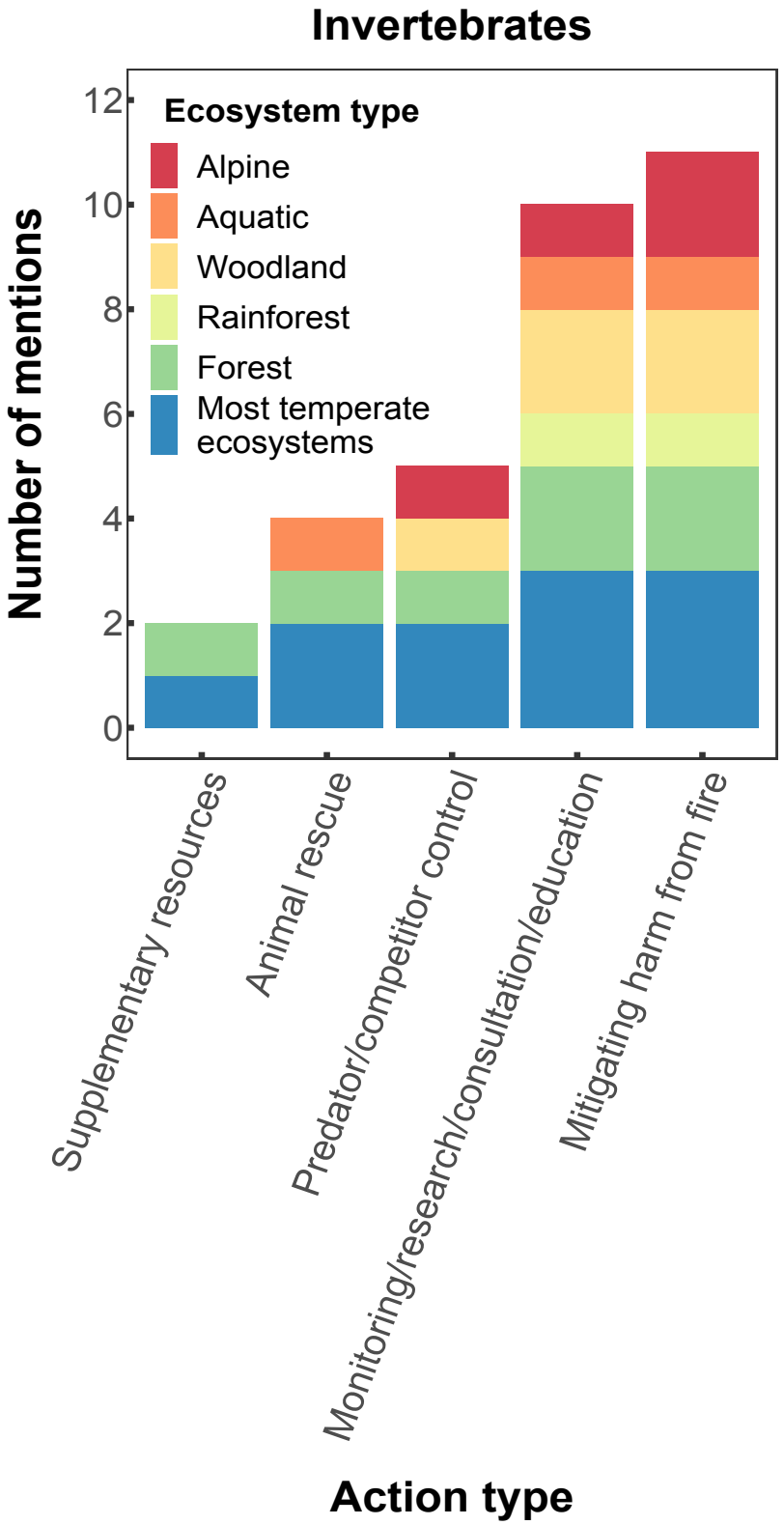


Figure 19. Total number of mentions of fire-associated actions involving invertebrates among all grey literature articles (y-axis), within each fire-associated action (x-axis) in different ecosystem types (stacked bars; colour legend defines ecosystem type).

Taxa not specified

Actions that were non-specific regarding taxa were highly general in nature and many of these actions were not ecosystem-specific (Fig 20). The most common of these types of actions represented some form of administrative protocol, e.g. scientific investigation or monitoring, allocation of funding resources or strategies to mitigate harm from fire (Fig 20). A range of other actions were mentioned through the filter of generalised fauna management (Fig 20).

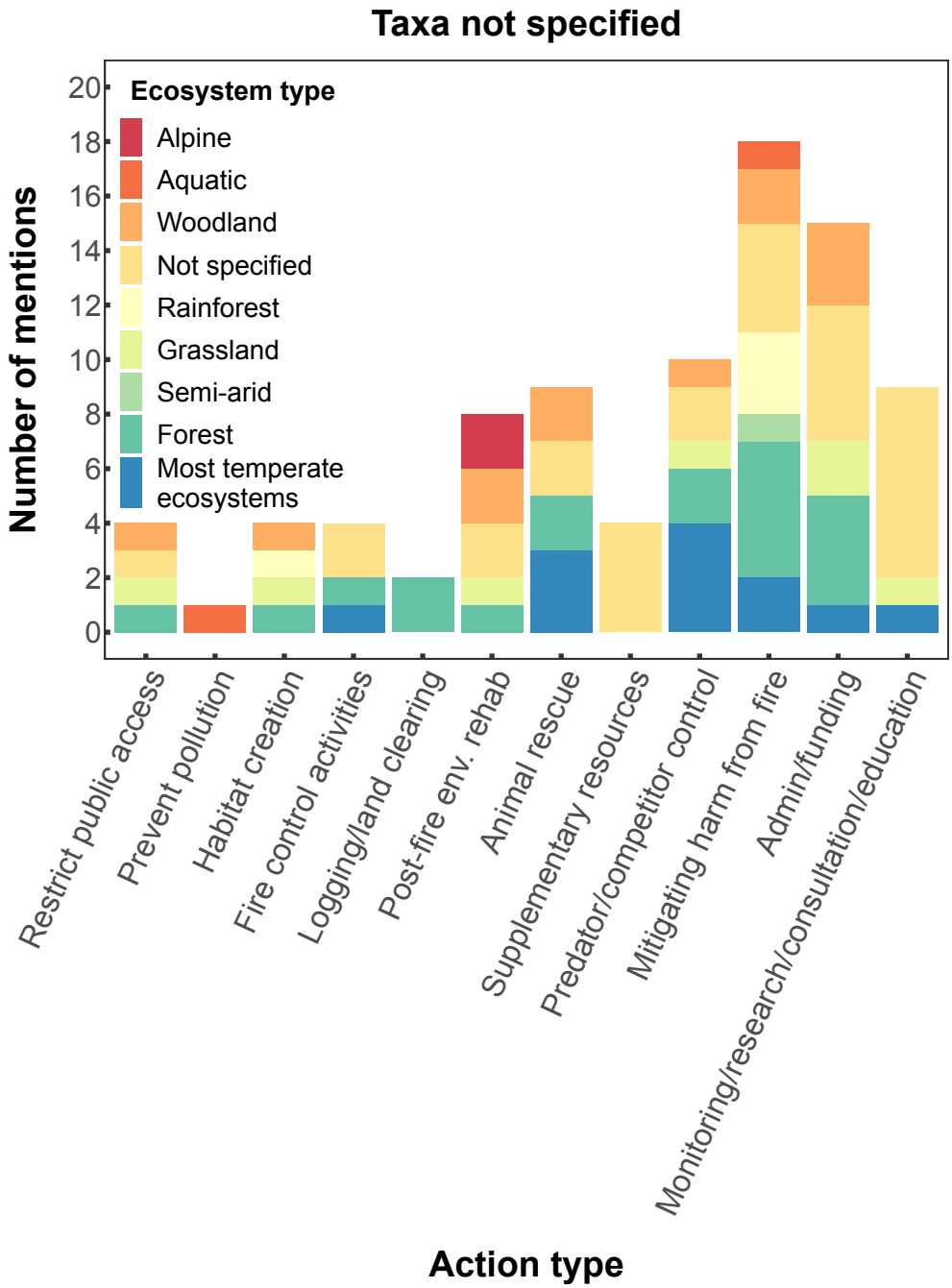


Figure 20. Total number of mentions of fire-associated actions among all grey literature articles where taxa was not specified (y-axis), within each fire-associated action (x-axis) in different ecosystem types (stacked bars; colour legend defines ecosystem type).

Discussion

Based on our systematic review of the peer-reviewed global literature, there is a wide range of fire-associated management actions that impact fauna. Studies examining actions intended for either fauna conservation or resource harvesting were comparably frequent, though fauna conservation actions were typically more diverse (Fig 3). Overall, the most common fire-associated actions related to some form of salvage logging and other types of forest logging, types of vegetation thinning or grazing (Fig 4). Studies that examined these actions typically aimed to quantify the effectiveness of alternative approaches to intensive, non-ecological management, or quantify the impacts of intensive approaches (e.g. Koivula and Schmiegelow 2007; Churchwell *et al.* 2008). Fire-associated actions that facilitated the departure of an ecosystem from a natural state, such as salvage logging, generally had negative impacts on fauna (Figs 6-9). However, we did find examples where some species (e.g. generalists, open-habitat specialists) benefitted from these practices (Rost *et al.* 2012, Rost *et al.* 2013). Conversely, fire-associated actions that attempted to return an ecosystem to a natural state, via ecological thinning or ecological grazing, generally resulted in positive impacts on native fauna (Kalies *et al.* 2010). In many cases there were species-specific responses to such actions and there were often both 'winners' and 'losers'. Thus, a common conclusion among studies we encountered was that 'one-size-fits-all' solutions are often inappropriate; and mosaic-style approaches to land management, that create environmental heterogeneity, are more likely to achieve conservation aims across taxa. More specifically, spatio-temporal variation in disturbance severity and type is usually recommended to fulfil the ecological requirements of co-existing species in disturbance-prone terrestrial ecosystems.

We also found a diverse range of actions within the Australian grey literature, which was substantially more focused on post-fire actions compared to the peer-reviewed literature (59% versus 39%; Figs 2,13). For example, there was much higher frequency of post-fire conservation actions such as habitat creation, supplementary resources and animal rescue within the grey literature, with much of this being published in recent years (last two years, data available at https://github.com/eli-bendall/fauna_actions.git). In contrast, the grey literature described relatively few pre-fire 'strategic' actions compared to the peer-reviewed literature (15% vs 36%; Figs 2,13). The clearest example of this result is the absence of grey literature describing long-term strategic ecosystem restoration actions that involved some form of vegetation thinning preceding prescribed fires.

There was also a distinct systemic difference in the content between the published literature and grey literature: most published literature was scientific studies describing the effectiveness of actions via testing and we were able to report impacts based on results, while the grey literature generally did not provide any measure of action effectiveness (Fig 11). Further, many actions that we identified within the Australian grey literature were highly general in nature and were non-specific regarding fauna and/or ecosystem type (Figs 13,19). Within this category of 'general fauna management', and for a number of taxa, some of the most frequently mentioned actions related to changes in administrative procedures, funding allocations or proposed scientific investigations (Figs 14-19), categories that were not of primary interest to our review. Other common actions, such as mitigating harm from fire or predator control were often implemented as part of the operational plans and procedures of land or fire management agencies.

