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SPECIAL ISSUE ARTICLES

Short-term impacts of the 2019–20 fire season on biodiversity in eastern Australia

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Abstract

To address uncertainties surrounding the impacts of unprecedented 2019–20 bushfires in south-eastern Australia, we convened a symposium on field-measured impacts on biodiversity for the 2020 Ecological Society of Australia conference. Nine presentations covered a range of studies on plant species and communities, and reptiles and mammals. Here, we summarize the presentations and review other field studies from NSW, some of which are currently unpublished. The impacts were extensive, but results also estimated survival rate perhaps higher than first reported in the media. More than half of individual mammal, reptile and threatened rainforest trees may have survived the fire, though small populations remain very vulnerable to second fire in the near future. Comprehensive understanding of the impacts of these fires requires much more field study, and for the results to be interpreted in the context of the broader fire regime. The symposium was an important early step in that understanding.

KEYWORDS
black summer bushfire, ESA symposium, fire recovery

[Correction added on 12 November 2022 after the first publication: Co-author, Berin Mackenzie's name has been corrected to Berin D. E. Mackenzie].

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INTRODUCTION

In December 2020, the Ecological Society of Australia conference held a symposium 'Short term impacts of the 2019–20 fires in eastern Australia'. This was an attempt to report and discuss early field assessments of those fires that stand as the largest forest fires in Australian history (Boer et al., 2020; Nolan et al., 2020). At the time of the symposium, the only published assessments of the environmental impacts of the fires were desktop analysis overlaying the extents of the fires and species distributions (Todd & Maurer, 2020; van Eeden et al., 2020), some of which also included assessment of the vulnerability of individual species to fire (Gallagher, 2020; Gallagher et al., 2021; Legge et al., 2020). Ecological evidence from field studies can take longer to accumulate, but is essential for complementing and refining conclusions drawn from broader inferences from spatial analyses. Moreover, rapid surveys undertaken within days, weeks or months after the fire event are tractable (perhaps surprisingly) and can yield valuable insights within time frames relevant to prioritizing post-fire management responses. As evidence of the need for information about fire impacts, a recent paper by Jolly et al. (2022) reviewed global evidence of the direct impact of fire on fauna and found only 13 published studies where individuals were observed before and after fire.

As these broad-scale spatial assessments were being undertaken, rapid field investigations were already underway. Gallagher et al. (2021) highlighted the importance of field studies to resolve and refine management responses inferred from their spatial analyses about risks identified from various aspects of the fire regime and interacting factors including antecedent drought, disease, post-fire herbivory and weed invasion, among others, which can only be verified and reliably diagnosed on the ground. Many ecologists from a variety of organizations including land management authorities, universities, citizen science groups and government-supported community organizations have been working in the fire grounds to assess the on-ground impacts and recovery actions required. They have been able to access the Federal Government's Wildlife and Habitat Bushfire Recovery Program, which provided $12 m to 37 survey projects (https://www.environment.gov.au/biodiversity/bushfire-recovery/open-grant-program).

The ESA symposium was an attempt to consolidate some of these efforts and help disseminate the information on early findings. The symposium was an open call to 'researchers to present concise studies of the recent fires that provide measurements of change in species, communities or biophysical variables that, taken together, will give a comprehensive picture of the immediate impact of the fires and the initial phases of recovery'. Priority was given to studies that collected pre- and post-fire data to estimate impact. We received nine presentations, six on plants or vegetation and three on vertebrates. Only four of them presented pre- and post-fire data, which partly reflects the fact that there is actually limited systematic data with which to compare post-fire data and partly reflects a focus on recovery processes. Only two of them observed the same individuals before and after fire (McKenzie and Mallee). This paper summarizes these presentations. Since these were only a sample of the field work being undertaken, we also sought information on other relevant studies, focussing on NSW, the state with the largest fire extent.

