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Impact of 2019–2020 mega-fires on Australian fauna habitat

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Australia's 2019–2020 mega-fires were exacerbated by drought, anthropogenic climate change and existing land-use management. Here, using a combination of remotely sensed data and species distribution models, we found these fires burnt ~97,000 km² of vegetation across southern and eastern Australia, which is considered habitat for 832 species of native vertebrate fauna. Seventy taxa had a substantial proportion (>30%) of habitat impacted; 21 of these were already listed as threatened with extinction. To avoid further species declines, Australia must urgently reassess the extinction vulnerability of fire-impacted species and assist the recovery of populations in both burnt and unburnt areas. Population recovery requires multipronged strategies aimed at ameliorating current and fire-induced threats, including proactively protecting unburnt habitats.

The impact of major fires on species and ecosystems is attracting increasing conservation attention in many parts of the world. Fire is an important disturbance in numerous ecosystems worldwide[1], yet changes to fire regimes are frequently implicated in extinctions[2]. Without fire, some plants and communities are unable to persist, while some animals rely on post-fire growth and flowering of plants for habitats and resources[3–6]. However, due to climate change and other factors[7], many parts of the world are experiencing larger, more frequent and more intense fires, often outside of the traditional fire season[8–11]. In the past few years, catastrophic fire events have occurred in the United States, Brazil, Democratic Republic of Congo, Indonesia and Russia[12–16].

The Australian mega-fires that occurred between July 2019 and February 2020 were unprecedented in their spatial extent and severity across the subtropical, Mediterranean and temperate bioregions of the continent[17]. Approximately 97,000 km² of the southern Australian forest, woodlands, heathlands, grasslands and farmlands burned. These fires were at least 50 times more extensive than California's worst wildfires on record[14] and five times the size of the 2019 fires in the Amazon[17]. They were also exceptionally severe, burning Australian ecosystems that typically do not burn, including the World Heritage-listed Gondwanan rainforest[18,19].

While fires are commonplace in large parts of the Australian landscape, many native fauna species depend on long-unburnt vegetation for the provision of specific food resources (for example, nectar and fruits), development of complex vegetation and ground-level structure for foraging and refuge from predation, and tree hollows for nesting and roosting[20–23]. The spatial extent and severity of wildfire, and the landscape context in which it burns, greatly influence how fire affects individual survival, post-fire recovery and long-term persistence of species in burnt landscapes[24–27].

The 2019–2020 mega-fires impacted native species in numerous ways. Many individual survivors will struggle in the short term to find food and shelter in burnt habitat or ash-impacted localities, leaving them vulnerable to starvation, environmental extremes and predators[28–30]. In the long term, the loss of key resources, such as tree hollows, nectar-bearing trees and deep pools, may impact species populations for decades or centuries[31]. Many impacted species were already in a state of decline caused by drought, disease, habitat destruction and invasive species[32,33]. The 2019–2020 mega-fires may have exacerbated the situation by abruptly and severely reducing population sizes and rendering habitat unsuitable for many years.

Here we assess the 2019–2020 bushfire season within temperate, Mediterranean and subtropical Australian landscapes, which are characterized by remnants of forest, woodland and heathland ecosystems in a human-dominated matrix. We quantify the overlap of the fires with all 243 nationally threatened (that is, those listed in Australia's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)) terrestrial and freshwater vertebrate fauna