Key knowledge gaps

Our analysis of the peer-reviewed literature revealed major knowledge gaps regarding the impacts of fire-associated actions on fauna globally. All ecosystems other than forests and grasslands had poor coverage and herpetofauna and fish were under-represented across all ecosystems. Further, the majority of studies that we encountered were based in temperate regions, with very few covering tropical regions (Fig 5). Studies that considered the impact of fire-associated actions on multiple taxa had adequate coverage in forests only (Fig 4). Fire-associated actions directly concerned with fauna conservation, such as artificial habitat, supplemental feeding or predator control were adequately covered for birds and mammals in forests, and for birds-only in grasslands, highlighting how little is known about the effectiveness of these measures in most ecosystems. With the exception of forests and grasslands, there was poor coverage of the impacts of actions on fauna where resource harvesting/fire control activities were concerned, or where management objectives aim to balance multiple landscape uses, such as resource harvesting, fuel reduction, restoration and fauna conservation. This suggests that little is known of the effects of resource timber harvesting-fire interactions or grazing-fire interactions in woodlands (e.g. both temperate and tropical) or semi-arid/arid regions.

At the coarse-group level used in our results, there was reasonable coverage of fire-associated actions directly concerned with fauna conservation for a range of ecosystems and fauna types within Australia. These actions included installation of artificial habitat, supplementary feeding and animal rescue. Further, there was reasonable coverage of general, non-taxa specific actions, such as consideration of threatened or fire-sensitive species/ecosystems in management plans (e.g. fire exclusion, fauna rescue protocols) and broad administrative actions. Our review revealed major knowledge gaps in the grey literature regarding the effectiveness, and thus the rationale, of fire-associated actions implemented in Australia (Fig 11). The only species that had multiple documents dedicated to its management in relation to fire was the koala (*Phascolarctos cinereus*), e.g. a number of koala management plans that detailed appropriate strategies for managing koala populations where fire-control or forest-harvesting related activities were concerned (e.g. Port Stephens Council 2002, NSW Government 2014, Clarence Valley Council 2015, QLD DES 2020). This grey literature on koalas outnumbered the two peer-reviewed studies that have investigated fire-associated actions relating to this species (Lunney *et al.* 2004, Wallis 2013). Combined, these studies and documents represent the largest body of knowledge related to fire-associated actions for an Australian animal species.

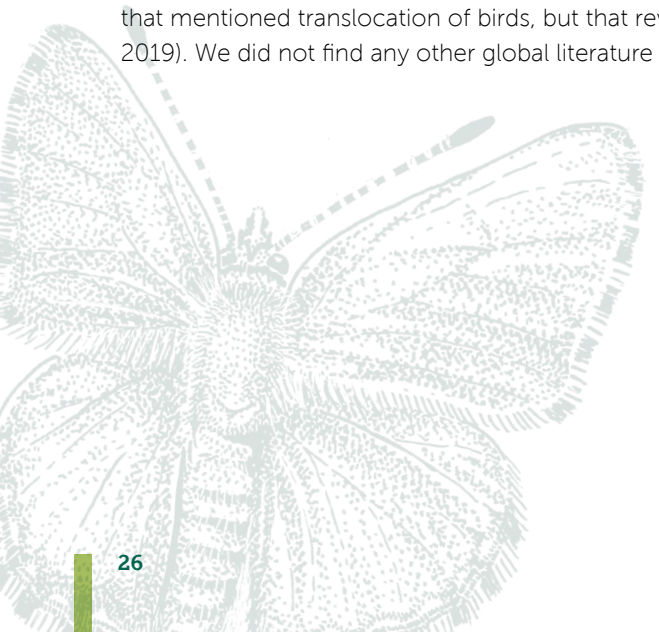
Although we did not explicitly seek to collate information on the costs and cost-effectiveness across the range of possible actions, we suspect that little such information is available. This may be an important knowledge deficiency, as budgets available for fire-related management programs are invariable finite, and those seeking to optimise the recovery of biodiversity post-fire, or to build resilience in ecosystems pre-fire, will need to select that suite of management actions that delivers the greatest cost-effectiveness.

Case study: Forest & woodland vertebrates

Our review scope and eligibility criteria placed limitations on the number of articles retrieved for some topics. For example, fire-associated management actions such as animal rescue, translocation, and artificial habitat are underpinned by a wealth of research that is not fire specific. However, for this review, we only included articles that specifically addressed these actions in the context of fire. This review demonstrates that empirical data on the responses of fauna to these actions within the context of fire are currently lacking. Thus, the case studies here reflect this and are not exhaustive narratives on these topics in general.

Animal rescue/translocation

We recognise that animal rescue can be primarily motivated by welfare considerations (reducing suffering caused by fire) rather than species conservation objectives. Our review is focussed on the latter. In the only study of its kind within our selected set, Lunney *et al.* (2004) quantified the survival rates of 39 burnt koalas (*Phascolarctos cinereus*) that had been rescued, rehabilitated and released. Rehabilitated koalas and a control group of uninjured koalas that remained in the fireground were monitored in the years following release and similar survival and reproductive rates were measured between the groups, suggesting that the fauna rescue and rehabilitation procedures followed in that case were effective for re-introducing koalas into forests. Lunney *et al.* (2004) found substantial long-term mortality in both burnt and unburnt groups (58% vs 67%), which reinforces the utility of experimental controls for drawing conclusions about the effectiveness of actions. We found two other mentions of fauna rescue in the peer-reviewed literature: Wallis (2013), which focused on administrative malfunction of a fauna management program and (McCarthy and Taylor 2018), which focused on the efficiency and coordination of fauna rescue operations during a fire emergency, rather than fauna conservation outcomes. We found one review of practitioner perspectives concerning a range of management actions used for red-cockaded woodpecker (*Leuconotopicus borealis*) conservation in the USA that mentioned translocation of birds, but that review did not present any details on action effectiveness (Weiss *et al.* 2019). We did not find any other global literature that tested the efficacy of fire-related fauna rescue/rehabilitation.



Habitat creation

We found several peer-reviewed studies that addressed both the design and use of artificial habitat by Australian forest and woodland fauna, within a management context related to fire. Saunders *et al.* (2020) found that endangered Carnaby's cockatoo (*Zanda latirostris*) will readily use and breed in artificial nest boxes installed in fire-affected landscapes. In their study, occupancy rates, predation rates and breeding rates were similar among repaired natural hollows and artificial nest boxes (n = 476), demonstrating the utility of such actions where hollow availability may be limiting (Saunders *et al.* 2020). In contrast, Lindenmayer *et al.* (2003) found that arboreal marsupials did not readily use artificial nest boxes in forests affected by fire and salvage logging. In their study, various nest box sizes were trialled at different heights on trees to account for the needs of different possum species. Most nest boxes (~80%) showed little evidence of occupation and around 10% were occupied by insects making them unsuitable for possums. Additionally, the high cost and labour of maintaining nest boxes in disturbance-prone wet forests was suggested to be a management challenge over the long term (Lindenmayer *et al.* 2003). Croft *et al.* (2010) installed unburnt habitat logs within a fire-affected forest and found that ground-dwelling vertebrates preferentially sheltered under these unburnt logs, compared to burnt, residual logs. However, Grigg and Steele (2011) found that artificially placed habitat log-piles may not be effective as a conservation measure for ground-dwelling fauna over the long term, without continued maintenance to replenish logs following fires. In particular, Grigg and Steele (2011) calculated the half-life of logs, i.e. the natural attrition rate due to fire as 1.1 fires for small logs, 1.5 fires for large logs and 3.7 fires for stumps.

We found few other studies globally that investigated artificial habitat as a fire-associated conservation action. Two reviews summarising actions used for the largely successful conservation of red-cockaded woodpeckers (USA) referred to artificial hollows as an important part of a broader range of conservation actions, though it appears that much of the data is contained within the North American grey literature, which was not covered by our review. Chambers *et al.* (2002) found that microbats will readily use artificial nest boxes that mimic their host tree species in fire-affected conifer forests, particularly where natural hollow availability has been reduced. Further, their study details the design, costs and longevity of different nest box designs, and proposes that the method can be adapted to any tree species.

Supplementary resources

We found one peer-reviewed study that examined the effectiveness of providing supplementary food and water to Australian fauna within the context of fire. Treby *et al.* (2007) assessed whether northern hairy-nosed wombats (*Lasiorhinus krefftii*) will readily take supplementary food and water over the long term, under the premise that wildfire or drought could result in depletion of the animal's natural supply. There was no fire or drought treatment used in the study but it was conducted longitudinally, spanning periods of low rainfall. Treby *et al.* (2007) found that the endangered wombats will readily take feed and water over the long term, with peak activity around feeding stations during periods of inadequate rainfall and thus reduced vegetation productivity. However, feeding stations were used extensively by macropods, which are natural competitors of norther hairy-nosed wombats for food resources (Treby *et al.* 2007). As such, increased competition for natural food resources by macropods was a perverse outcome of supplementary feeding in this study. Details on food ingredients and feeding station design are provided in Treby *et al.* (2007).

Similarly, we found very few studies globally that examined providing supplementary resources to fauna within the context of fire. In two related studies, Morris *et al.* (2011b, 2011a) assessed the abundance and survival of sympatric rodent species in relation to fire and supplemental feeding. Supplemental feeding dramatically increased the abundance of cotton mice in between prescribed fire cycles in both burned and unburned plots, suggesting that cotton mice (*Peromyscus gossypinus*) benefit from supplemental food following fire (Morris *et al.* 2011b). Sympatric hispid cotton rats (*Sigmodon hispidus*) also benefitted from supplemental feeding but these benefits were strongly negated by the effects of fire, which dramatically reduced rat populations (Morris *et al.* 2011a). Though mammalian predators were excluded in both studies, predation by reptiles and birds was suggested as a likely reason for the sharp decline in rats following fire, due to their requirements for dense vegetation cover. In alignment with Treby *et al.* (2007), these studies suggest that supplemental feeding may come with additional management issues that need to be considered.

A third study assessed the potential for transplanting reindeer lichen mats into post-fire salvage-logged boreal forests to supply reindeer with food, while in-situ lichens recolonise (Roturier *et al.* 2017). Lichen transplant was successful in both salvaged and unsalvaged stands, although lichens were slower to colonise in salvaged stands, likely due to increased exposure and thus desiccation (Roturier *et al.* 2017).

Conclusions

Which actions?

Our review provides clear evidence that many of the fire-associated actions that are currently used or proposed to be used within Australia may be valid and reasonable, but have little supporting scientific evidence demonstrating their effectiveness. A key caveat that we acknowledge is that we only reviewed literature that described actions implemented in association with fire. A number of management actions included in our review are implemented outside of fire (e.g. supplementary feeding, nest boxes), and are likely to inform post-fire fauna recovery. For example, there may be a range of ecological, veterinary or zoological studies that quantify the effectiveness of fauna rescue/translocation, habitat creation or supplemental feeding that were not identified during our search of the literature. It is likely that many actions described in the grey literature, and the expert advice informing them (e.g. see Legge *et al.* 2020), are derived from such publications and have been adapted for use in the context of fire. Thus, our review should be seen as complimentary to other sources of information for informing fauna conservation and recovery in the context of fire.

Some fire-associated actions were reported to generally have positive or neutral impacts on fauna globally, while meeting other management aims such as fuel reduction, which we generally did not encounter in the Australian grey literature. Table 3 summarises these actions, and where/for which fauna they might be applied in an Australian context.