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THE NINE PRESENTATIONS

Prioritizing plant species at risk, Rachael Gallagher, Macquarie University

Rachael presented a summary of the report that she led, the 'Interim national prioritisation of Australian plants affected by the 2019–20 bushfire season' (Gallagher, 2020), which was used to prioritize species for recovery actions after the fires and highlight the need for on-ground monitoring. The geographic ranges of 26 000 species were intersected with fire extent layers to calculate the proportion of species' total range burnt. These data were coupled with information on persistence traits and spatial data representing 10 interacting threats to post-fire recovery—including antecedent fire frequency, fire severity, disease, pre-fire drought conditions and feral animal herbivory—to assess the likelihood of recovery and identify 487 priority at-risk taxa. The most serious risk identified was the 2019–20 fires burning plant populations that were still recovering from a previous fire. The role of high fire frequency (repeated short fire intervals) was also systemically assessed (Gallagher et al., 2021).

Post-fire collapse of under-mined peatlands David Keith, University of NSW

David and colleagues conducted a field study of recovering montane peatlands in the upper Blue Mountains, NSW. The study sampled the valley floors and sides of 10 swamps at 10 weeks after fire, with follow-up surveys at 11 months and 16 months after fire. A range of structural, compositional and functional variables was analysed with linear models. Ten weeks after burning, some swamps of this endangered ecological community were recovering vigorously, while others showed high levels of plant mortality, major consumption of peat and two orders of magnitude less plant regrowth biomass. In these latter swamps, pre- and post-fire monitoring of soil moisture showed that long-wall coal mining underneath the peatland had substantially reduced water retention, eroding the resilience of the swamps to fire and predisposing them to collapse when the 2019–20 fires swept through the landscape, while unmined swamps remained functional and are rapidly recovering (Keith et al., 2022). A year after the fire, the collapsed swamps remain poorly vegetated, while eucalypts are invading their margins.

Post-fire plant responses in the McPherson range, Queensland, David Donatiu, healthy land and water

In a collaboration between Queensland National Parks and Wildlife Service, Queensland Department of Environment and Science and Healthy Land and Water, teams opportunistically surveyed rainforest and wet sclerophyll plants in Gondwanan National Parks in fire-affected areas of south-eastern Queensland. They found persistent weed invasion, especially White Passion Flower (*Passiflora subpeltata*), Lantana (*Lantana camara*) and Devils Fig (*Solanum chrysotrichum*). Regeneration of native species was vigorous. Of the resprouting trees, 25% of individuals were early succession species, as expected, but 43% were species normally associated with mature forest. The team recorded the endangered pink underwing moth (*Phyllodes imperialis*) in Lamington National Park for the first time, and this has prompted a programme to survey populations of its preferred host plant.

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Bushfire impacts on the Wollemi Pine (*Wollemia nobilis*), Berin Mackenzie, Department of Planning, Industry and Environment, NSW

The critically endangered Wollemi Pine is known from a single remnant population in a remote canyon of Wollemi National Park. The 2019–20 bushfires impacted the steep rainforest gorge the species occupies, although considerable efforts by DPIE scientists, the NSW National Parks and Wildlife Service and the Rural Fire Service reduced the impacts. In an ongoing monitoring and conservation programme, Berin found that the majority of adult trees survived the fire with their upper canopies intact. Impacts were greater for juvenile trees with two-thirds suffering 100% canopy scorch and half of these resprouting to date. Several hundred seedlings and smaller juveniles up to 2 m tall are yet to resprout and may have been eliminated by the fires. The population is being closely monitored and will need to be protected from fire for an extended period to facilitate recovery.

Range restricted threatened flora in north-east NSW, Justin Mallee, Department of Planning, Industry and Environment

DPIE and NSW National Parks and Wildlife Service conduct a monitoring programme for five threatened tree species in the Gondwana rainforests of northern NSW in Nightcap National Park: (*Uromyrtus australis* (peach myrtle), *Eidothea hardeniana* (nightcap oak), *Elaeocarpus sedentarius* (minyon quandong), *Corokia whiteana* (corokia) and *Symplocos baeuerlenii* (small-leaved hazelwood)). Pre- and post-fire surveys revealed that 20% of the population of 388 nightcap oaks were burnt and 16% of the 388 had failed to resprout, while for the peach myrtle, 38% were burnt and 4% not resprouting. Subsequent observations showed severe infection of resprouting survivors by myrtle rust disease. Changes to the structure of the rainforests these species inhabit has been considerable, but tree species composition has remained fairly stable.

Interactive effects of logging and wildfire on forest carbon stability, Nicholas Wilson, University of Wollongong

Nick surveyed above-ground carbon stocks in seeding and resprouting forests in NSW, that were subject to both logging and wildfire prior to the 2019 fires. He found that the fires reduced carbon stocks by 17 t/ha on average compared with pre-fire stocks, although there was considerable variability. Sites that burnt at high severity typically lost 10 t/ha more carbon than sites that burnt at low severity. Carbon stock losses increased by 15 t/ha with recent antecedent logging and 8 t/ha with recent antecedent wildfire compared with the sites that had not been disturbed for approximately 80 years prior to the 2019 fires.

Fire impact on koalas, Romane Critescu, University of the Sunshine Coast

The USC 'Detection Dogs for Conservation' team deployed two methods to survey koala (*Phascolarctos cinereus*) in burnt and unburnt forests in southern Queensland and southern NSW: fresh scat detection by trained

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dogs coupled with genetic fingerprinting, and thermal imaging from drones. In NSW, the drones were able to cover large areas (more than 5000 ha of burnt and unburnt control sites). The drone-generated koala density estimates showed a 25% lower density in burnt compared with very closely matched unburnt forest sites. In Queensland, the dog survey covered smaller areas and found variable densities, but confirmed Koala presence in all areas. More detail of this study can be found in (Critescu et al., 2021) in this special edition.

Ground-dwelling mammals in the Clyde Mountain fire, Katarina Mikac, University of Wollongong

Pre- and post-fire camera trap data were presented for numerous sites in Monga National Park. The team found that while the number of mammals was greatly reduced immediately after fire, it took 4 months for the full pre-fire complement of species to return and the delay was longest in the more severely burnt sites. More detail of this study can be found in (Mikac et al., 2021) in this special edition.

Impacts on the endangered broad headed Snake, Jonathon Webb, University of Technology Sydney

The broad headed snake (*Hoplocephalus bungaroides*) has been monitored in Morton National Park for ~30 years. Over that time, survey counts fell about 20% after bushfires in 2002 and also 20% after the 2019 fires. More detail of this study can be found in (Webb et al., 2021) in this special edition.

OTHER POST-FIRE BIODIVERSITY DATA IN NSW

The symposium represented only a small proportion of the field impact assessments that have been conducted since the 2019–20 fires. Citizen naturalists have recorded many observations of species present since the fires on widely accessible phone app platforms. Two examples are FrogID (Rowley et al., 2020) and iNaturalist (Kirchhoff et al., 2021). FrogID was started in 2017 by the Australian Museum and by comparing 2600 pre-fire and 632 post-fire observations, (Rowley et al., 2020) found that all 33 species with more than five pre-fire records were also recorded post-fire in the burnt areas, though their population trajectories could not be determined. The iNaturalist project set up report on the 2019–20 bushfires had recorded 3265 citizen observations by March 2020, which are being used to document the post-fire recovery of a range of taxa (Kirchhoff et al., 2021).

The NSW Department of Planning, Industry and Environment (DPIE) commenced a camera monitoring programme in 2012 at 200 sites throughout eastern NSW (Mills, 2020). The 2020 post-fire data have not been formally documented, but initial analysis for the species common enough to detect changes indicates a variety of responses in site occupancy with respect to severity of wildfire. For example, site occupancy of the short-beaked echidna and eastern grey kangaroo was inversely related to fire severity. Conversely, site occupancy of the common wombat and superb lyrebird was positively related to fire severity. Other species such as the swamp wallaby and common brushtail possum showed no discernible change (D. Mills, personal communication). Forestry Corporation NSW conducted extensive surveys in production forests within 5 months of the 2019–20 fires (Anon, 2020a). At the time of reporting in June 2020, the

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surveys were still in progress, but already 41 threatened species had been observed in burnt areas (17 plants, nine mammals, four frogs and 11 birds).

University teams have also been active. The NSW Bushfire Risk Management Research Hub at the University of Wollongong conducted an active search with 24 volunteers in severely burnt areas of Morton National Park 6 weeks after the fire. They observed 69 reptiles of eight species and 87 fresh wallaby scats and 60 wombat scats in a 20 ha area, indicating at least some fire survival. More recently, UoW has teamed up with Prof. Michael Letnic from the University of NSW (with federal Wildlife and Habitat Bushfire Recovery Grant Program funding) to survey reptiles across the Blue Mountains region. Initial results from 79 sites indicate that reptile species richness was higher in burnt sites than unburnt, suggesting that burnt areas may be used preferentially for foraging by survivors and/or immigrants (Figure 1a). We also observed similar numbers of greater gliders before and after the fires in the Wollemi National Park, at least 5 km from the nearest unburnt forest (Figure 1b). Ecological consultancies have also been active using government and non-government funding. For example, koala surveys have been conducted in prime koala habitat affected by fires in northern NSW (Phillips et al., 2020). This study surveyed for scats in 123 sites and found a 71% reduction in koala abundance, broadly consistent across the six regions studied.

DISCUSSION

The eight field studies in the symposium together with other post-fire surveys reported here found substantial impacts from the fires. Rainforests were a particular concern because the fires burnt a far higher proportion than usual, and rainforest plants are thought to be sensitive to bushfire (Zimmer et al., 2015). The two rainforest presentations showed appreciable mortality of juvenile trees, while adults of a range of species were top-killed with a variable portion of those surviving and resprouting from the base. Adult post-fire survival rates of Wollemi Pine were high, although the impacts would likely have been much greater without the significant intervention to reduce fire severity. The population remains vulnerable to future fires until seedlings mature and replace lost individuals, and resprouting individuals regain their pre-fire structure. The long-term prognosis for these rainforests remains uncertain, given increasing incidence of droughts and

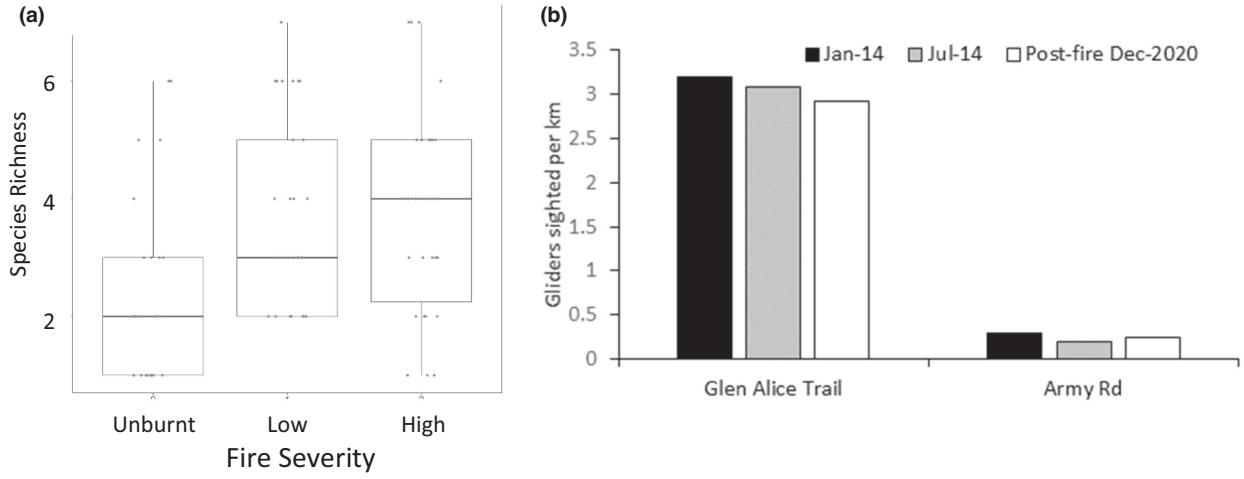

FIGURE 1 Two additional examples of fauna response to the 2019–20 bushfires (unpublished data from authors B.R and M.L.): (a) reptile species richness at 79 sites in the Blue Mountains region 10 months after bushfire, from a combination of trapping and active searches; (b) vehicle-based spotlight counts along two trails in Wollemi National Park, comparing 2014 to 1 year after the 2019–20 bushfire.

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extreme fire weather (Boer et al., 2020), and the possible increased flammability due to the loss of moist microclimates while the tree canopies are regenerating (Cawson et al., 2018; Lindenmayer et al., 2011). Invasion of flammable plants such as Lantana probably exacerbate the propensity for fire to spread when conditions are dry. Consequently, the main priorities for federal funding for recovery of the rainforests of south-east Queensland are reducing the likelihood of future fire and controlling invasive species, rather than direct intervention in plant populations (Anon, 2020c).

Like rainforests, many arboreal mammals, are considered to be in decline and vulnerable to bushfire. For example, substantial impacts on habitat and numbers of animals from these bushfires have been predicted for greater gliders (Smith & Smith, 2020), koalas (Anon, 2020b) and other arboreal mammals (Lindenmayer et al., 2020). The post-fire surveys described above suggest a range of species responses in the burnt areas, although the mechanisms underpinning persistence of survivors and recolonization from unburnt refuges remain poorly understood, especially for such large fires as these. The reduction in abundance in the three studies here is higher than those reported by Jolly et al. (2022) (mean 3% reduction), though unlike Jolly et al. (2022), they did not observe the fate of individual animals.

Overall, the surveys of post-fire biodiversity impacts demonstrate four important conclusions:

1. The species examined in this symposium demonstrate a variety of responses to the 2019–20 fire event, including residual persistence and long-lasting impacts.
2. The 2019–20 fires have made many species (especially plants) vulnerable to future fires that occur before their populations have fully recovered, and to other threats including feral animals, weeds, disease and drought.
3. An understanding of the full implications of the 2019–20 bushfire seasons requires much more information. Species differ in their response to fire events and we have canvassed only a small proportion of the species. Species also differ in their response to other fire regime aspects: particularly fire interval and severity but also season and size. Much less is known about these aspects. Finally, the longer-term trajectory of the recovery is uncertain due to added threats from weeds, feral animals, disease and climate change.
4. Gaining this understanding requires a commitment to field-based research and monitoring. The most important focus should be on monitoring the species identified as high risk, but also general biodiversity monitoring is required because the future may not eventuate as we currently predict. The monitoring should be matched with research to highlight long-term responses to fire regime variables and their interactions with other threats.
5. The eight studies showed that the fires had impacts of a scale that should make us very concerned, given existing extinction rates.
6. The studies that examined interactions between fire and existing anthropogenic disturbances (logging and mining) showed that disturbed communities were less resilient to fire impacts.

AUTHOR CONTRIBUTIONS

Owen F. Price: Conceptualization (lead); methodology (lead); project administration (lead); writing – original draft (lead); writing – review and editing (lead). **Katarina Mikac:** Data curation (equal); writing – original draft (supporting); writing – review and editing (supporting). **Nicholas Wilson:** Writing – original draft (supporting); writing – review and editing (supporting). **Bridget Roberts:** Writing – original draft (supporting); writing – review

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and editing (supporting). **Romane H. Cristescu:** Writing – original draft (supporting); writing – review and editing (supporting). **Rachael Gallagher:** Writing – original draft (supporting); writing – review and editing (supporting). **Justin Mallee:** Writing – original draft (supporting); writing – review and editing (supporting). **Paul Donatiu:** Writing – original draft (supporting); writing – review and editing (supporting). **Jonathan Webb:** Writing – original draft (supporting); writing – review and editing (supporting). **David A. Keith:** Writing – original draft (supporting); writing – review and editing (supporting). **Michael Letnic:** Writing – original draft (supporting); writing – review and editing (supporting). **Berin D.W. Mackenzie:** Writing – original draft (supporting); writing – review and editing (supporting).

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DATA AVAILABILITY STATEMENT

The data in this research note represent work from a range of authors. Some of these are available from detailed publications (including in this edition of Austral Ecology), while others are still being collected and as such are not yet available to readers.

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