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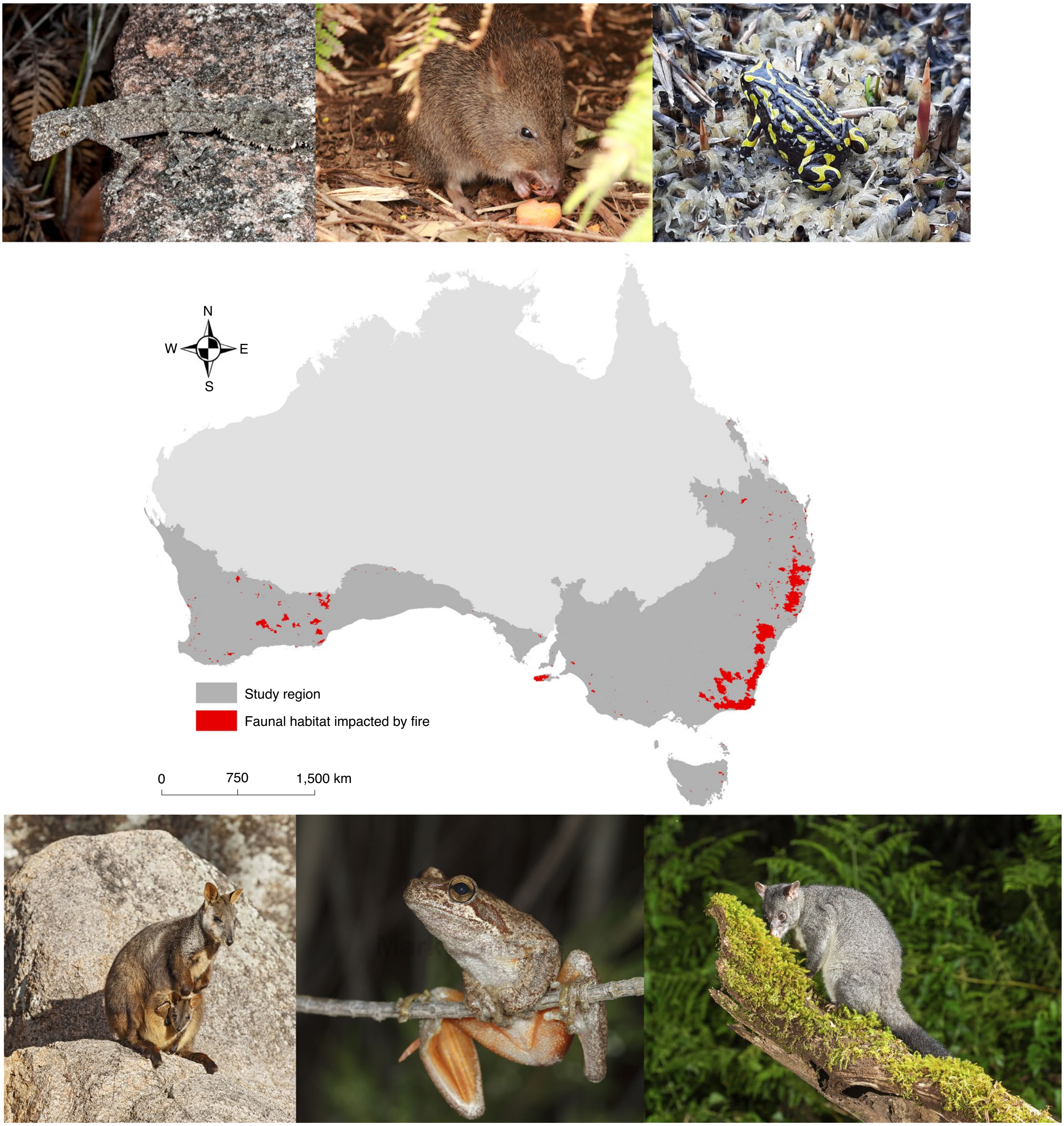

Fig. 1 | Vertebrate fauna habitat burned during the 2019–2020 mega-fires. The photographs show taxa impacted by the recent bushfires (clockwise from top left): Kate's leaf-tailed gecko *S. kateae* (100% of habitat burnt), long-footed potoroo *P. longipes* (82%), northern corroboree frog *Pseudophryne pengilleyi* (26%), short-eared brushtail possum *T. caninus* (64%), Littlejohn's tree frog *L. littlejohni* (62%) and brush-tailed rock-wallaby *Petrogale penicillate* (38%). Credit: Anders Zimny (Kate's leaf-tailed gecko), George Bayliss (long-footed potoroo), Ben Scheele (northern corroboree frog) and Mark Sanders (brush-tailed rock-wallaby, Littlejohn's tree frog and short-eared brushtail possum).

species or subspecies (hereinafter referred to collectively as 'taxa')[34] whose ranges intersect with the study region. We also examine the overlap with almost all (those with reasonable distribution data) non-threatened terrestrial and semiterrestrial vertebrate taxa in the study region, comprising 71 mammals, 500 birds, 554 reptiles and 143 frogs. We quantify potential impacts by intersecting the Australian Government's national fire dataset[35] with the realized and potential habitat of taxa (hereinafter referred to collectively as 'habitat') derived from species distribution models and/or expert opinion[36–38] (see Methods). Our assessment does not consider plants, invertebrates and non-threatened freshwater fish and turtles, and hence captures only a subset of the fires' impact on Australian biodiversity.