Table 3. Table of fire-associated actions that were reported to have positive or neutral impacts for most taxa globally, ecosystems where they have been tested (G = grassland; F = Forest; W = Woodland) and the potential Australian ecosystems and taxa where they might be considered for further inquiry.

Fire-associated action	Which ecosystems has it been tested for?	Which fauna has it been tested for?	Which Australian ecosystems might this action be considered for use in?	Which Australian fauna might this action be considered for?	Potential issues for consideration
Ecological/patch-burn grazing	Grasslands	Birds (G) Mammals (G) Inverts (G)	Grasslands Woodlands Farmland	Birds: open-habitat specialists or ground-dwelling Mammals: wide range Inverts: unknown	Studies mostly in areas historically grazed by bison Trampling effects on nesting birds and reptiles
Ecological vegetation thinning	Forests Woodlands Grasslands	Birds (F,W,G) Mammals (F) Herps (F) Inverts (F,G)	Dry sclerophyll forests Wet sclerophyll forests Overgrown or weedy ecosystems	Birds: open-habitat specialists, generalists Mammals: open-habitat specialists, generalists Herps: most Inverts: pollinators	May be inappropriate for taxa requiring dense cover Damage by vehicles or machinery Weed ingress

Our review has highlighted some major knowledge gaps around the effectiveness of fire-associated actions that are currently implemented or proposed to be used in Australia. This may need to be addressed for the following reasons:

i. Fire-related fauna rescue/rehabilitation/release, habitat creation and supplemental feeding are widely recognised and utilised actions within Australian land management agencies and animal welfare organisations (NSW DECC 2008, International Fund for Animal Welfare 2020, National Parks and Wildlife Service South Australia 2020, NSW DPIE 2020b);

ii. Such actions have been widely proposed for most taxonomic groups following the 2019-2020 fire season, including threatened and endangered species (Australian Government 2020b, a, DELWP 2020, Legge *et al.* 2020);

iii. While these actions may be presumed to be appropriate or effective, there is very little published evidence available in the context of bushfires.

We recognise that these actions may have a range of objectives besides conservation management, including welfare of individual animals, and community engagement, recovery and empowerment. However, understanding their conservation benefit, and how that could be optimised, could help make conservation funding more effective. Furthermore, we note that in some cases, such as the need for emergency conservation response precipitated by the 2019-2020 Australian wildfires, there is likely to be benefit in implementing actions that are broadly consonant with what is known of an affected species' ecology, threats and resource requirements, rather than robust direct evidence, especially when it may take many years to establish such evidence. In such cases, there is a need to ensure that such actions are counterpointed by well designed monitoring programs and implemented in a manner that can most robustly assess the extent to which the actions provide benefit and/or may cause detriment.

Some of these key knowledge gaps are likely to be addressed through the implementation of a program of major research, management and monitoring projects undertaken in Australia following the catastrophic 2019-20 wildfires (e.g., https://www.environment.gov.au/biodiversity/bushfire-recovery). The capability to harvest this knowledge will depend on the extent to which the outcomes of this investment are robustly monitored and the results documented and collated. Results from this set of studies should provide a much more robust evidence base to help guide and prioritise management actions in any future comparable fire events. Indeed, it may take events as catastrophic as the 2019-20 Australian fires to reveal the sparseness of the evidence base needed to guide post-fire recovery, and hence to generate a major research effort to address such knowledge gaps.

Kangaroo Island shortly after the 2019-20 bushfires. The scale of the fires left few unburnt refuge patches for wildlife. Image: Nicolas Rakotopare

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Appendix 1

Materials and methods

Databases

On 29/09/2020, we searched the bibliographic databases Scopus (https://www.scopus.com), Web of Science (https://www.webofknowledge.com) and ProQuest (https://www-proquest-com). We did not update any search results following this single round of searching.

Search terms: Peer-reviewed literature

We searched Web of Science using the crude (or naïve) search string: (("post-fire" OR fire* OR "post fire" OR "postfire" OR burn*) AND (manag* OR strategi* OR restor* OR action* OR practice* OR salvage) AND (fauna OR animal* OR wildlife OR bird* OR mammal* OR reptile* OR amphibian* OR vertebrate* OR invertebrate*))). The first 2000 relevant titles returned in this search were downloaded as a bibliographic list (.bib) from both Web of Science and Scopus. We used the 'litsearchr' package for R version 3.5.0 (Grames et al. 2019; R Core Team 2020) to extract keywords from the list using the function 'extract_terms' and then built a term co-occurrence network using the functions 'create_dfm' and 'create_network'. Potential search terms were then manually screened and irrelevant terms removed, before using the function 'write_search' to generate a string that was used to search Web of Science and Scopus (see below). We searched other select smaller databases, such as CSIRO publishing using a simplified search string (see below).

Search terms: Peer-reviewed literature

Primary search string

(("aborigin* burn*" OR "aborigin* burn* practic*" OR "annual* burn*" OR "annual* spring* burn*" OR "area* burn*" OR back-burn* OR "black-out* burn*" OR "burn* area*" OR "burn* forest*" OR "burn* forest* stand*" OR "burn* grassland*" OR "burn* habitat*" OR "burn* landscap*" OR "burn* marsh*" OR "burn* stand*" OR "burn* treatment*" OR "burn* veget*" OR "burn* frequenc*" OR "burn* practic*" OR "burnt* area*" OR "burnt* forest*" OR "burnt* habitat*" OR "burnt* patch*" OR "burnt* plot*" OR "burnt* site*" OR "burnt* veget*" OR bushfir* OR "catastroph* wildfir*" OR "control* burn*" OR "crown* fire*" OR "cultur* burn*" OR "cultur* burn* practic*" OR "discret* fire*" OR "ecolog* burn*" OR "experiment* burn*" OR "extens* wildfir*" OR "fire* frequenc*" OR "fire* intens*" OR "fire* regim*" OR "fire* sever*" OR fireground* OR "fire* threaten*" OR "forest* fire*" OR "forest* wildfir*" OR "frequent* burn*" OR "frequent* fire*" OR "frequent* prescrib*" OR "frequent* wildfir*" OR "high* intens* burn*" OR "indigen* burn*" OR "indigen* burn* practic*" OR "intens* fire*" OR "intens* burn*" OR "intens* prescrib* burn*" OR "intens* wildfir*" OR "larg* wildfir*" OR "low intens* burn*" OR "mosaic* burn*" OR "natur* fire*" OR "natur* wildfir*" OR "plan* burn*" OR post-fir* OR "postfir* forest*" OR "postfir* landscap*" OR "postfir* manag*" OR "postfir* salvag*" OR "postfir* salvag* logging" OR "prescrib* burn*" OR "prescrib* fire*" OR "prescrib* spring* burn*" OR "recent* burn*" OR "recent* fire*" OR "recent* wildfir*" OR "recent* burn* area*" OR "recent* burn* forest*" OR "recent* burn* patch*" OR "recent* burnt*" OR "recent* burnt* site*" OR "recent* burnt* veget*" OR "repeat* burn*" OR "repeat* fire*" OR "replac* crown*" OR "replac* crown* fire*" OR "replac* fire*" OR "replac* wildfir*" OR "restor* burn*" OR "scale* wildfir*" OR "season* burn*" OR "season* fire*" OR "sever* wildfir*" OR "sever* burn* forest*" OR "sever* burn*" OR "sever* fire*" OR "spring* burn*" OR "spring* prescrib*" OR "spring* prescrib* burn*" OR "summer* burn*" OR "summer* wildfir*" OR "surfac* fire*" OR "unplan* fire*" OR wildfir* OR "wildfir* disturb*" OR "wildfir* effect*" OR "wildfir* frequenc*" OR "wildfir* regim*" OR "winter* burn*") AND ("action* plan*" OR "activ* manag*" OR "adapt* manag* approach*" OR "aerial* food* drop*" OR "aerial* re-seed*" OR "altern* manag*" OR "anim* rescu*" OR "anim* transloc*" OR "artifici* habitat*" OR bait* OR "biolog* control*" OR "bulldoz* line*" OR chain* OR "conserv* action*" OR "conserv* approach*" OR "conserv* effort*" OR "conserv* initi*" OR "conserv* manag*" OR "conserv* measur*" OR "conserv* outcom*" OR "conserv* practic*" OR "conserv* program*" OR "conserv* strategi*" OR "contour* bank*" OR "control* line*" OR "control* program*" OR "control* strategi*" OR cull* OR "dozer* line*" OR "drainag* line*" OR "ecolog* monitor*" OR "effect* approach*" OR "effect* conserv*" OR "effect* conserv* strategi*" OR "effect* control*" OR "effect* manag*" OR "effect* manag* strategi*" OR "effect* strategi*" OR "emerg* salvag*" OR "emerg* transloc*" OR "enhanc* wildlif* habitat*" OR "eros* control*" OR "evalu* restor*" OR "ex-situ* conserv*" OR "fire* break*" OR "fire* retard*" OR "firewood* collect*" OR "food* drop*" OR "gulli* eros* control*" OR "habitat* augment*" OR "habitat* manag* practic*" OR "habitat* manag* strategi*" OR "habitat* manipul*" OR "herbicid* applic*" OR "herbicid* treatment*" OR "landscap* restor*" OR "leaf* litter* augment*" OR "manag* action*" OR "manag* activ*" OR "manag* altern*" OR "manag* approach*" OR "manag* experi*" OR "manag* intervent*" OR "manag* measur*" OR "manag* method*" OR "manag* option*" OR "manag* outcom*" OR "manag* practic*" OR "manag* practic* affect*" OR "manag* program*" OR "manag* programm*" OR "manag* project*" OR "manag* scheme*" OR "manag* strategi*" OR "manag* techniqu*" OR "manag* tool*" OR "manual* re-seed*" OR "monitor* program*" OR "monitor* protocol*" OR "moorland* manag*" OR "popul* manag*" OR "postfir* logging" OR "postfir*

manag*" OR "postfir* salvag*" OR "postfir* salvag* logging" OR "postfir* timber*" OR "postfir* timber* harvest*" OR "predat* control*" OR "predat* refug*" OR "predat* shelter*" OR "prevent* action*" OR rake-ho* OR re-se* OR re-seed* OR "recoveri* action*" OR refug* OR "refug* habitat*" OR refugia* OR rehabili* OR "restor* action*" OR "restor* activ*" OR "restor* ecolog*" OR "restor* effort*" OR "restor* experi*" OR "restor* measur*" OR "restor* object*" OR "restor* practic*" OR "restor* program*" OR "restor* strategi*" OR "restor* success*" OR "restor* techniqu*" OR "restor* treatment*" OR "restor* habitat*" OR "salvag* harvest*" OR "salvag* logged" OR "salvag* logging" OR "salvag* logging oper*" OR "salvag* logging prescript*" OR "salvag* oper*" OR "salvag* area*" OR "sediment* control*" OR shelter* OR "siltat* control*" OR "speci* manag*" OR "speci* recoveri*" OR "supplement* feed*" OR "supplement* food*" OR "supplement* water*" OR "supplementari* shelter*" OR "treatment* effect*" OR "undergo* restor*" OR "water* station*" OR "wild-to-wild* transloc*" OR "wildlif* habitat* improv*" OR "wildlif* manag*" OR "wildlif* stand* improv*") AND ("acadian* flycatch*" OR "aerial* insectivor*" OR "affect* anim*" OR "affect* wildlif*" OR "agelaius* phoeniceus*" OR "aimophila* aestivali*" OR "alpin* fauna*" OR "american* kestrel*" OR "american* robin*" OR "american* toad*" OR "ammodramus* henslowii*" OR "ammodramus* leconteii*" OR "ammodramus* maritimus*" OR "ammodramus* savannarum*" OR amphibian* OR "amphibian* communiti*" OR "amphibian* popul*" OR "amphibian* respons*" OR "amphibian* speci*" OR anim* OR "anim* abund*" OR "anim* assemblag*" OR "anim* communiti*" OR "anim* distribut*" OR "anim* divers*" OR "anim* group*" OR "anim* movement*" OR "anim* popul*" OR "anim* respons*" OR "anim* speci*" OR ants OR "aphelocoma* coerulescen*" OR "aquat* fauna*" OR "aquat* invertebr*" OR "arbor* fauna*" OR "arbor* mammal*" OR "arbor* marsupi*" OR "arthropod* abund*" OR "assemblag* composit*" OR "assemblag* structur*" OR "australian* mammal*" OR avian* OR "avian* abund*" OR "avian* assemblag*" OR "avian* biodivers*" OR "avian* communiti*" OR "avian* communiti* composit*" OR "avian* communiti* respons*" OR "avian* communiti* structur*" OR "avian* conserv*" OR "avian* divers*" OR "avian* habitat*" OR "avian* occup*" OR "avian* popul*" OR "avian* predat*" OR "avian* product*" OR "avian* respons*" OR "avian* speci*" OR "avian* speci* rich*" OR avifauna* OR "back* vole*" OR "back* woodpeck*" OR "bartramia* longicauda*" OR "beetl* abund*" OR "beetl* assemblag*" OR "beetl* larva*" OR "beetl* outbreak*" OR "beetl* popul*" OR "beetl* speci*" OR "bill* cuckoo*" OR "bird* compar*" OR "bird* increas*" OR "bird* nest*" OR "bird* respond*" OR "bison* bison*" OR "bobwhit* habitat*" OR "boreal* forest* bird*" OR "bore* beetl*" OR "breast* nuthatch*" OR "breed* bird*" OR "breed* speci*" OR "brown* bandicoot*" OR "brown* creeper*" OR "brushtail* possum*" OR "burrow* fauna*" OR "burrow* mammal*" OR "butterfli* speci*" OR "california* spot*" OR "calluna* vulgari*" OR "carabid* beetl*" OR "cardinali* cardinali*" OR "caribou* habitat*" OR "carnivor* mammal*" OR "caviti* nester*" OR "caviti* tree*" OR cavity-depend* OR cavity-dwel* OR cavity-nest* OR "centrocercus* urophasianus*" OR "certhia* americana*" OR "cervus* elaphus*" OR "charadrius* montanus*" OR "chip* sparrow*" OR chordata* OR chordat* OR "cistothorus* platensi*" OR "coccyzus* americanus*" OR "cockad* woodpeck*" OR "colapt* auratus*" OR "colinus* virginianus*" OR "color* sparrow*" OR "colub* constrictor*" OR "common* brushtail*" OR "common* brushtail* possum*" OR "common* speci*" OR "common* yellowthroat*" OR "conilurus* penicillatus*" OR "contopus* viren*" OR "crepuscular* fauna*" OR "critcal* endang* fauna*" OR "critic* endang*" OR "critic* endang* speci*" OR "cynomi* ludovicianus*" OR "dendroica* coronata*" OR "depend* bird*" OR "depend* speci*" OR "depend* wildlif*" OR "direct* mortal*" OR "dispers* speci*" OR "distanc* migrant*" OR "dolichonyx* oryzivorus*" OR "domin* speci*" OR "dwell* invertebr*" OR "dwell* mammal*" OR "eastern* fenc* lizard*" OR "eastern* meadowlark*" OR "eastern* towhe*" OR "eating warbler*" OR "ecosystem* engin*" OR "empidonax* virescen*" OR "endang* florida* grasshopp*" OR "endang* florida* grasshopp* sparrow*" OR "endang* speci*" OR "endem* speci*" OR "eurasian* curlew*" OR "european* golden*" OR "european* golden* plover*" OR "falco* sparverius*" OR "fauna* assemblag*" OR "fauna* habitat*" OR "fauna* speci*" OR "faunal* assemblag*" OR "faunal* communiti*" OR "faunal* distribut*" OR "faunal* divers*" OR "faunal* group*" OR "faunal* respons*" OR "feder* endang*" OR "feli* catus*" OR "femal* eastern*" OR "femal* greater*" OR "femal* greater* prairi*" OR "fenc* lizard*" OR "feral* anim*" OR "feral* predat*" OR "field* sparrow*" OR fish* OR "fledg* success*" OR "florida* grasshopp*" OR "florida* grasshopp* sparrow*" OR "flying squirrel*" OR "focal* speci*" OR folivor* OR "foot* mous*" OR "forag* abund*" OR "forag* avail*" OR "forag* biomass*" OR "forag* plant*" OR "forag* product*" OR "forag* qualiti*" OR "forag* resourc*" OR "forag* activ*" OR "forag* behavior*" OR "forag* bird*" OR "forag* condit*" OR "forag* guild*" OR "forag* habitat*" OR "forag* opportun*" OR "forest* biota*" OR "forest* bird*" OR "forest* insect*" OR "forest* songbird*" OR "forest* specialist*" OR "forest* wildlif*" OR formicida* OR "freshwat* invertebr*" OR fungivor* OR "gallopavo* silvestri*" OR "geothlypi* tricha*" OR "glaucomi* sabrinus*" OR "golden* plover*" OR "golden* plover* pluviali*" OR "golden* plover* pluviali* apricaria*" OR "gopher* tortois*" OR "gopherus* polyphemus*" OR "grasshopp* sparrow*" OR "grassland* bird*" OR "grassland* passerin*" OR "ground* beetl*" OR "ground* nest*" OR "ground* squirrel*" OR ground-dwel* OR "grous* habitat*" OR "grous* popul*" OR "gymnobelideus* leadbeateri*" OR "habitat* specialist*" OR "habitat* speci*" OR "hairi* woodpeck*" OR "head* cowbird*" OR "head* nuthatch*" OR "head* woodpeck*" OR "helmithero* vermivorum*" OR "herbivor* popul*" OR herbivor* OR herpetofauna* OR "herpetofaun* communiti*" OR "herpetofaun* respons*" OR "herpetofaun* speci*" OR "higher* forag*" OR "high* threaten*" OR hollow-depend* OR "hollow-depend* fauna*" OR "hood* warbler*" OR "horn* lark*" OR "hous* mous*" OR "hylocichla* mustelina*" OR "icteria* viren*" OR

"indic* speci*" OR "individu* anim*" OR "individu* bird*" OR "influenc* anim*" OR insect* OR insectivor* OR "intoler* speci*" OR "introduc* herbivor*" OR "introduc* hous* mous*" OR "introduc* predat*" OR "invertebr* abund*" OR "invertebr* assemblag*" OR "invertebr* biomass*" OR "invertebr* communiti*" OR "invertebr* divers*" OR "invertebr* fauna*" OR "invertebr* group*" OR "invertebr* popul*" OR "invertebr* speci*" OR invertebr* OR "isoodon* macrourus*" OR "isoodon* obesulus*" OR "kentucki* warbler*" OR "keyston* speci*" OR "larg* herbivor*" OR "larg* mammal*" OR "larg* mammalian*" OR "larg* mammalian* herbivor*" OR "larg* ungul*" OR "lepus* americanus*" OR "line* skink*" OR "lizard* speci*" OR "local* extinct*" OR macroinvertebr* OR macropod* OR "maintain* popul*" OR "mammal* abund*" OR "mammal* assemblag*" OR "mammal* biomass*" OR "mammal* communiti*" OR "mammal* declin*" OR "mammal* divers*" OR "mammal* fauna*" OR "mammal* occurr*" OR "mammal* popul*" OR "mammal* respons*" OR "mammal* speci*" OR "mammal* speci* rich*" OR mammalian* OR "mammalian* herbivor*" OR "mammalian* predat*" OR "mammalian* speci*" OR "marsh* bird*" OR marsupi* OR "mart* pennanti*" OR "melanerp* lewi*" OR "meleagri* gallopavo*" OR "meleagri* gallopavo* silvestri*" OR "mniotilta* varia*" OR monotrem* OR "mortal* rate*" OR "mountain* bluebird*" OR "mountain* chickade*" OR "mountain* plover*" OR "mous* popul*" OR "myoti* septentrionali*" OR "nativ* fauna*" OR "nativ* mammal*" OR "nativ* mammal* speci*" OR "nativ* rodent*" OR "nativ* small*" OR "nativ* small* mammal*" OR "nativ* vertebr*" OR "nativ* wildlif*" OR "nativ* wildlif* speci*" OR "neotrop* migrant*" OR "neotrop* migratori*" OR "nest* activ*" OR "nest* bird*" OR "nest* guild*" OR "nest* habitat*" OR "nest* season*" OR "nest* site*" OR "nest* speci*" OR "nest* success*" OR noctur* OR "nocturn* anim*" OR "nocturn* fauna*" OR "northern* bobwhit*" OR "northern* brown* bandicoot*" OR "northern* cardin*" OR "northern* flicker*" OR "northern* flying squirrel*" OR "numer* wildlif*" OR "numer* wildlif* speci*" OR "occidentali* caurina*" OR "occidentali* occidentali*" OR "odocoileus* hemionus*" OR "odocoileus* virginianus*" OR omnivor* OR "passerculus* sandwichensi*" OR "passerina* cyanea*" OR "passerin* bird*" OR "passerin* speci*" OR "peromyscus* maniculatus*" OR "picoid* arcticus*" OR "picoid* boreali*" OR "picoid* villosus*" OR "pipilo* erythrophthalmus*" OR "piranga* rubra*" OR "plestiodon* fasciatus*" OR "plover* pluviali*" OR "plover* pluviali* apricaria*" OR "pluviali* apricaria*" OR "prairi* warbler*" OR "pseudomi* desertor*" OR "rangif* tarandus*" OR "rangif* tarandus* caribou*" OR "rattus* fuscip*" OR reptil* OR "reptil* abund*" OR "reptil* assemblag*" OR "reptil* communiti*" OR "reptil* fauna*" OR "reptil* respons*" OR "reptil* speci*" OR "reptil* speci* rich*" OR reptilian* OR "resid* speci*" OR "rodent* speci*" OR "roost* select*" OR "roost* site*" OR "roost* tree*" OR "roost* habitat*" OR "rump* warbler*" OR "salamand* abund*" OR "salamand* popul*" OR "salamandra* salamandra*" OR "saproxyl* beetl*" OR "savannah* sparrow*" OR "savannarum* floridanus*" OR "sceloporus* undulatus*" OR "sciurus* niger*" OR "seasid* sparrow*" OR "seiurus* aurocapilla*" OR semi-aquat* OR "semi-aquat* fauna*" OR "setonix* brachyurus*" OR "setophaga* discolor*" OR "shrubland* bird*" OR "sialia* mexicana*" OR "singl* speci*" OR "sitta* pusilla*" OR "size* mammal*" OR "slimi* salamand*" OR "small* mammal*" OR "small* mammal* abund*" OR "small* mammal* assemblag*" OR "small* mammal* communiti*" OR "small* mammal* divers*" OR "small* mammal* popul*" OR "small* mammal* respons*" OR "small* mammal* speci*" OR "snowsho* hare*" OR "solenopsi* invicta*" OR "solenopsi* invicta* buren*" OR "songbird* communiti*" OR "songbird* speci*" OR "sorex* cinereus*" OR "southeastern* american* kestrel*" OR "sparrow* abund*" OR "sparrow* nest*" OR "speci* abund*" OR "speci* assemblag*" OR "speci* declin*" OR "speci* manag*" OR "speci* persist*" OR "speci* recoveri*" OR spider* OR "spiza* americana*" OR "spizella* breweri*" OR "spizella* pallida*" OR "spizella* pusilla*" OR "squirrel* popul*" OR "strix* occidentali*" OR "strix* occidentali* caurina*" OR "strix* occidentali* occidentali*" OR "sturnella* magna*" OR "sturnella* neglecta*" OR stygofauna* OR "summer* tanag*" OR "survey* bird*" OR "survey* small* mammal*" OR "tamia* amoenus*" OR "tarandus* caribou*" OR "terrestri* invertebr*" OR "terrestri* mammal*" OR "terrestri* salamand*" OR "terrestri* vertebr*" OR "terrestri* wildlif*" OR "threaten* mammal*" OR "threaten* speci*" OR "toler* speci*" OR "total* invertebr*" OR "trap* small* mammal*" OR "trichosurus* vulpecula*" OR "tuft* titmous*" OR "turdus* migratorius*" OR "tympanuchus* cupido*" OR "ungul* brows*" OR "ungul* herbivori*" OR "ungul* popul*" OR "ungul* speci*" OR "upland* sandpip*" OR "ursus* americanus*" OR vertebr* OR "vertebr* biodivers*" OR "vertebr* divers*" OR "vertebr* fauna*" OR "vertebr* speci*" OR "vulp* vulp*" OR water-depend* OR "western* bluebird*" OR "western* meadowlark*" OR "white* warbler*" OR "wild* popul*" OR "wildlif* communiti*" OR "wildlif* conserv*" OR "wildlif* manag*" OR "wildlif* popul*" OR "wildlif* rehabilit*" OR "wildlif* respons*" OR "wildlif* speci*" OR "wing* blackbird*" OR "winter* bird*" OR "winter* waterfowl*" OR "woodland* bird*" OR "woodland* caribou*" OR "woodland* generalist*" OR "woodpeck* nest*" OR "woodpeck* popul*" OR "woodpeck* speci*" OR "wyomingensi* beetl*" OR "zenaida* macroura*"))