Our results show that the 2019–2020 fires overlapped with habitat for 107 threatened vertebrate fauna (44% of taxa assessed)

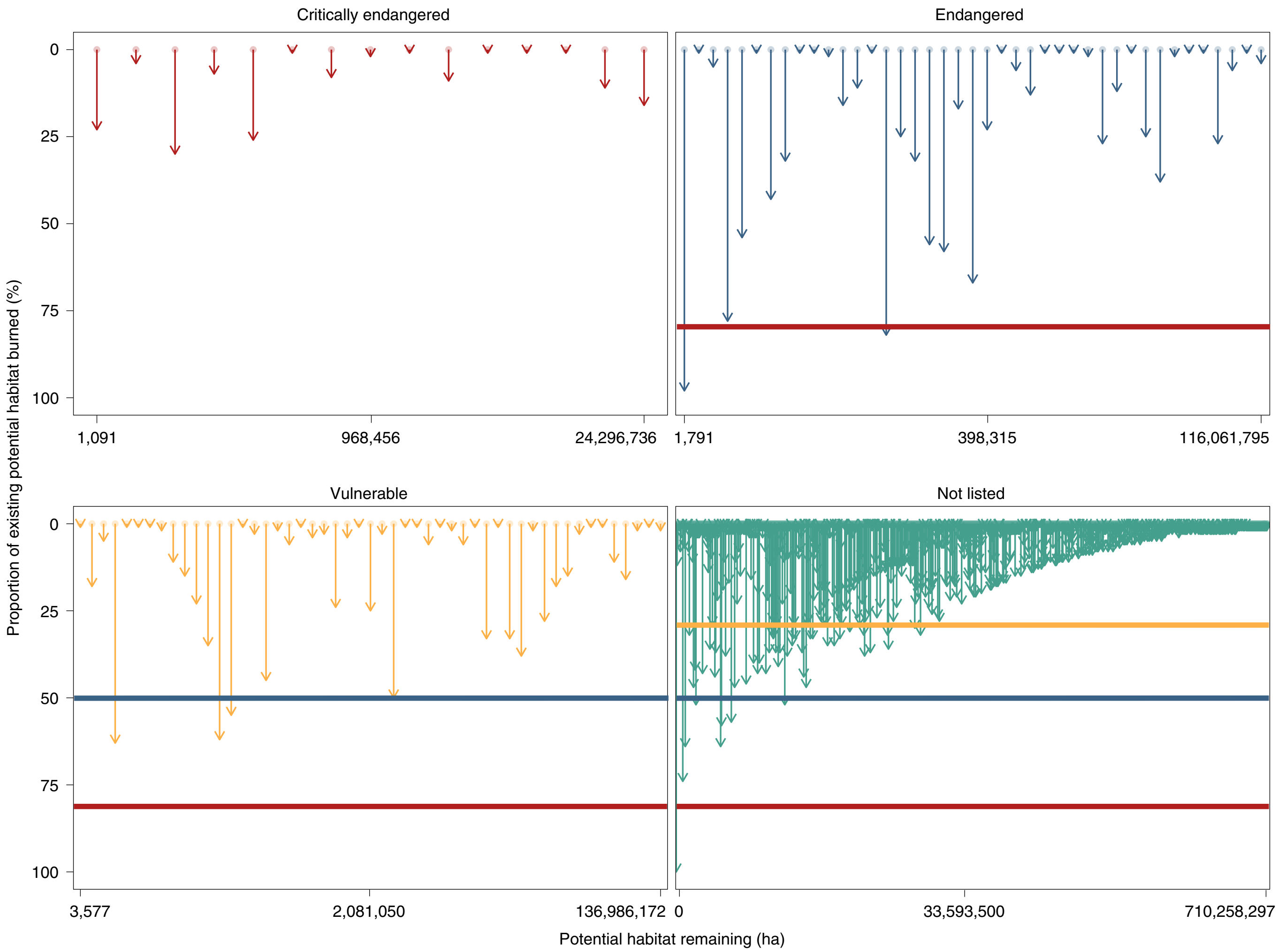

Fig. 2 | Proportional impact of the 2019–2020 mega-fires on the habitats of 832 species. Change in available habitat area for each threatened and non-threatened vertebrate species, categorized by their current EPBC Act threat status. The horizontal lines indicate EPBC Act threat status thresholds of >30% (yellow), >50% (blue) and >80% (red) for vulnerable, endangered and critically endangered, respectively.

and 725 non-threatened vertebrate fauna (57% of non-threatened taxa assessed). These fires burned ~97,000 km^2 of remnant vegetation, all of which is considered habitat for at least one threatened or non-threatened faunal taxa (Fig. 1). In total, 378 birds, 254 reptiles, 102 frogs, 83 mammals and 15 freshwater fish have habitats overlapped by these fires. Of these 832 taxa, 196 had 10–30% of the Australian extent of their habitat burned, 51 had 30–50% of habitat burned, 16 had 50–80% of habitat burned and 3 had >80% of habitat burned.