Secondary search string

((fauna OR animal OR wildlife OR bird OR marsupial OR wallaby OR mammal OR reptile OR amphibian OR vertebrate OR invertebrate) AND (post-fire OR fire OR post fire OR postfire OR burn) AND (management action OR strategy OR restoration OR action OR management practice OR graze OR grazing OR salvage))

Tertiary search string

((fauna OR animal* OR wildlife OR bird* OR mammal* OR reptil* OR amphibian* OR verterbrate* OR invertebrate*) AND ("post-fire" OR "post fire" OR "postfire") AND ("management action*" OR strategi* OR restor* OR action* OR "management practice*" OR salvage))

Search terms: Australian grey literature

The decentralised and often ephemeral manner in which most types of grey literature are stored across government agencies and organisations necessitated the development of a clear approach to accessing information. Searches were conducted with a top-down approach, beginning at the highest level of governance/custodianship down to individual organisations operating at regional-scale. Where possible, whole of government databases were first searched using the keywords: ((fauna OR wildlife) AND (fire AND (conservation OR management))). Where advanced searches using Boolean operators were not possible, individual keywords were used in combination or individually. In addition, we searched federal- and state-level databases such as https://trove.nla.gov.au/. Following these higher-level searches, web pages for individual agencies or organisations at all levels were manually searched using either keywords or using site maps/following internal links. We also searched within fire management or biodiversity/conservation agencies for guidance and/or procedures for responding to fauna needs in relation to fire, such as reviews, debriefs, responses to past wildfire events and how wildlife were managed. It is important to note that our grey literature search was not exhaustive and generally we did not search at local government/regional level. For example, the New South Wales National Parks and Wildlife Service has individual management plans for every reserve within their estate, but it was not feasible to assess each one of these documents within our project's timeframe and they were excluded. Between November 2020 to March 2021, we approached fire management and conservation practitioners within government agencies and the private sector with a survey to obtain knowledge and insights not covered by the literature. These survey results are provided in a supplementary report (to be finalised).

Deduplication

Bibliographic lists were generated (format = .ris & .bib) from each database searched. Where this was not possible, articles were manually downloaded. Using the statistical computing program R (RCoreTeam 2020), duplicates were identified and then manually screened using the find_duplicates and screen_duplicates functions in the R package 'revtools' (Westgate 2019).

Screening

We followed the screening workflow suggested in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Moher et al. 2009). All articles were screened at title/abstract level were manually screened using the functions screen_titles and screen_abstracts in revtools, which allowed for manual decision making regarding the inclusion of articles based on the eligibility criteria. Any articles that were not excluded at this step were screened at full-text level. Screening at full-text level was completed by two reviewers. Each article excluded at full-text level is listed in an online data repository (https://github.com/eli-bendall/fauna_actions.git), with details justifying exclusion.

Critical appraisal

For the peer-reviewed literature, each piece of evidence that passed the screening process was critically appraised and where necessary categorical variables were developed related to data quality and type, for potential inclusion as a weighting variable in future statistical models.

Appendix 2

Lists of specific actions

Table S1. Table of peer-reviewed studies accepted in our review with taxa, ecosystem, specific action and coarse action group. CWD = coarse woody debris; DWR = downed wood retention.

Taxa	Ecosystem	Specific action	Coarse action group
bird	forest	herbicide application between prescribed fire cycles	chemical thinning
bird	forest	herbicide application followed by prescribed burning	chemical thinning
bird	forest	herbicide application or mechanical thinning	chemical thinning
bird	forest	shelterwood and gap-release harvest followed by regeneration burn	forest logging
bird	forest	difficult to determine: replanting & removal of coarse woody debris, snags	forest logging
bird	forest	partial salvage logging	forest logging
bird	forest	post-fire salvage logging	forest logging
bird	forest	post-fire salvage logging	forest logging
bird	forest	post-fire snag removal	forest logging
bird	forest	salvage logging	forest logging
bird	forest	salvage logging	forest logging
bird	forest	prescribed fire, thinning, artificial nest boxes, translocation	habitat creation
bird	forest	artificial nest boxes	habitat creation
bird	forest	thin and burn	mechanical thinning
bird	forest	thinning plus prescribed burning	mechanical thinning
bird	forest	forest thinning followed by prescribed burning	mechanical thinning
bird	forest	thinning	mechanical thinning
bird	forest	tree thinning and prescribed fire	mechanical thinning
bird	forest	thinning followed by prescribed burn	mechanical thinning
bird	forest	CWD removal, tree planting	mechanical thinning
bird	forest	mechanical understory thinning followed by prescribed fire	mechanical thinning
bird	forest	pre-fire thinning followed by prescribed burning	mechanical thinning
bird	forest	pre-fire thinning followed by prescribed burn	mechanical thinning
bird	forest	winter disking and supplemental feeding in areas subjected to annual prescribed fire	supplemental resources
bird	grassland	herbicide and/or mowing following prescribed burning	chemical thinning
bird	grassland	prescribed fire followed by herbicide application	chemical thinning
bird	grassland	herbicide spraying in multiple years following prescribed burn	chemical thinning
bird	grassland	cattle grazing, haying	grazing (bison/cattle)
bird	grassland	bison and cattle grazing with prescribed fire, patch-burn grazing	grazing (bison/cattle)
bird	grassland	cattle grazing in association with prescribed burning	grazing (bison/cattle)
bird	grassland	frequent prescribed burns plus bison grazing	grazing (bison/cattle)
bird	grassland	patch-burn grazing	grazing (bison/cattle)
bird	grassland	patch-burn grazing	grazing (bison/cattle)
bird	grassland	patch-burn-grazing	grazing (bison/cattle)
bird	grassland	bison and cattle grazing with prescribed fire at various return intervals	grazing (bison/cattle)
bird	grassland	cattle grazing before and following fire	grazing (bison/cattle)
bird	grassland	patch-burn grazing	grazing (bison/cattle)

Taxa	Ecosystem	Specific action	Coarse action group
bird	grassland	patch-burn grazing	grazing (bison/cattle)
bird	multiple	spraying fire retardant foam	fire control activities
bird	shrubland	post-fire seeding and transplanting habitat plants	habitat creation
bird	wetland	post-fire grazing	grazing (bison/cattle)
bird	wetland	cattle grazing and prescribed fire	grazing (bison/cattle)
bird	wetland	pre-fire vegetation shearing (bulldozer blade cutting) followed by prescribed fire at either 3 or 6 years	mechanical thinning
bird	wetland	artificial water impoundments	soil management
bird	woodland	post-fire herbicide application	chemical thinning
bird	woodland	pre-fire herbicide application	chemical thinning
bird	woodland	artificial nest boxes	habitat creation
bird	woodland	repair natural hollows and install artificial hollows	habitat creation
bird	woodland	roller-chopping followed by prescribed burn	mechanical thinning
fish	aquatic	aerial fire retardant use	fire control activities
fish	aquatic	fire retardant foam used during fire control	fire control activities
fish	forest	disturbances resulting from forest management activities	forest logging
herpetofauna	forest	prescribed fire followed by mechanical thinning, herbicide and additional prescribed fire at 2-3 year intervals	chemical thinning
herpetofauna	forest	herbicide spraying followed by prescribed burn	chemical thinning
herpetofauna	forest	thinning or herbicide followed by prescribed burn	chemical thinning
herpetofauna	forest	pre-fire thinning followed by prescribed burning followed by herbicide application	chemical thinning
herpetofauna	forest	herbicide application followed by prescribed fire	chemical thinning
herpetofauna	forest	damage to habitat from vehicles used during fire management or other activities	fire control activities
herpetofauna	forest	post-fire salvage logging	forest logging
herpetofauna	forest	prescribed fire followed by shelterwood harvest	forest logging
herpetofauna	forest	thinning followed by prescribed burn	mechanical thinning
herpetofauna	forest	mechanical thinning followed by prescribed fire	mechanical thinning
herpetofauna	grassland	bison/cattle grazing	grazing (bison/cattle)
herpetofauna	grassland	artificial rock installation followed by prescribed fire and herbicide application	habitat creation
herpetofauna	grassland	pre-fire mowing	mechanical thinning
herpetofauna	grassland	earthen berm construction plus herbicide application followed by annual prescribed burning	soil management
herpetofauna	semi-arid	disking and grazing in association with frequent prescribed fire	grazing (bison/cattle)
herpetofauna	wetland	repeated prescribed burning followed by grazing between burns	grazing (bison/cattle)
herpetofauna	wetland	mechanical midstory removal/mulching followed by prescribed fire	mechanical thinning
herpetofauna	woodland	pre-fire herbicide application	chemical thinning
herpetofauna	woodland	addition of CWD, reduced grazing	habitat creation
herpetofauna	woodland	pre-fire thinning followed by frequent prescribed burns	mechanical thinning
herpetofauna	woodland	herbivore exclusion followed by prescribed fire	predator/competitor control
invertebrate	aquatic	aerially-sprayed fire retardant foam	fire control activities
invertebrate	forest	thinning or herbicide plus prescribed fire	chemical thinning
invertebrate	forest	track clearing for mining activity	fire control activities

Taxa	Ecosystem	Specific action	Coarse action group
invertebrate	forest	partial harvesting with varying levels of DWR followed by prescribed burn	forest logging
invertebrate	forest	pre-fire thinning and deadwood creation followed by prescribed burning	forest logging
invertebrate	forest	thinning with varying levels of downed wood retention followed by prescribed burn	forest logging
invertebrate	forest	clearcut followed by prescribed fire	forest logging
invertebrate	forest	logging (70% of overstorey removal)	forest logging
invertebrate	forest	logging with variable tree retention followed by prescribed burning	forest logging
invertebrate	forest	pre-fire logging with varying levels of retention followed by prescribed burn	forest logging
invertebrate	forest	various silvicultural treatments followed by prescribed burn	forest logging
invertebrate	forest	post-fire salvage logging	forest logging
invertebrate	forest	salvage logging	forest logging
invertebrate	forest	salvage logging	forest logging
invertebrate	forest	pre-fire logging and post-fire salvage logging	forest logging
invertebrate	forest	cattle grazing plus prescribed fire	grazing (bison/cattle)
invertebrate	forest	CWD addition	habitat creation
invertebrate	forest	pre-fire thinning using different methods followed by two prescribed burns and supplemental plant seeding	habitat creation
invertebrate	forest	thinning plus prescribed burning	mechanical thinning
invertebrate	forest	mechanical understory thinning plus prescribed fire	mechanical thinning
invertebrate	forest	pre-fire thinning followed by repeated prescribed burns	mechanical thinning
invertebrate	forest	pre-fire thinning treatments followed by prescribed fire	mechanical thinning
invertebrate	forest	post-fire thinning and soil cultivation	mechanical thinning
invertebrate	forest	pre-fire forest thinning followed by prescribed fire	mechanical thinning
invertebrate	forest	pre-fire mechanical thinning of understory and small trees followed by prescribed fire	mechanical thinning
invertebrate	forest	thinning followed by repeated prescribed burns	mechanical thinning
invertebrate	forest	mechanical understory removal plus repeated prescribed burns	mechanical thinning
invertebrate	forest	pre-fire mechanical fuel reduction followed by fire	mechanical thinning
invertebrate	forest	pre-fire thinning followed by prescribed fire	mechanical thinning
invertebrate	forest	thinning plus prescribed fire	mechanical thinning
invertebrate	forest	thinning in association with burning	mechanical thinning
invertebrate	forest	mechanical thinning of midstory followed by repeated prescribed fires	mechanical thinning
invertebrate	forest	thinning & mastication	mechanical thinning
invertebrate	forest	thinning to vary fuel load followed by prescribed burn	mechanical thinning
invertebrate	forest	herbivore exclusion followed by prescribed fire	predator/competitor control
invertebrate	forest	post-fire beetle trapping	soil management
invertebrate	grassland	bison grazing in association with prescribed fire	grazing (bison/cattle)
invertebrate	grassland	bison grazing in association with prescribed fire	grazing (bison/cattle)
invertebrate	grassland	patch-burn-grazing	grazing (bison/cattle)
invertebrate	grassland	post-fire grazing	grazing (bison/cattle)
invertebrate	grassland	cattle grazing plus prescribed fire	grazing (bison/cattle)
invertebrate	grassland	mowing and cutting in association with burning	mechanical thinning

Taxa	Ecosystem	Specific action	Coarse action group
invertebrate	grassland	mowing, haying and replanting in association with either wildfire or prescribed fire	mechanical thinning
invertebrate	grassland	post-fire mowing or fertiliser application	mechanical thinning
invertebrate	grassland	mowing and/or fertilizer application between prescribed fire cycles	mechanical thinning
invertebrate	plantation	post-fire salvage logging	forest logging
invertebrate	plantation	post-fire salvage logging and experimental treatments	forest logging
invertebrate	plantation	selective thinning over a decade after wildfire	forest logging
invertebrate	plantation	postfire disking+seeding or herbicide or disking+herbicide+seeding	mechanical thinning
invertebrate	plantation	erosion control - soil mulching	soil management
invertebrate	shrubland	aerial fire retardant use	fire control activities
invertebrate	shrubland	use of fire retardant	fire control activities
invertebrate	woodland	pre-fire herbicide application	chemical thinning
invertebrate	woodland	pre-fire mowing	mechanical thinning
invertebrate	woodland	overstory thinning in between biennial prescribed burns	mechanical thinning
mammal	forest	post-fire animal rescue, rehabilitation and release	animal rescue
mammal	forest	post-fire rescue, rehabilitation and release of koalas	animal rescue
mammal	forest	pre-fire herbicide application	chemical thinning
mammal	forest	herbicide application followed by prescribed burn	chemical thinning
mammal	forest	firebreaks constructed for fire management activities	fire control activities
mammal	forest	construction of firebreaks and water supply points	fire control activities
mammal	forest	harvest and thinning followed by varying numbers of prescribed burns	forest logging
mammal	forest	pre-fire shelterwood harvest/retention cut with and without herbicide application followed by prescribed fire	forest logging
mammal	forest	clearcutting followed by slash burning	forest logging
mammal	forest	post-fire logging	forest logging
mammal	forest	post-fire salvage logging	forest logging
mammal	forest	post-fire salvage logging	forest logging
mammal	forest	salvage logging	forest logging
mammal	forest	post-fire grazing	grazing (bison/cattle)
mammal	forest	forest thinning plus addition of artificial roost followed by prescribed fire	habitat creation
mammal	forest	artificial nest boxes	habitat creation
mammal	forest	thinning in association with prescribed fire	mechanical thinning
mammal	forest	forest thinning with various burning regimes	mechanical thinning
mammal	forest	pre-fire overstory thinning followed by prescribed fire in different seasons	mechanical thinning
mammal	forest	thinning & mastication	mechanical thinning
mammal	forest	forest thinning followed by prescribed fire	mechanical thinning
mammal	forest	mechanical thinning plus prescribed fire	mechanical thinning
mammal	forest	mechanical understory thinning plus prescribed burning	mechanical thinning

Taxa	Ecosystem	Specific action	Coarse action group
mammal	forest	pre-fire fuel reduction thinning	mechanical thinning
mammal	forest	exclusion of mammalian predators	predator/competitor control
mammal	forest	predator exclusion fences and supplemental feeding in association with prescribed fire	supplemental resources
mammal	forest	post-fire lichen transplanting for reindeer	supplemental resources
mammal	grassland	patch-burn grazing	grazing (bison/cattle)
mammal	grassland	patch-burn grazing	grazing (bison/cattle)
mammal	grassland	grazing and prescribed burning	grazing (bison/cattle)
mammal	multiple	forest thinning followed by prescribed fire	mechanical thinning
mammal	multiple	exclusion fencing, baiting, artificial habitat	predator/competitor control
mammal	plantation	herbicide application followed by prescribed burning	chemical thinning
mammal	plantation	salvage logging	forest logging
mammal	plantation	salvage logging with varying levels of CWD retention	forest logging
mammal	semi-arid	artificial shelter installation following wildfire	habitat creation
mammal	shrubland	prescribed burn followed by mechanical shrub removal (checkerboarding)	mechanical thinning
mammal	woodland	cattle grazing and fire management	grazing (bison/cattle)
mammal	woodland	cattle grazing regimes in association with prescribed fire	grazing (bison/cattle)
mammal	woodland	pre-fire thinning	mechanical thinning
mammal	woodland	mammalian predator exclusion followed by prescribed fire and supplemental feeding	predator/competitor control
mammal	woodland	post-fire or during-drought supplementary feeding	supplemental resources
multiple	forest	repeated aerially-sprayed herbicide application and prescribed fires	chemical thinning
multiple	forest	post-fire logging in riparian areas	forest logging
multiple	forest	post-fire salvage logging	forest logging
multiple	forest	salvage logging	forest logging
multiple	forest	habitat rehabilitation using log piles as CWD followed by wildfire	habitat creation
multiple	forest	post-fire addition of CWD	habitat creation
multiple	forest	tree planting	habitat creation
multiple	forest	mechanical thinning followed by prescribed burn	mechanical thinning
multiple	forest	thin and burn	mechanical thinning
multiple	forest	post-fire ecological thinning	mechanical thinning
multiple	grassland	cattle grazing plus burning	grazing (bison/cattle)
multiple	multiple	mechanical understory cutting followed by prescribed fire	mechanical thinning
multiple	woodland	animal welfare and rescue	animal rescue

Table S2. Table of Australian grey literature articles accepted in our review with document ID, taxa, ecosystem, specific action and coarse action group. STE = most southern temperate ecosystems; CWD = coarse woody debris; SA = South Australia.

ID	Taxa	Ecosystem	Specific action	Coarse action group
1	not specified	not specified	vegetation clearing around properties before or following fire	fire control activities
2	bird	STE	multiple	mitigating harm from fire control
2	bird	heath	multiple	animal rescue
2	bird	STE	multiple	monitoring/research/consultation/ education
2	bird	STE	multiple	predator/competitor control
2	bird	STE	multiple	supplementary resources
2	bird	woodland	multiple	supplementary resources
2	fish	aquatic	multiple	animal rescue
2	fish	STE	multiple	mitigating harm from fire control
2	fish	STE	multiple	monitoring/research/consultation/ education
2	herp	STE	multiple	mitigating harm from fire control
2	herp	STE	multiple	monitoring/research/consultation/ education
2	herp	STE	multiple	predator/competitor control
2	invert	STE	multiple	animal rescue
2	invert	STE	multiple	mitigating harm from fire control
2	invert	STE	multiple	monitoring/research/consultation/ education
2	invert	STE	multiple	predator/competitor control
2	mammal	forest	multiple	animal rescue
2	mammal	STE	multiple	mitigating harm from fire control
2	mammal	STE	multiple	monitoring/research/consultation/ education
2	mammal	STE	multiple	predator/competitor control
2	mammal	alpine	multiple	supplementary resources
2	mammal	forest	multiple	supplementary resources
3	not specified	not specified	provide funding for research and support	admin/funding
4	not specified	STE	wildlife rescue and strategies for protecting Wollemi pines	animal rescue
4	not specified	STE	wildlife rescue and strategies for protecting Wollemi pines	fire control activities
4	not specified	STE	wildlife rescue and strategies for protecting Wollemi pines	predator/competitor control
5	not specified	not specified	inclusion of 'environmental mitigation strategies' including fire surrogates, exclusion of sensitive areas/habitats from planned burns, post fire weed and pest control, rescheduling burns. whenever mis are implemented monitoring is required	mitigating harm from fire control
5	not specified	not specified	inclusion of 'environmental mitigation strategies' including fire surrogates, exclusion of sensitive areas/habitats from planned burns, post fire weed and pest control, rescheduling burns. whenever mis are implemented monitoring is required	predator/competitor control
6	not specified	not specified	rehabilitation of natural areas following damage during fire management activities and fauna rescue during emergencies	animal rescue