The EPBC Act is Australia's primary legislation for protecting threatened species and includes criteria for classifying species and subspecies as threatened[39] (see Methods). Our analysis shows a high level of overlap between fire and the distribution of many taxa, potentially translating into major declines in abundance and distribution. Crucially, in many cases, taxa affected by the fires were already in a state of decline, compounding the fire impact and possibly reducing their capacity to recover. For example, three taxa had >80% of habitat impacted by these fires. Two of these species, the Kangaroo Island dunnart *Sminthopsis griseoventer aitkeni* and the long-footed potoroo *Potorous longipes* (both categorized as endangered by the EPBC Act), were already threatened with extinction, while a third, Kate's leaf-tailed gecko *Saltuarius kateae*, is a narrow-range endemic that is currently not listed. The threat status of all three taxa requires re-evaluation as it is likely the immediate and ongoing effects of the fires will translate into substantial population size reductions. Four vulnerable taxa, including the South Australian Bassian thrush *Zoothera lunulata halmaturina* and Littlejohn's tree frog *Litoria littlejohni*, as well as seven currently non-threatened species, including Pugh's frog *Philoria pughi* and short-eared possum *Trichosurus caninus*, had >50% of their habitat impacted, suggesting they may now meet the endangered criteria if fire impacts translate commensurately into reductions in population size.

Forty-one species not currently listed as threatened, such as the long-nosed bandicoot *Perameles nasuta* and pilotbird *Pycnoptilus floccosus*, had >30% of their habitat impacted, warranting assessment for listing as threatened (Fig. 2). If extinction risk assessments find that these 49 species meet listing criteria[39], the number of threatened Australian terrestrial and freshwater vertebrate fauna would increase by 14%. Rapid extinction risk assessment of non-threatened species is urgent, as without listing, there is no trigger for dedicated monitoring and recovery efforts.

Our preliminary results indicate that 55 threatened and non-threatened taxa probably warrant detailed reassessment or initial assessment against the criteria for listing under the EPBC Act. While our fundamental aim was different to that of other assessments[40], the species we have identified are largely consistent, except for an additional 16 freshwater fish and crayfish listed as threatened by the International Union for Conservation of Nature that may also require an initial assessment. The formal conservation status assessments must consider fire severity (and hence the extent to which habitat suitability has been reduced), the susceptibility of species to fire and prolonged drought[41] and their capability to survive in burnt landscapes. These detailed assessments can be used to target species that will require a range of strategic and targeted post-fire management actions to maintain and recover surviving populations. While some species are monitored sufficiently, many are not[42], and additional resources are required to support on-ground surveys that quantify fire impacts on species abundance and distribution, and help identify priority areas for immediate management efforts. The range of population recovery actions required is broad and informed by the sensitivity of each species to fire and to the suite of threatening processes that affect it[43]. Such actions include invasive species control, supplementary feeding and captive breeding programmes[28,44,45]. Surveys could also inform assessments of the areas to be prioritized for long-term conservation action, including protecting unburnt refuges and large intact areas of forests or streams, and, where needed, restoration of habitats[46].

The 2019–2020 fires highlight the need for better information on species' responses to fire, in particular, mega-fires. Many assessments of the likely impact of fire on species are based on best guesses rather than empirical evidence. These fires provide an opportunity to closely examine species' responses to landscape-scale fires, which are projected to become more frequent[47–49]; they also provide scope for monitoring the extent and pace of species' recovery (or failure to recover) and of the effectiveness of different remedial management responses. We have explored the extent of overlap with fire, but for some species, this may be an imprecise proxy for fire impact. Further consideration of fire severity, susceptibility to other threats, downstream impacts from ash and sediment inputs to streams, and life history traits of species will provide more refined evaluation of impacts[26]. We also need to better understand the relative influence of factors such as topography, local climate, land use and land management on fire susceptibility and spread, both to improve predictions of the probable spatial distribution of fires in the future and to manage in ways that minimize the likelihood of mega-fires. For example, historical and contemporary logging in Australian forests has increased fire severity[50] and flammability[51].

Australia has one of the worst extinction rates in the world, including the highest mammal extinction rate[52]. Species declines showed no sign of slowing, even before the 2019–2020 fires[53]. This extinction crisis is the result of major changes in land management (for example, land clearing, logging and extensive grazing), combined with the impacts of introduced species across the continent, transforming many Australian ecosystems[32,52,53]. Some Australian landscapes have become more prone to catastrophic wildfire[54–56] due to ecosystem transformations[7] and the escalating climate crisis causing drier forests and more frequent, longer periods of extreme fire weather[57]. As well as threatening native wildlife, mega-fires affect human life and property. Australia has the opportunity to pursue synergistic strategies for achieving human safety, climate change mitigation and species conservation through improved native vegetation retention and management. Avoiding further species extinctions will require assessment and recovery of species imperilled by mega-fires, including stopping habitat loss and managing threats to species survival in remaining unburnt forests.