ID	Taxa	Ecosystem	Specific action	Coarse action group
7	not specified	not specified	rehabilitation of natural areas following damage during fire management activities and fauna rescue during emergencies	animal rescue
8	bird	forest	artificial nest boxes	supplementary resources
8	bird	woodland	artificial nest boxes	supplementary resources
8	mammal	forest	artificial nest boxes	supplementary resources
8	mammal	woodland	artificial nest boxes	supplementary resources
9	mammal	STE	wildlife rescue, supplemental food and water	supplementary resources
10	mammal	forest	wildlife rescue, supplemental food and water	supplementary resources
10	mammal	woodland	wildlife rescue, supplemental food and water	supplementary resources
11	bird	STE	wildlife rescue, supplemental food and water	supplementary resources
11	herp	STE	wildlife rescue, supplemental food and water	supplementary resources
11	mammal	STE	wildlife rescue, supplemental food and water	supplementary resources
12	mammal	forest	exclusion of harvesting and post-harvest fire from koala habitat	mitigating harm from fire control
13	mammal	forest	ecological burning, cultural burning, fire breaks, restoration, protection of refugia	habitat creation
13	mammal	woodland	ecological burning, cultural burning, fire breaks, restoration, protection of refugia	habitat creation
13	mammal	forest	ecological burning, cultural burning, fire breaks, restoration, protection of refugia	supplementary resources
13	mammal	woodland	ecological burning, cultural burning, fire breaks, restoration, protection of refugia	supplementary resources
14	not specified	STE	fauna rescue and post-fire salvage logging	animal rescue
14	not specified	forest	fauna rescue and post-fire salvage logging	logging/land clearing
15	bird	STE	multiple	animal rescue
15	bird	forest	multiple	logging/land clearing
15	bird	STE	multiple	mitigating harm from fire control
15	bird	STE	multiple	monitoring/research/consultation/education
15	bird	heath	multiple	post-fire control rehabilitation
15	bird	forest	multiple	post-fire control rehabilitation
15	bird	woodland	multiple	post-fire control rehabilitation
15	bird	forest	multiple	predator/competitor control
15	bird	heath	multiple	predator/competitor control
15	bird	hanging swamp	multiple	predator/competitor control
15	bird	forest	multiple	supplementary resources
15	fish	aquatic	multiple	animal rescue
15	fish	forest	multiple	logging/land clearing
15	fish	aquatic	multiple	mitigating harm from fire control
15	fish	aquatic	multiple	monitoring/research/consultation/education
15	fish	aquatic	multiple	predator/competitor control
15	fish	aquatic	multiple	preventing poaching
15	fish	aquatic	multiple	supplementary resources

ID	Taxa	Ecosystem	Specific action	Coarse action group
15	herp	forest	multiple	animal rescue
15	herp	aquatic	multiple	animal rescue
15	herp	alpine	multiple	logging/land clearing
15	herp	forest	multiple	logging/land clearing
15	herp	STE	multiple	mitigating harm from fire control
15	herp	STE	multiple	monitoring/research/consultation/ education
15	herp	STE	multiple	predator/competitor control
15	herp	forest	multiple	preventing poaching
15	herp	woodland	multiple	preventing poaching
15	herp	aquatic	multiple	preventing pollution
15	herp	forest	multiple	restricting public access
15	herp	forest	multiple	supplementary resources
15	herp	woodland	multiple	supplementary resources
15	invert	forest	multiple	animal rescue
15	invert	forest	multiple	mitigating harm from fire control
15	invert	woodland	multiple	mitigating harm from fire control
15	invert	alpine	multiple	mitigating harm from fire control
15	invert	forest	multiple	monitoring/research/consultation/ education
15	invert	woodland	multiple	monitoring/research/consultation/ education
15	invert	alpine	multiple	monitoring/research/consultation/ education
15	invert	forest	multiple	predator/competitor control
15	invert	woodland	multiple	predator/competitor control
15	invert	forest	multiple	supplementary resources
15	mammal	STE	multiple	animal rescue
15	mammal	STE	multiple	logging/land clearing
15	mammal	STE	multiple	mitigating harm from fire control
15	mammal	STE	multiple	monitoring/research/consultation/ education
15	mammal	STE	multiple	predator/competitor control
15	mammal	aquatic	multiple	preventing pollution
15	mammal	STE	multiple	supplementary resources
16	not specified	forest	multiple	mitigating harm from fire control
16	not specified	rainforest	multiple	mitigating harm from fire control
16	not specified	wetland	multiple	mitigating harm from fire control
16	not specified	wetland	multiple	preventing pollution
17	bird	STE	rapid on-ground survey and protecting unburnt refugia	mitigating harm from fire control
17	bird	STE	rapid on-ground survey and protecting unburnt refugia	monitoring/research/consultation/ education
17	fish	aquatic	rapid on-ground survey and protecting unburnt refugia	mitigating harm from fire control
17	fish	aquatic	rapid on-ground survey and protecting unburnt refugia	monitoring/research/consultation/ education

ID	Taxa	Ecosystem	Specific action	Coarse action group
17	herp	STE	rapid on-ground survey and protecting unburnt refugia	mitigating harm from fire control
17	herp	STE	rapid on-ground survey and protecting unburnt refugia	monitoring/research/consultation/education
17	invert	STE	rapid on-ground survey and protecting unburnt refugia	mitigating harm from fire control
17	invert	STE	rapid on-ground survey and protecting unburnt refugia	monitoring/research/consultation/education
17	mammal	STE	rapid on-ground survey and protecting unburnt refugia	mitigating harm from fire control
17	mammal	STE	rapid on-ground survey and protecting unburnt refugia	monitoring/research/consultation/education
18	invert	STE	multiple	animal rescue
18	invert	STE	multiple	mitigating harm from fire control
18	invert	STE	multiple	monitoring/research/consultation/education
18	invert	STE	multiple	predator/competitor control
18	invert	STE	multiple	supplementary resources
19	bird	forest	post-harvest regeneration burns and other prescribed burns	habitat creation
19	bird	forest	post-harvest regeneration burns and other prescribed burns	mitigating harm from fire control
19	bird	forest	post-harvest regeneration burns and other prescribed burns	predator/competitor control
19	herp	forest	post-harvest regeneration burns and other prescribed burns	habitat creation
19	herp	forest	post-harvest regeneration burns and other prescribed burns	mitigating harm from fire control
19	herp	forest	post-harvest regeneration burns and other prescribed burns	predator/competitor control
19	mammal	forest	post-harvest regeneration burns and other prescribed burns	habitat creation
19	mammal	forest	post-harvest regeneration burns and other prescribed burns	mitigating harm from fire control
19	mammal	forest	post-harvest regeneration burns and other prescribed burns	predator/competitor control
20	not specified	forest	fire exclusion, considering biodiversity values during fire suppression, raking around habitat trees and logs	mitigating harm from fire control
20	bird	forest	fire exclusion, considering biodiversity values during fire suppression, raking around habitat trees and logs	mitigating harm from fire control
20	mammal	forest	fire exclusion, considering biodiversity values during fire suppression, raking around habitat trees and logs	mitigating harm from fire control
21	not specified	not specified	compliance with conditions issued with hazard reduction certificate	mitigating harm from fire control
21	mammal	forest	compliance with conditions issued with hazard reduction certificate	mitigating harm from fire control
21	mammal	woodland	compliance with conditions issued with hazard reduction certificate	mitigating harm from fire control
22	bird	woodland	CWD addition, planting, ecological grazing, herbivore and predator control	ecological grazing
22	bird	woodland	CWD addition, planting, ecological grazing, herbivore and predator control	habitat creation
22	bird	woodland	CWD addition, planting, ecological grazing, herbivore and predator control	predator/competitor control
23	not specified	not specified	supplementary food and water, rescue, extra funding, feral animal control	admin/funding

ID	Taxa	Ecosystem	Specific action	Coarse action group
23	not specified	STE	supplementary food and water, rescue, extra funding, feral animal control	predator/competitor control
23	herp	forest	supplementary food and water, rescue, extra funding, feral animal control	animal rescue
23	herp	alpine	supplementary food and water, rescue, extra funding, feral animal control	animal rescue
23	herp	aquatic	supplementary food and water, rescue, extra funding, feral animal control	animal rescue
23	herp	alpine	supplementary food and water, rescue, extra funding, feral animal control	mitigating harm from fire control
23	herp	alpine	supplementary food and water, rescue, extra funding, feral animal control	restricting public access
23	mammal	STE	supplementary food and water, rescue, extra funding, feral animal control	animal rescue
23	mammal	forest	supplementary food and water, rescue, extra funding, feral animal control	supplementary resources
23	mammal	alpine	supplementary food and water, rescue, extra funding, feral animal control	supplementary resources
24	not specified	not specified	supplementary food and water	supplementary resources
25	not specified	not specified	fauna rescue/rehabilitation/release	admin/funding
26	not specified	STE	multiple	mitigating harm from fire control
26	not specified	STE	multiple	monitoring/research/consultation/education
26	not specified	STE	multiple	predator/competitor control
26	bird	heath	multiple	animal rescue
26	bird	forest	multiple	habitat creation
26	bird	heath	multiple	monitoring/research/consultation/education
26	fish	aquatic	multiple	animal rescue
26	fish	aquatic	multiple	monitoring/research/consultation/education
26	herp	forest	multiple	monitoring/research/consultation/education
26	herp	aquatic	multiple	monitoring/research/consultation/education
26	invert	aquatic	multiple	animal rescue
26	invert	aquatic	multiple	monitoring/research/consultation/education
26	mammal	forest	multiple	habitat creation
26	mammal	forest	multiple	monitoring/research/consultation/education
27	not specified	not specified	improvement of the mapping of biodiversity values, including fauna, to better inform fire management	monitoring/research/consultation/education
27	not specified	not specified	improvement of the mapping of biodiversity values, including fauna, to better inform fire management	monitoring/research/consultation/education
28	bird	foreshore	avoiding damage to bird rookeries and pollution of sensitive areas	mitigating harm from fire control
28	bird	foreshore	avoiding damage to bird rookeries and pollution of sensitive areas	monitoring/research/consultation/education
28	bird	foreshore	avoiding damage to bird rookeries and pollution of sensitive areas	preventing pollution
29	not specified	not specified	administrative/management changes	monitoring/research/consultation/education

ID	Taxa	Ecosystem	Specific action	Coarse action group
29	not specified	not specified	administrative/management changes	post-fire control rehabilitation
30	mammal	forest	pre-fire koala surveys and planning	mitigating harm from fire control
30	mammal	woodland	pre-fire koala surveys and planning	mitigating harm from fire control
30	mammal	forest	pre-fire koala surveys and planning	monitoring/research/consultation/ education
30	mammal	woodland	pre-fire koala surveys and planning	monitoring/research/consultation/ education
31	mammal	forest	administrative changes	admin/funding
31	mammal	woodland	administrative changes	admin/funding
32	not specified	not specified	clearing of vegetation for fire management	fire control activities
33	not specified	forest	animal welfare	admin/funding
33	not specified	woodland	animal welfare	admin/funding
33	not specified	forest	animal welfare	animal rescue
33	not specified	woodland	animal welfare	animal rescue
34	not specified	not specified	environmental mitigation for sensitive/threatened flora and fauna during fire emergency	mitigating harm from fire control
35	not specified	grassland	facilitate access to information and funding for revegetation projects within community and agencies	admin/funding
35	not specified	grassland	facilitate access to information and funding for revegetation projects within community and agencies	habitat creation
35	not specified	grassland	facilitate access to information and funding for revegetation projects within community and agencies	monitoring/research/consultation/ education
36	not specified	forest	animal welfare	admin/funding
36	not specified	forest	animal welfare	fire control activities
37	not specified	forest	improving provisions for animal welfare during bushfires	admin/funding
37	not specified	forest	improving provisions for animal welfare during bushfires	animal rescue
38	not specified	woodland	revise animal welfare procedures and responsibilities	admin/funding
38	not specified	woodland	revise animal welfare procedures and responsibilities	animal rescue
39	not specified	forest	pre-fire surveys and fire exclusion	logging/land clearing
39	not specified	forest	pre-fire surveys and fire exclusion	mitigating harm from fire control
39	bird	forest	pre-fire surveys and fire exclusion	mitigating harm from fire control
39	herp	forest	pre-fire surveys and fire exclusion	mitigating harm from fire control
39	herp	aquatic	pre-fire surveys and fire exclusion	mitigating harm from fire control
39	invert	aquatic	pre-fire surveys and fire exclusion	mitigating harm from fire control
39	mammal	forest	pre-fire surveys and fire exclusion	mitigating harm from fire control
40	bird	woodland	multiple	habitat creation
40	bird	woodland	multiple	monitoring/research/consultation/ education
40	bird	alpine	multiple	predator/competitor control
40	fish	aquatic	multiple	animal rescue
40	fish	aquatic	multiple	monitoring/research/consultation/ education
40	fish	aquatic	multiple	post-fire control rehabilitation
40	fish	aquatic	multiple	preventing pollution
40	herp	woodland	multiple	habitat creation
40	herp	woodland	multiple	monitoring/research/consultation/ education

ID	Taxa	Ecosystem	Specific action	Coarse action group
40	herp	alpine	multiple	post-fire control rehabilitation
40	herp	alpine	multiple	predator/competitor control
40	invert	alpine	multiple	predator/competitor control
40	mammal	woodland	multiple	habitat creation
40	mammal	forest	multiple	monitoring/research/consultation/education
40	mammal	woodland	multiple	monitoring/research/consultation/education
40	mammal	aquatic	multiple	post-fire control rehabilitation
40	mammal	alpine	multiple	predator/competitor control
40	mammal	aquatic	multiple	preventing pollution
41	not specified	not specified	multiple	monitoring/research/consultation/education
41	not specified	alpine	multiple	post-fire control rehabilitation
41	not specified	woodland	multiple	post-fire control rehabilitation
41	not specified	alpine	multiple	post-fire control rehabilitation
41	not specified	forest	multiple	predator/competitor control
41	mammal	alpine	multiple	monitoring/research/consultation/education
41	mammal	alpine	multiple	post-fire control rehabilitation
42	not specified	not specified	undertake research and monitoring of the effects of fire on biodiversity	admin/funding
43	bird	forest	public factsheet containing description of how to build and install nest boxes for fauna in SA	habitat creation
43	bird	woodland	public factsheet containing description of how to build and install nest boxes for fauna in SA	habitat creation
43	mammal	forest	public factsheet containing description of how to build and install nest boxes for fauna in SA	habitat creation
43	mammal	woodland	public factsheet containing description of how to build and install nest boxes for fauna in SA	habitat creation
44	not specified	semi-arid	patch-burning	mitigating harm from fire control
45	bird	forest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	bird	rainforest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	bird	woodland	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	bird	forest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/education
45	bird	rainforest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/education
45	bird	woodland	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/education
45	herp	forest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	herp	rainforest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	herp	woodland	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	herp	forest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/education
45	herp	rainforest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/education
45	herp	woodland	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/education

ID	Taxa	Ecosystem	Specific action	Coarse action group
45	invert	forest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	invert	rainforest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	invert	woodland	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	invert	forest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/ education
45	invert	rainforest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/ education
45	invert	woodland	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/ education
45	mammal	forest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	mammal	rainforest	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	mammal	woodland	raking around habitat trees and logs, fire exclusion	mitigating harm from fire control
45	mammal	forest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/ education
45	mammal	rainforest	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/ education
45	mammal	woodland	raking around habitat trees and logs, fire exclusion	monitoring/research/consultation/ education
46	not specified	not specified	post-fire biodiversity monitoring	monitoring/research/consultation/ education
47	mammal	forest	exclusion fencing, rescue & rehabilitation, research and monitoring	animal rescue
47	mammal	forest	exclusion fencing, rescue & rehabilitation, research and monitoring	monitoring/research/consultation/ education
47	mammal	forest	exclusion fencing, rescue & rehabilitation, research and monitoring	restricting public access
48	mammal	forest	fire exclusion, mosaic burning, fire suppression, maximising resources for koala welfare	admin/funding
48	mammal	forest	fire exclusion, mosaic burning, fire suppression, maximising resources for koala welfare	animal rescue
48	mammal	forest	fire exclusion, mosaic burning, fire suppression, maximising resources for koala welfare	mitigating harm from fire control
49	mammal	forest	vegetation clearing for fire management	fire control activities
49	mammal	woodland	vegetation clearing for fire management	fire control activities
49	mammal	forest	vegetation clearing for fire management	logging/land clearing
49	mammal	woodland	vegetation clearing for fire management	logging/land clearing
50	mammal	forest	fire exclusion, avoidance of tree felling during 'mop-up', exclusion fencing, rescue/rehabilitation/release, emergency translocation	animal rescue
50	mammal	forest	fire exclusion, avoidance of tree felling during 'mop-up', exclusion fencing, rescue/rehabilitation/release, emergency translocation	mitigating harm from fire control
50	mammal	woodland	fire exclusion, avoidance of tree felling during 'mop-up', exclusion fencing, rescue/rehabilitation/release, emergency translocation	mitigating harm from fire control
50	mammal	forest	fire exclusion, avoidance of tree felling during 'mop-up', exclusion fencing, rescue/rehabilitation/release, emergency translocation	monitoring/research/consultation/ education
50	mammal	woodland	fire exclusion, avoidance of tree felling during 'mop-up', exclusion fencing, rescue/rehabilitation/release, emergency translocation	monitoring/research/consultation/ education

ID	Taxa	Ecosystem	Specific action	Coarse action group
50	mammal	woodland	fire exclusion, avoidance of tree felling during 'mop-up', exclusion fencing, rescue/rehabilitation/release, emergency translocation	restricting public access
51	not specified	not specified	not specified	monitoring/research/consultation/education
52	not specified	forest	raking around habitat trees and logs, fire exclusion, planning animal escape routes/refugia, using 'soft-mowing' alternatives, e.g. remote-controlled flail mowers to construct control lines	mitigating harm from fire control
52	not specified	woodland	raking around habitat trees and logs, fire exclusion, planning animal escape routes/refugia, using 'soft-mowing' alternatives, e.g. remote-controlled flail mowers to construct control lines	mitigating harm from fire control
52	not specified	rainforest	raking around habitat trees and logs, fire exclusion, planning animal escape routes/refugia, using 'soft-mowing' alternatives, e.g. remote-controlled flail mowers to construct control lines	mitigating harm from fire control
53	not specified	forest	raking around habitat trees	mitigating harm from fire control
53	not specified	woodland	raking around habitat trees	mitigating harm from fire control
53	not specified	rainforest	raking around habitat trees	mitigating harm from fire control
54	not specified	forest	guidelines for nest box design	habitat creation
54	not specified	woodland	guidelines for nest box design	habitat creation
54	not specified	rainforest	guidelines for nest box design	habitat creation
55	not specified	STE	fire exclusion around habitat trees/logs/riparian areas, herbicide use, predator control, vehicle/equipment washdown to prevent weeds/disease, encourage burning of large trees to facilitate hollow development	mitigating harm from fire control
55	not specified	STE	fire exclusion around habitat trees/logs/riparian areas, herbicide use, predator control, vehicle/equipment washdown to prevent weeds/disease, encourage burning of large trees to facilitate hollow development	predator/competitor control
56	not specified	forest	funding to support regeneration programs, feral animal control, weed control	admin/funding
56	not specified	woodland	funding to support regeneration programs, feral animal control, weed control	admin/funding
56	not specified	grassland	funding to support regeneration programs, feral animal control, weed control	admin/funding
56	not specified	forest	funding to support regeneration programs, feral animal control, weed control	post-fire control rehabilitation
56	not specified	woodland	funding to support regeneration programs, feral animal control, weed control	post-fire control rehabilitation
56	not specified	grassland	funding to support regeneration programs, feral animal control, weed control	post-fire control rehabilitation
56	not specified	forest	funding to support regeneration programs, feral animal control, weed control	predator/competitor control
56	not specified	woodland	funding to support regeneration programs, feral animal control, weed control	predator/competitor control
56	not specified	grassland	funding to support regeneration programs, feral animal control, weed control	predator/competitor control
56	not specified	forest	funding to support regeneration programs, feral animal control, weed control	restricting public access
56	not specified	woodland	funding to support regeneration programs, feral animal control, weed control	restricting public access
56	not specified	grassland	funding to support regeneration programs, feral animal control, weed control	restricting public access

ID	Taxa	Ecosystem	Specific action	Coarse action group
57	mammal	heath	ecological surveys, feral predator control, exclusion fencing	monitoring/research/consultation/education
57	mammal	heath	ecological surveys, feral predator control, exclusion fencing	predator/competitor control
58	bird	forest	artificial nest boxes and planting she-oak trees	habitat creation
58	bird	woodland	artificial nest boxes and planting she-oak trees	habitat creation
58	bird	forest	artificial nest boxes and planting she-oak trees	post-fire control rehabilitation
58	bird	woodland	artificial nest boxes and planting she-oak trees	post-fire control rehabilitation
59	not specified	not specified	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	admin/funding
59	not specified	not specified	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	monitoring/research/consultation/education
59	not specified	not specified	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	post-fire control rehabilitation
59	not specified	not specified	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	predator/competitor control
59	not specified	not specified	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	restricting public access
59	not specified	not specified	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	supplementary resources
59	mammal	forest	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	animal rescue
59	mammal	woodland	food/water drops, monitoring, surveys, feral animal control, plantings, translocation	animal rescue
60	not specified	STE	funding for enclosures, fire equipment, watering stations, rescue equipment, triage clinics	admin/funding
60	not specified	STE	funding for enclosures, fire equipment, watering stations, rescue equipment, triage clinics	animal rescue
61	not specified	not specified	supplemental food and water	supplementary resources
62	not specified	not specified	supplemental food and water	supplementary resources
63	bird	STE	supplemental food and water	supplementary resources
63	herp	STE	supplemental food and water	supplementary resources
63	mammal	STE	supplemental food and water	supplementary resources
64	herp	alpine	fire fighting chemicals; track construction	mitigating harm from fire control
64	invert	alpine	fire fighting chemicals; track construction	mitigating harm from fire control
64	mammal	alpine	fire fighting chemicals; track construction	mitigating harm from fire control
65	not specified	not specified	special fire management zones for conservation purposes	mitigating harm from fire control
66	bird	forest	artificial nest boxes	habitat creation
66	bird	woodland	artificial nest boxes	habitat creation
66	herp	forest	artificial nest boxes	habitat creation
66	herp	woodland	artificial nest boxes	habitat creation
66	mammal	forest	artificial nest boxes	habitat creation
66	mammal	woodland	artificial nest boxes	habitat creation
67	bird	heath	post-fire predator control	predator/competitor control
68	bird	STE	design and installation of wildlife drinking stations	supplementary resources
68	herp	STE	design and installation of wildlife drinking stations	supplementary resources
68	mammal	STE	design and installation of wildlife drinking stations	supplementary resources

Further information:
http://www.nespthreatenedspecies.edu.au

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