Methods

The study region for this analysis is composed of 43 temperate, Mediterranean and subtropical bioregions across 2.2 million km^2, as defined in the Interim Biogeographic Regionalization for Australia dataset[58]. This geographic unit was selected because fire is a much more frequent and normal event in other bioregions, mostly comprising tropical savannahs and arid and semiarid environments. Species distributions for non-threatened mammals and birds were obtained from Graham et al.[36], who modelled the distribution of every continental Australian species of bird and mammal where sufficient data were available to fit a useful model[59,60]. Models were fitted using MaxEnt (version 3.4.0)[61], standard bioclimatic variables and taxonomically relevant target-group background points. Models were evaluated using the area under the receiver operating characteristic curve statistic, and through extensive expert vetting, and only those with an area under the curve >0.7 and that sufficiently approximated the species' known range were retained[36]. Data for non-threatened mammal and bird subspecies were aggregated and modelled as a single distribution. Post-processing of model outputs involved using expert-derived species-specific thresholds to indicate where modelled habitat suitability was sufficiently low that the species was likely to be absent. Data on frogs and reptiles were obtained from Hoskin et al.[37] and Tingley et al.[38], respectively. Reptile polygons were refined by experts as part of the International Union for Conservation of Nature Red List assessment process for Australian squamates. While some vertebrate species can use microrefugia to reduce mortality rates during wildfires[62], many studies report substantial fire-associated mortality and habitat loss of such species[63–65]. These are the largest and most consistent datasets of distribution models for non-threatened terrestrial and semiterrestrial vertebrate fauna in Australia. For threatened species, we used 100 m × 100 m gridded species distributions of Species of National Environmental Significance supplied and stored by the Australian Government[34]. We used only 'known' and 'likely' habitat ranges for all listed terrestrial mammals, birds, reptiles, frogs and freshwater fish. We included only threatened freshwater species directly intersecting with fire extents, but recognize the impact of freshwater species will be much more extensive due to mass sedimentation events that impact downstream populations.

We used the Australian Government National Indicative Aggregated Fire Extent Dataset (version 20200225)[35], downloaded on 13 February 2020, to generate an estimate of the fire impact on species habitat. This dataset combined information from multiple sources, including from state and territory agencies responsible for emergency and natural resource management, and from the Northern Australian Fire Information website. The variety of mapping methods and attribution approaches means, conceptually, that the dataset lacks national coherency and, in some areas, may identify false positives; however, this is the most comprehensive and reliable dataset currently available. This dataset includes satellite imagery from 1 July 2019 to 13 February 2020, which covers the majority of the 2019–2020 Australian fire season in the bioregions considered.

To calculate the area impacted for each species, we intersected the burn extent with the realized and potential habitat for each species, and calculated the total area remaining and percentage of habitat burnt. To evaluate which species should be assessed for re-evaluation under the EPBC Act, we used the Australian Government's guidelines for assessing the conservation status of native species according to the EPBC Act[39]. Under the EPBC Act, a species may be listed as critically endangered, endangered or vulnerable if it experiences a population size reduction of >80%, >50% or >30%, respectively, measured over the longer of ten years or three generations (where threats are ongoing and unresolved, and given temporal considerations). A decline in area of occupancy, extent of occurrence and/or quality of habitat is identified under this listing criterion as a driver (and indicator) of such population declines.

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

All datasets used in this analysis are available via the citations identified in the Methods. The raw data used to create Figs. 1 and 2 are available in Supplementary Table 1 and in figshare with the identifier https://figshare.com/s/62ef92b49704bb139333.

Code availability

The code used in this study is freely available at https://figshare.com/s/d9140d7c22e5ebbf2e03.

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References

1. Bowman, D. et al. Fire in the Earth system. *Science* **324**, 481–484 (2009).
2. Mangel, M. & Tier, C. Four facts every conservation biologist should know about persistence. *Ecology* **75**, 607–614 (1994).
3. Gill, A. M. Fire and the Australian flora: a review. *Aust. For.* **38**, 4–25 (1975).
4. Brotons, L., Herrando, S. & Pons, P. Wildfires and the expansion of threatened farmland birds: the ortolan bunting *Emberiza hortulana* in Mediterranean landscapes. *J. Appl. Ecol.* **45**, 1059–1066 (2008).
5. Bird, R. B., Tayor, N., Codding, B. F. & Bird, D. W. Niche construction and Dreaming logic: Aboriginal patch mosaic burning and varanid lizards (*Varanus gouldii*) in Australia. *Proc. Biol. Sci.* **280**, 20132297 (2013).
6. Bowman, D. M. J. S., Wood, S. W., Neyland, D., Sanders, G. J. & Prior, L. D. Contracting Tasmanian montane grasslands within a forest matrix is consistent with cessation of Aboriginal fire management. *Austral Ecol.* **38**, 627–638 (2013).

7. Lindenmayer, D. B., Kooyman, R. M., Taylor, C., Ward, M. & Watson, J. E. M. Recent Australian wildfires made worse by logging and associated forest management. *Nat. Ecol. Evol.* **4**, 898–900 (2020).
8. Jolly, W. M. et al. Climate-induced variations in global wildfire danger from 1979 to 2013. *Nat. Commun.* **6**, 7537 (2015).
9. Murphy, B. P. & Russell-Smith, J. Fire severity in a northern Australian savanna landscape: the importance of time since previous fire. *Int. J. Wildl. Fire* **19**, 46–51 (2010).
10. Mantgem, P. J. et al. Climatic stress increases forest fire severity across the western United States. *Ecol. Lett.* **16**, 1151–1156 (2013).
11. Fonseca, M. G. et al. Climatic and anthropogenic drivers of northern Amazon fires during the 2015-2016 El Nino event. *Ecol. Appl.* **27**, 2514–2527 (2017).
12. *Huge Wildfires in Russia's Siberian Province Continue* (NASA, 2019).
13. Escobar, H. Amazon fires clearly linked to deforestation, scientists say. *Science* **365**, 853 (2019).
14. *2018 Incident Archive Report* (California Government, 2019).
15. Dennis, R., Hoffmann, A., Applegate, G., von Gemmingen, G. & Kartawinata, K. Large-scale fire: creator and destroyer of secondary forests in western Indonesia. *J. Trop. Sci.* **13**, 786–799 (2001).
16. Verhegghen, A. et al. The potential of sentinel satellites for burnt area mapping and monitoring in the Congo Basin forests. *Remote Sens.* **8**, 986 (2016).
17. Boer, M. M., Resco de Dios, V. & Bradstock, R. A. Unprecedented burn area of Australian mega forest fires. *Nat. Clim. Change* **10**, 171–172 (2020).
18. Borunda, A. See how much of the Amazon is burning, how it compares to other years. *National Geographic* (29 August 2019).
19. Nolan, R. H. et al. Causes and consequences of eastern Australia's 2019–20 season of mega-fires. *Glob. Change Biol.* **26**, 1039–1041 (2020).
20. Kooyman, R. M., Watson, J. & Wilf, P. Gondwana World Heritage Site burns. *Science* **367**, 1083 (2020).
21. Kelly, L. T., Bennett, A. F., Clarke, M. F. & Mccarthy, M. A. Optimal fire histories for biodiversity conservation. *Conserv. Biol.* **29**, 473–481 (2015).
22. Davis, R. et al. Conserving long unburnt vegetation is important for bird species, guilds and diversity. *Biodivers. Conserv.* **25**, 2709–2722 (2016).
23. Doherty, T. S., Davis, R. A., van Etten, E. J. B., Collier, N. & Krawiec, J. Response of a shrubland mammal and reptile community to a history of landscape-scale wildfire. *Int. J. Wildl. Fire* **24**, 534–543 (2015).
24. Dixon, K. M., Cary, G. J., Worboys, G. L. & Gibbons, P. The disproportionate importance of long-unburned forests and woodlands for reptiles. *Ecol. Evol.* **8**, 10952–10963 (2018).
25. Taylor, R. S. et al. Landscape-scale effects of fire on bird assemblages: does pyrodiversity beget biodiversity? *Divers. Distrib.* **18**, 519–529 (2012).
26. Lindenmayer, D. B. et al. Fire severity and landscape context effects on arboreal marsupials. *Biol. Conserv.* **167**, 137–148 (2013).
27. Chia, E. K. et al. Effects of the fire regime on mammal occurrence after wildfire: site effects vs landscape context in fire-prone forests. *Ecol. Manag.* **363**, 130–139 (2016).
28. Leahy, L. et al. Amplified predation after fire suppresses rodent populations in Australia's tropical savannas. *Wildl. Res.* **42**, 705–716 (2015).
29. Murphy, S. A. & Legge, S. M. The gradual loss and episodic creation of palm cockatoo (*Probosciger aterrimus*) nest-trees in a fire- and cyclone-prone habitat. *Emu* **107**, 1–6 (2007).
30. Lyon, J. P. & O'Connor, J. P. Smoke on the water: can riverine fish populations recover following a catastrophic fire-related sediment slug? *Austral Ecol.* **33**, 794–806 (2008).
31. Haslem, A. et al. Time-since-fire and inter-fire interval influence hollow availability for fauna in a fire-prone system. *Biol. Conserv.* **152**, 212–221 (2012).
32. Kearney, S. et al. The threats to Australia's imperilled species and implications for a national conservation response. *Pac. Conserv. Biol.* 25, 231–244 (2018).
33. Ward, M. S. et al. Lots of loss with little scrutiny: the attrition of habitat critical for threatened species in Australia. *Conserv. Sci. Pract.* **1**, e117 (2019).
34. *Species of National Environmental Significance* (Commonwealth of Australia, 2019).
35. *National Indicative Aggregated Fire Extent Dataset* Version 20200225 (Commonwealth of Australia, 2020); https://go.nature.com/38wZSRr
36. Graham, E. M. et al. Climate change and biodiversity in Australia: a systematic modelling approach to nationwide species distributions. *Australas. J. Environ. Manag.* **26**, 112–123 (2019).
37. Hoskin, C., Grigg, G., Stewart, D. & Macdonald, S. *Frogs of Australia* (James Cook University, 2015).
38. Tingley, R. et al. Geographic and taxonomic patterns of extinction risk in Australian squamates. *Biol. Conserv.* **238**, 108203 (2019).
39. *Guidelines for Assessing the Conservation Status of Native Species According to the Environment Protection and Biodiversity Conservation Act 1999 and Environment Protection and Biodiversity Conservation Regulations 2000* (Commonwealth of Australia, 2000).
40. *Rapid Analysis of Impacts of the 2019–20 Fires on Animal Species, and Prioritisation of Species for Management Response – Preliminary Report* (Commonwealth of Australia, 2020).
41. Brodribb, T. J., Powers, J., Cochard, H. & Choat, B. Hanging by a thread? Forests and drought. *Science* **368**, 261–266 (2020).
42. Scheele, B. C. et al. Continental-scale assessment reveals inadequate monitoring for threatened vertebrates in a megadiverse country. *Biol. Conserv.* **235**, 273–278 (2019).
43. *Victoria's Bushfire Emergency: Biodiversity Response and Recovery* (Victoria State Government, 2020).
44. Smales, I., Brown, P., Menkhorst, P., Holdsworth, M. & Holz, P. Contribution of captive management of orange-bellied parrots to the recovery programme for the species in Australia. *Int. Zoo. Yearb.* **37**, 171–178 (2000).
45. Broughton, S. K. & Dickman, C. R. The effect of supplementary food on home range of the southern brown bandicoot, *Isoodon obesulus*. *Aust. J. Ecol.* **16**, 71–78 (1991).
46. Legge, S., Kennedy, M. S., Lloyd, R., Murphy, S. A. & Fisher, A. Rapid recovery of mammal fauna in the central Kimberley, northern Australia, following the removal of introduced herbivores. *Austral Ecol.* **36**, 791–799 (2011).
47. IPCC *Special Report on Global Warming of 1.5 °C* (eds Masson-Delmotte, V. et al.) (WMO, 2018).
48. Clarke, H. & Evans, J. P. Exploring the future change space for fire weather in southeast Australia. *Theor. Appl. Climatol.* **136**, 513–527 (2019).
49. Dowdy, A. J. et al. Future changes in extreme weather and pyroconvection risk factors for Australian wildfires. *Sci. Rep.* **9**, 10073 (2019).
50. Taylor, C., Mccarthy, M. A. & Lindenmayer, D. B. Nonlinear effects of stand age on fire severity. *Conserv. Lett.* **7**, 355–370 (2014).
51. Zylstra, P. J. Flammability dynamics in the Australian Alps. *Austral Ecol.* **43**, 578–591 (2018).
52. Woinarski, J. C. Z., Burbidge, A. A. & Harrison, P. L. Ongoing unraveling of a continental fauna: decline and extinction of Australian mammals since European settlement. *Proc. Natl Acad. Sci. USA* **112**, 4531–4540 (2015).
53. Woinarski, J. C. Z. et al. Reading the black book: the number, timing, distribution and causes of listed extinctions in Australia. *Biol. Conserv.* **239**, 108261 (2019).
54. Lindenmayer, D. B., Hunter, M. L., Burton, P. J. & Gibbons, P. Effects of logging on fire regimes in moist forests. *Conserv. Lett.* **2**, 271–277 (2009).
55. Berry, Z. C., Wevill, K. & Curran, T. J. The invasive weed *Lantana camara* increases fire risk in dry rainforest by altering fuel beds. *Weed Res.* **51**, 525–533 (2011).
56. McAlpine, C. A. et al. A continent under stress: interactions, feedbacks and risks associated with impact of modified land cover on Australia's climate. *Glob. Change Biol.* **15**, 2206–2223 (2009).
57. Dale, V. H. et al. Climate Change and forest disturbances. *BioScience* **51**, 723–734 (2001).
58. *Interim Biogeographic Regionalisation for Australia (IBRA)* Version 7 (Subregions) (Commonwealth of Australia, 2018); https://go.nature.com/3e6j21L
59. Lobo, J. M., Jiménez-Valverde, A. & Real, R. AUC: a misleading measure of the performance of predictive distribution models. *Glob. Ecol. Biogeogr.* **17**, 145–151 (2008).
60. Reside, A. E., Watson, I., Vanderwal, J. & Kutt, A. S. Incorporating low-resolution historic species location data decreases performance of distribution models. *Ecol. Model.* **222**, 3444–3448 (2011).
61. Phillips, S. J., Anderson, R. P. & Schapire, R. E. Maximum entropy modeling of species geographic distributions. *Ecol. Model.* **190**, 231–259 (2006).
62. Fenner, A. L. & Bull, C. M. Short-term impact of grassland fire on the endangered pygmy bluetongue lizard. *J. Zool.* **272**, 444–450 (2007).
63. Kuchling, G. Impact of fuel reduction burns and wildfires on the critically endangered western swamp tortoise *Peudemydura umbrina*. In *Ecological Society of Australia Conference Proceedings* (2007).
64. Driscoll, D. A. & Dale Roberts, J. Impact of fuel-reduction burning on the frog *Geocrinia lutea* in southwest Western Australia. *Austral Ecol.* **22**, 334–339 (1997).
65. Smith, A., Meulders, B., Bull, C. M. & Driscoll, D. Wildfire-induced mortality of Australian reptiles. *Herpetol. Notes* **5**, 233–235 (2012).

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Author contributions

J.E.M.W. conceived the idea. M.W., J.E.M.W., A.I.T.T., J.Q.R., B.A.W., A.E.R., S.L.M., H.J.M., M.M., H.P.P., S.J.V., J.L.O., E.J.M., A.C.G. and L.J.S. designed the research. A.E.R. and S.L.M. extracted non-threatened species data. M.W. and B.A.W. assembled and revised the database and analysed the data. M.W., A.I.T.T., J.Q.R., B.A.W., A.E.R., S.L.M., H.J.M., M.M., H.P.P., S.J.V., J.L.O., E.J.M., A.C.G., J.C.Z.W., S.T.G., M.L., B.C.S., J.C., D.G.N., D.B.L., R.M.K., J.S.S., L.J.S. and J.E.M.W. wrote and edited the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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Reporting Summary

Nature Research wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Research policies, see Authors & Referees and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed	
☐	☒	The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☒	☐	A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☒	☐	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐	A description of all covariates tested
☒	☐	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☒	☐	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☒	☐	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	No software was used for data collection.
Data analysis	ArcGIS 10.7.1 was used for the data analysis.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors/reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

All datasets used in this analysis are available via the citations identified in the Methods section. The raw data used to create Figure 1 and Figure 2 are available in Supplementary Table 1 and in the Figshare repository.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	We assess the 2019–2020 bushfire season within the temperate, Mediterranean, and subtropical Australian landscape. We quantify potential impacts by intersecting the Australian Government's national fire dataset with species' realized and potential habitat derived from species distribution models and/or expert opinion. To evaluate which species might need to be assessed for re-evaluation under the EPBC Act, we used the Australian Government's Guidelines for assessing the conservation status of native species.
Research sample	All fires within the study region (temperate, Mediterranean, and subtropical bioregions) were included, as these areas experienced extreme mega-fires, outside of what is considered their normal fire regime.
Sampling strategy	All fires from study region were used.
Data collection	All fires from study region were used.
Timing and spatial scale	The fire dataset is from July 2019 to February 2020. The threatened species dataset was updated in November 2019, while the reptile dataset was created 2017, frogs dataset was created 2015, mammals dataset was created in 2019, and birds dataset was created in 2019.
Data exclusions	We only included fire within the temperate, Mediterranean, and subtropical landscape, as these areas experienced extreme mega-fires, outside of what is considered their normal fire regime.
Reproducibility	Not an experimental study
Randomization	Not an experimental study
Blinding	Not an experimental study

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology
☒	☐ Animals and other organisms
☒	☐ Human research participants
☒	☐ Clinical data

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging