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Consequences of the Australian 2019–20 wildfires for sites important for biodiversity and other World Heritage values

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Summary

- Australia's 2019–20 wildfire season was unprecedented in its extent and severity, yet the consequences for sites important for biodiversity conservation and other World Heritage values remain unknown.
- Here, we summarise the 2019–20 wildfire impacts on key sites set aside for, or identified as being important for, Australian biodiversity, with specific reference to nationally designated protected areas, World Heritage listings and Key Biodiversity Areas (KBAs). We also explore patterns between burn extent and severity, and how they differ when considering underlying landscape characteristics.
- Over 7 months, approximately 10 million ha of native vegetation burnt. Of these burnt landscapes, ~3.2 million ha (41%) were within the Australian protected area estate, with 834 protected areas impacted.
- Six Australian World Heritage listings were impacted by the 2019–20 wildfires, with the largest impact in the Greater Blue Mountains Area (680 000 ha or 67% was affected by the fires).
- The 2019–20 fires impacted over 2 million ha across 69 KBAs. Of these, 18 KBAs had > 15% of their area burnt.
- Of management importance, we show that the degree of overall forest 'integrity' affected the chances of fire severity, with the more degraded forests experiencing higher severity burns. This held true across both the protected area estate and those areas identified as KBAs.
- Recovery of many of these fire-affected areas will require targeted restoration efforts as well as resources to help reduce the likelihood of future megafires, as well as increase resilience in the face of other catastrophic climate events.

Introduction

The 2019–20 wildfire season had devastating impacts on many populations of Australia's species and was unprecedented in its extent and severity. An estimated 10 million ha (approximately the size of Iceland) burnt from July 2019 to the March 2020 (Chapter 2), affecting sites important for Australian biodiversity such as national parks, Indigenous Protected Areas, World Heritage listings and Key Biodiversity Areas (KBAs).

Australia has ~19% of its terrestrial extent protected in its National Reserve System, which includes more than 13 500 protected areas. Since Indigenous Protected Areas were first recognised in the early 1990s, there are now > 78 declared areas covering > 74 million ha across Australia making up 46% of the areal extent of Australia's network of protected areas (Commonwealth of Australia 2021b). Every Australian protected area is classified into an International Union for Conservation of Nature (IUCN) protected area management category according to its management objectives. IUCN categories I–IV make up 8.10% of the 19% of Australia's landmass under protection, while categories V–VI make up 11.62% (Table 4.1). Many of these conservation areas are important not only for biodiversity (Watson *et al*. 2010; Kearney *et al*. 2020), but also for cultural values (through Indigenous Protected Areas such as Dorodong Indigenous Protected Area) and ecosystem services. Such services provide Australian communities with purified water to drink and protection against natural hazards such as floods and soil erosion (Potts *et al*. 2014; Figgis *et al*. 2015; Ferraro *et al*. 2015). These ecosystem services within Australia's protected area estate have an estimated value of more than $1.3 trillion per year (Commonwealth of Australia 2021a).

Nominated UNESCO World Heritage sites are inscribed on the list only after they have been carefully assessed as representing the best examples of the world's cultural and natural heritage. Australia currently has 20 properties on the World Heritage List, including the Gondwana Rainforests of Australia, Greater Blue Mountains Area and K'gari (Fraser Island). The *Environment Protection and Biodiversity Conservation Act 1999* is Australia's primary legislative tool for protecting and managing World Heritage listings, as per its obligations under the World Heritage Convention.

KBAs are places identified as globally significant for the persistence of biodiversity and are recognised, by some groups, as focal areas for practical conservation action (IUCN 2016). There are currently 314 KBAs spread across the Australian continent, covering 4 468 900 ha. All 314 were first identified as Important Bird and Biodiversity Areas (Birdlife International 2021) or Alliance of Zero Extinction Sites (n = 34) (Alliance for Zero Extinction 2018). KBAs do not convey a legal conservation status in Australia.

Using a study region that includes 2.2 million km^2 across 43 temperate, Mediterranean, and subtropical bioregions, as defined in the Interim Biogeographic Regionalisation for Australia (IBRA) dataset (Commonwealth of Australia 2018; Roff 2020), we summarise the 2019–20 wildfire impacts on key sites set aside for, or identified as being important for, biodiversity, with specific reference to protected areas, World Heritage listings and KBAs. We investigate total area burnt and the severity of burns, and provide examples to further highlight the fine-scale impacts of this disaster. We also explore patterns between burn extent or severity and underlying landscape characteristics. To do this, we quantify the relationship between forest integrity and either the 2019–20 wildfire severity or proportion burnt for each protected area, World Heritage listing or KBA.

Table 4.1. Overview of terrestrial protected areas in Australia by IUCN Management Category (Commonwealth of Australia 2021a).

IUCN category	Description	Number	Area (ha)	Average size (ha)	% of Australia	Contribution to protected area network
Ia	A Strict Nature Reserve is set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values.	2619	15 981 368	6102	2.08%	10.52%
Ib	A Wilderness Area is usually large unmodified or slightly modified area, which retains its natural character and influence without permanent or significant human habitation and is protected and managed to preserve its natural condition.	66	3 847 645	58 298	0.50%	2.53%
II	A national park is a large natural or near natural area set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provides a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.	1096	38 190 170	34 845	4.97%	25.14%
III	A Natural Monument or Feature is set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove.	2395	1 867 857	780	0.24%	1.23%
IV	A Habitat/Species Management Area aims to protect species or habitats and management reflects this priority.	4248	2 401 392	565	0.31%	1.58%
I–IV Total		**10 424**	**62 288 431**	**5975**	**8.10%**	**41.01%**

continued

Table 4.1. Continued

IUCN category	Description	Number	Area (ha)	Average size (ha)	% of Australia	Contribution to protected area network
V	A Protected Landscape/Seascape is managed for both conservation and recreation, where the interaction of people and nature has produced an area of distinct character with significant, ecological, biological, cultural, and scenic value, and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.	359	7 924 748	22 075	1.03%	5.22%
VI	A Managed Resource Protected Area is managed mainly for the sustainable use of natural ecosystems.	1320	81 450 986	61 705	10.59%	53.63%
V–VI Total		**1679**	**89 375 734**	**53 232**	**11.62%**	**58.85%**
Not applicable		8	2444	305	0.00%	0.00%
Not assigned		1377	214 860	156	0.03%	0.14%
Not reported		1	0.4	0.4	0.00%	0.00%
TOTAL		**13 488**	**151 881 469**	**11 260**	**19.75%**	**100.00%**

To calculate the area and intensity of the fire's impacts on iconic places, we intersected the Australian Google Earth Engine Burnt Area Map (AUS GEEBAM) (Commonwealth of Australia 2020a) with the extent of protected areas, World Heritage listings and KBAs. The AUS GEEBAM dataset is based on 40 m^2 Sentinel 2 satellite imagery from 1 July 2019 to 24 February 2020. AUS GEEBAM relies on a vegetation reflectance index (Relativised Normalized Burnt Ratio, RNBR) that calculates the difference in reflectance before and after the fire season for burnt areas and adjacent unburnt areas within the fire footprint. Combined with national vegetation mapping (Commonwealth of Australia 2020b) the result is a map of four fire severity classes that represent how severely vegetation was burnt during the 2019–20 wildfires. The classes presented have been designed for rapid response and were not trained with ground data, and so do not have confidence intervals or accuracy reports.

A wildfire may have very different impacts on biodiversity at different locations; these impacts depend on many factors, one of which is ecosystem condition before the fire. For example, forest degradation and fragmentation can interact with natural disturbance regimes such as fire to perturb forests beyond their capacity to regenerate (Lindenmayer *et al*. 2017), whereas forests with high ecologically integrity might provide refuge for forest species from increased fire frequencies in degraded landscapes (Watson *et al*. 2018). To explore patterns between forest integrity and wildfire severity for each protected area, World Heritage listing and KBA, we used ordinal response regression models (Guisan and Harrell 2000). To identify 'forest integrity' we used a global 'forest integrity' metric for forest ecosystems (Grantham *et al*. 2020). The forest integrity metric uses integrated data on forest extent, observed human pressures (e.g. infrastructure), other inferred human pressures (e.g. collection of forest materials and logging), and alterations in forest connectivity. Higher cell scores (at a 500 m^2 resolution) indicate higher landscape-level forest integrity for the beginning of 2019, whereas lower scores indicate lower integrity.

Key findings

Sites set aside for biodiversity: protected areas

Over 7 months, ~10 million ha of native vegetation burnt. Of these burnt landscapes ~3.2 million ha (41%) were within the protected area estate (see Box 4.1). More than half of these fires was classified as high to very high severity (1.8 million ha), with 1.4 million ha falling within the low to moderate severity classification (Fig. 4.1). In total, 834 protected areas burnt, the majority of which were IUCN classifications II (285) and Ia (228). Approximately 70% of all Australia's 1b IUCN protected areas were impacted by the 2019–20 wildfires (Table 4.2).

When we disaggregated protected area burning by IUCN category, the most impacted category by area burnt was II (national parks: 1 601 460 ha), closely followed by Ib (Wilderness Areas: 1 201 878 ha; Table 4.2). This ranking changed when we assessed proportion burnt, with IUCN category Ib most impacted (31% burnt, of which ~54% was high or very high severity).

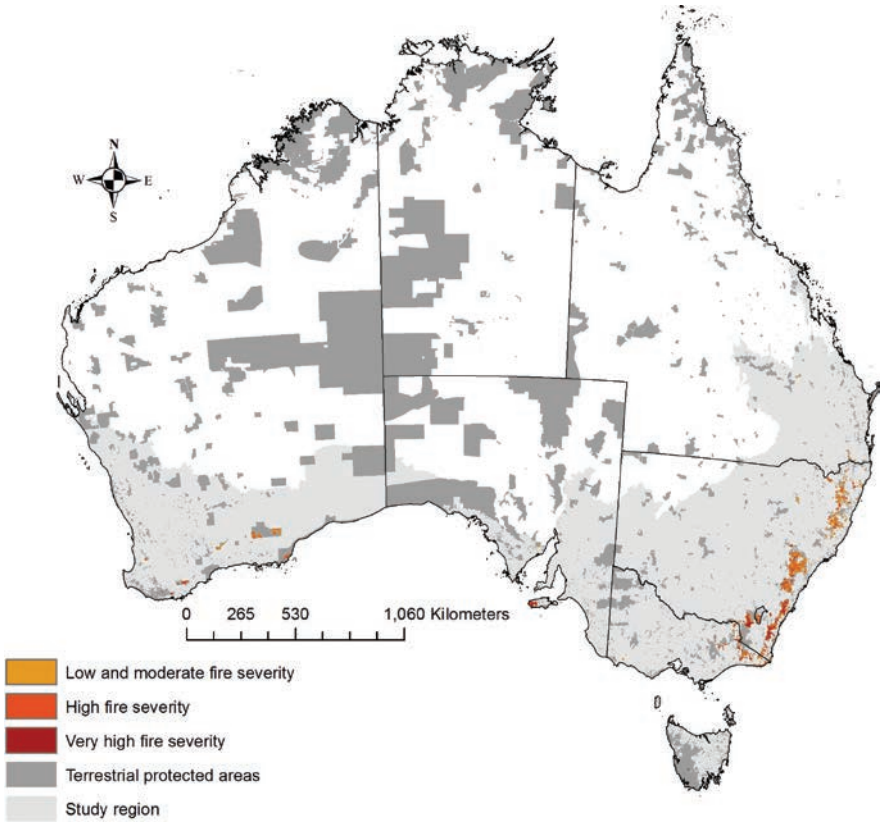

Fig. 4.1. Extent and severity of wildfires between July 2019 and February 2020 and impacts on protected areas. Yellow indicates low and moderate fire severity, orange indicates high fire severity, and red indicates very high fire severity. Dark grey shows all terrestrial protected areas, while light grey shows the study region.

Table 4.2. Overview of the proportion burnt in each burn severity category within each IUCN protected area listing.

IUCN listing	Number of protected areas burnt (% of all protected areas in this category)	Extent burnt – low and moderate fire severity (ha)	Extent burnt – high fire severity (ha)	Extent burnt – very high fire severity (ha)	Cumulative extent burnt (ha)	Proportion of total extent burnt (%)
Ia	228 (9%)	186 362	120 614	30 164	337 150	2%
Ib	46 (70%)	550 015	448 492	203 371	1 201 878	31%
II	285 (27%)	647 436	582 567	371 457	1 601 460	4%
III	126 (5%)	17 887	9754	14 901	42 542	2%
IV	88 (2%)	92 546	53 705	13 261	159 512	7%
V	10 (3%)	10 804	8678	5288	24 770	0.3%
VI	51 (4%)	12 370	4959	2431	19 760	0.02%
Total	834	1 517 420	1 228 769	640 873	3 387 072	

Box 4.1. Protected areas in Victoria: impacts and consequences for management

The 2019–20 wildfires burnt ~1.5 million ha across Victoria, including 30 national parks and nature conservation reserves that had over 80% of their area within the fire extent (DELWP 2020). This comprised some of Victoria's best-known national parks, including Croajingolong (87%), Snowy River (76%) and Errinundra (66%). National parks such as the Burrowa-Pine Mountain National Park and the Lind National Park had their entire extents burnt (DELWP 2020). Across Victoria's reserve system, over 280 000 ha were impacted by high-severity fire in the 2019–20 fire season (DELWP 2020).

The 2019–20 wildfires disproportionately affected areas of Victoria's highest biodiversity value (DELWP 2020), much of which occurs in Victoria's protected areas. Species such as spotted tree frog (*Litoria spenceri*) and eastern bristlebird (*Dasyornis brachpterus*) have important populations within Victoria's protected areas that were affected by the 2019–20 wildfires. These wildfires also compounded the effects of other recent large fires (e.g. 2003 and 2006–07), meaning some parts of Victoria's protected areas have been burnt multiple times in the last 20 years, severely impacting species and environments such as Victoria's alpine ash (*Eucalyptus delegatensis*) ecosystems (Fig. 4.2) (Geary *et al.* 2022). Since the fires, management of impacted species has focused on facilitating recovery through management of threats (e.g. invasive predator and herbivore control), as well as proactive actions that can help to reduce the risks of future extreme fires to these species such as emergency extraction (Selwood *et al.* 2021), translocation to new areas and captive breeding.

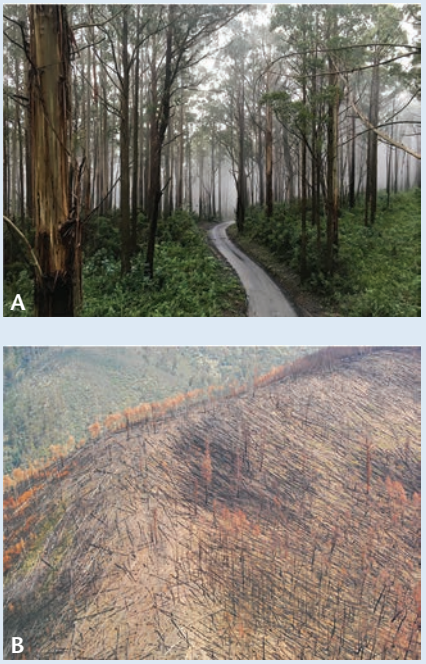

Fig. 4.2. Long unburnt (1939 regrowth) alpine ash forest in Victoria's Central Highlands (A), and alpine ash forest burnt by successive fires between 2007 and 2019–20 leading to population collapse (B). (Photos: Tom Fairman, University of Melbourne)

Sites set aside for biodiversity: World Heritage listings

Of the 18 terrestrial Australian World Heritage listings, six were impacted by the 2019–20 wildfires (Fig. 4.3; Table 4.3). The World Heritage listing with the largest impact was the Greater Blue Mountains Area, with ~680 000 ha burnt (of which 362 000 ha was high and very high severity and 321 000 ha was low and moderate severity) (see Box 4.2). This represents more than 65% of the entire Greater Blue Mountains Area. The Budj Bim Cultural Landscape, located in the traditional Country of the Gunditjmara people in south-eastern Australia, was also greatly impacted with ~54% of its extent affected by the 2019–20

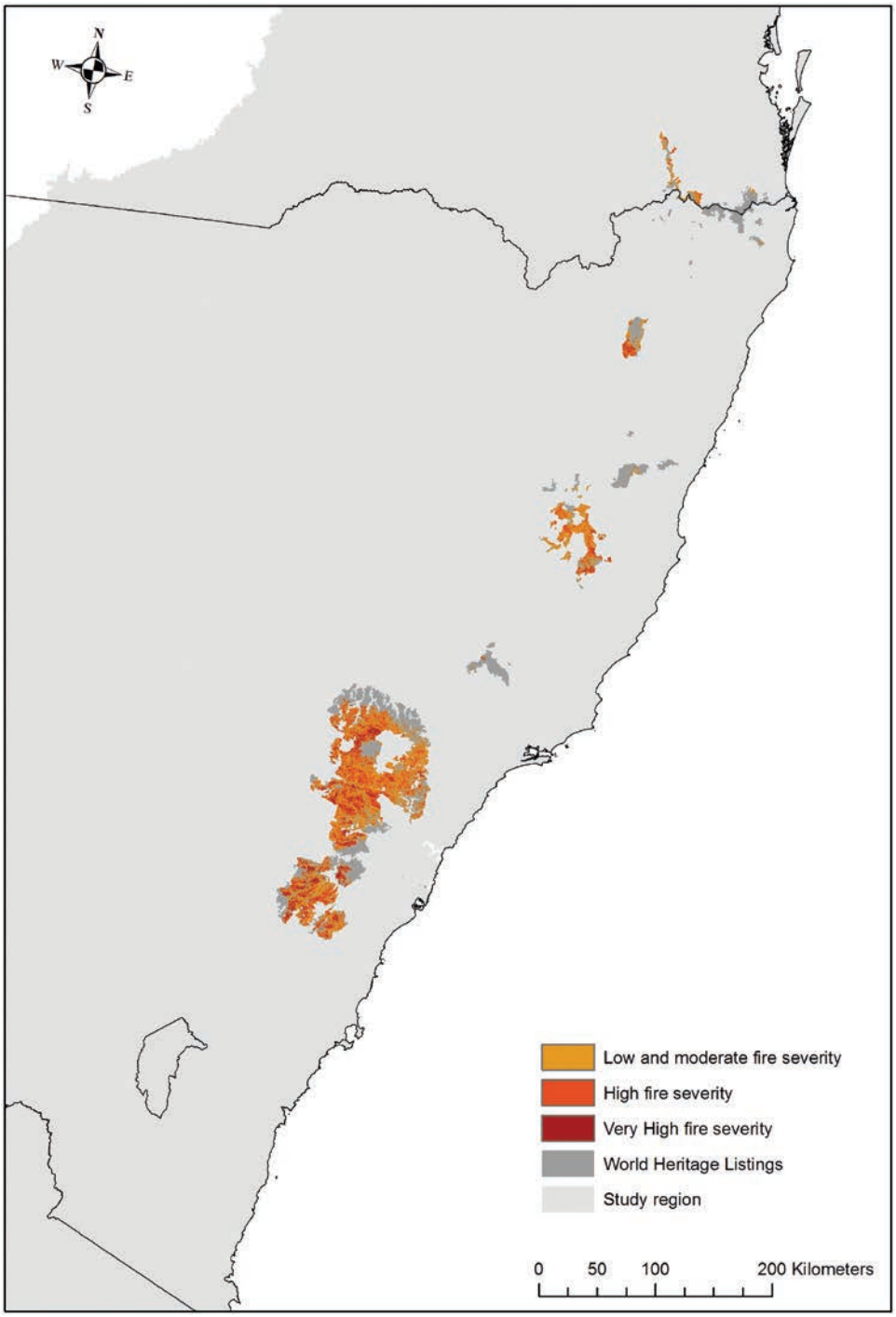

Fig. 4.3. Extent and severity of wildfires between July 2019 and February 2020 and impacts on World Heritage listings. Yellow indicates low and moderate fire severity, orange indicates high fire severity, and red indicates very high fire severity. Dark grey shows all terrestrial World Heritage listings, while light grey shows the study region.

Table 4.3. Overview of World Heritage listings and the extent and severity of 2019–20 wildfires.

Note: Some World Heritage listings spatially overlap with protected areas.

World Heritage listing	Total area (ha)	Extent burnt – low and moderate fire severity (ha)	Extent burnt – high fire severity (ha)	Extent burnt – very high fire severity (ha)	Extent burnt – high and very high fire severity (ha)	Cumulative extent burnt (ha)	Proportion of total extent burnt (%)	Proportion of total extent burnt not overlapping with PA (%)
Greater Blue Mountains Area	1 043 825	320 903	292 176	69 333	361 509	682 412	65%	0%
Budj Bim Cultural Landscape	9935	5329	84	1	85	5414	54%	0%
Gondwana Rainforests of Australia	368 727	85 273	53 533	6989	60 522	145 795	40%	0%
Australian Convict Sites	389	122	23	0	23	145	37%	0%
Fraser Island	181 838	5073	2970	844	3814	8887	5%	0%
Tasmanian Wilderness	1 585 523	197	371	1782	2153	2350	0%	0%
TOTAL	3 190 237	416 897	349 157	78 950	428 106	845 003		

wildfires. The Gondwana Rainforests of Australia, an area that does not generally burn (Kooyman *et al*. 2020) and harbours the highest concentrations of threatened species in subtropical south-east Queensland and northern New South Wales (Kooyman *et al*. 2020), had 40% of its extent burnt.

Box 4.2. Greater Blue Mountains Area

The Greater Blue Mountains Area west of Sydney is one of the most fire-prone regions in the world (Bradstock *et al*. 2009). The region experiences wildfires during dry El Niño years that result in a major wildfire season once or twice a decade (Bradstock *et al*. 2009; Hammill and Tasker 2010). Following extreme drought in 2019–20, the moisture content of fine dead fuel was well below the critical threshold for large wildfires to occur within the Sydney (Nolan *et al*. 2020). Lightning from dry summer storms and one escaped hazard reduction burn provided the ignition points for seven major wildfires, with some joining up across the 'Black Summer'. The 2019–20 megafires burnt 65% of the Greater Blue Mountains World Heritage Area (682 412 ha), with 35% of the region recording either

Fig. 4.4. A very high fire severity site one month after the Gospers Mountain Fire was extinguished after a major rainfall event. (Photo: Aaron Greenville)

high or extreme fire severity. The first fire – Gospers Mountain Fire and the largest of the megafires (Nolan *et al.* 2021) – started in late October 2019 and was also the last fire to be extinguished after a major rainfall event in February 2020 (Fig. 4.4). The Gospers Mountain Fire is the largest single-ignition fire in modern records for the region – burning 512 000 ha over 107 days (NSW Government 2020; Nolan *et al.* 2021). As a result of the extensive nature and severity of the wildfires, the conservation outlook for the Greater Blue Mountains World Heritage Area was downgraded to 'Significant Concern' by the IUCN and the thresholds for optimal return-time of fire were exceeded, placing the region's vegetation into vulnerable–too frequently burnt ecological states (Osipova *et al.* 2020; Nolan *et al.* 2021).

Important sites for biodiversity: Key Biodiversity Areas

The 2019–20 wildfire impacted over 2 million ha across 69 KBAs (see Box 4.3). Of these, 18 KBAs had > 15% of their area burnt. Jerrawangala KBA – based on Jerrawangala National Park boundary – is located on the Great Eastern Escarpment of New South Wales. Approximately 99% of Jerrawangala KBA was impacted by the 2019–20 wildfires. The Gibraltar Range and Werrikimbe KBAs were also severely impacted the 2019–20 wildfire, with ~68% and 67% burnt, respectively (Fig. 4.5; Table 4.4).

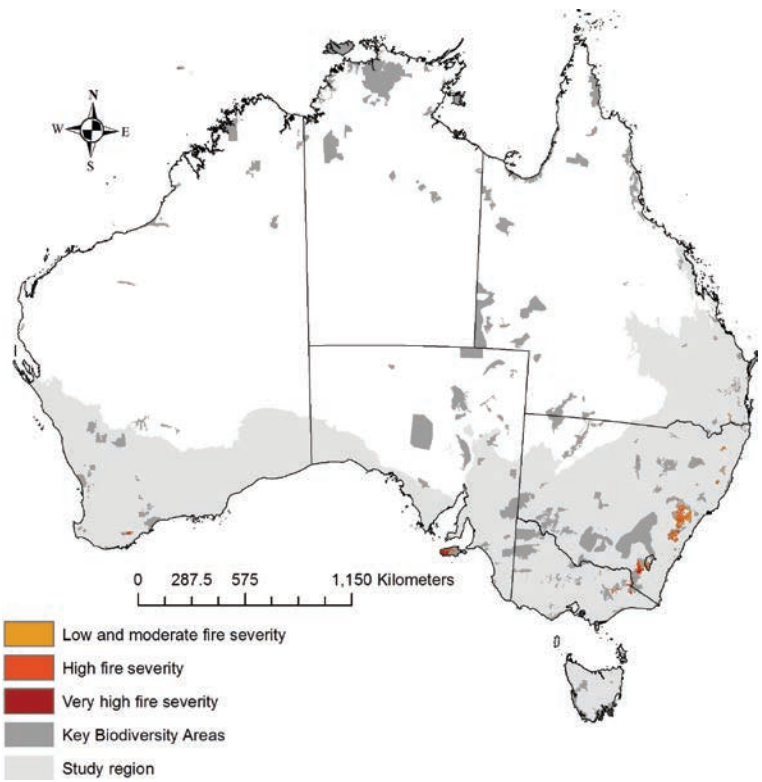

Fig. 4.5. Extent and severity of wildfires between July 2019 and February 2020 and impacts on KBAs. Yellow indicates low and moderate fire severity, orange indicates high fire severity, and red indicates very high fire severity. Dark grey shows all KBAs, while light grey shows the study region.

Table 4.4. Overview of the top 10 KBAs with the highest proportion of total extent and severity of the 2019–20 wildfires.

Name	Total area (ha)	Extent burnt – low and moderate fire severity (ha)	Extent burnt – high severity (ha)	Extent burnt – very high severity (ha)	Extent burnt – high and very high severity (ha)	Cumulative extent burnt (ha)	Proportion of total extent burnt (%)
Jerrawangala	4024	2100	1300	600	1900	4000	99
Gibraltar Range	36 563	10 000	12 600	2200	14 800	24 800	68
Werrikimbe	1 074 505	9000	1800	1700	14 500	23 500	67
Greater Blue Mountains	35 127	322 600	286 700	68 800	355 500	678 100	63
Nadgee to Mallacoota Inlet	38 171	11 200	5400	1300	6700	17 900	47
Fitzroy Falls and associated hydrobasin	12 395	1500	2000	1800	3800	5300	43
Palmgrove	25 188	9600	200	–	200	9800	39
Kangaroo Island	441 672	27 600	40 700	94 700	135 400	163 000	37
Stirling Range	112 580	7000	15 300	15 800	31 100	38 100	34
Ulladulla to Merimbula	138 357	34 400	22 200	6200	28 400	62 800	29

Box 4.3. Stirling Range KBA

Not only eastern states were affected by the 2019–20 wildfires – large areas of south-west Western Australia were also impacted. This is a region famous for its high levels of biodiversity and endemism (Beard *et al.* 2000). Stirling Range KBA is internationally recognised as important for the persistence of 15 bird species (DPaW 2014) and also contains 80 endemic plant species, 13 species of endemic trapdoor spiders, an isolated subpopulation of quokkas (*Setonix brachyurus*), and a threatened ecological community (Parks and Wildlife Service 2017) (Chapter 8). Over a third of Stirling Range KBA (37 826 ha) burnt in December 2019 during two blazes ignited by lightning strikes. Aided by drought and hot, windy weather, 37 826 ha of vegetation burnt with very high intensity, scorching the canopy and leaving few unburnt refuges (Fig. 4.6; Roff 2020). Impacts were compounded by a large fire having occurred the previous year, leaving a combined scar covering 43% of the KBA. While both Carnaby's (*Zanda latirostris*) and Baudin's black-cockatoo (*Z. baudinii*) feeding habitat in Stirling Range KBA were badly damaged by the 2019–20 wildfires, most of their known roosting and nesting habitat remained

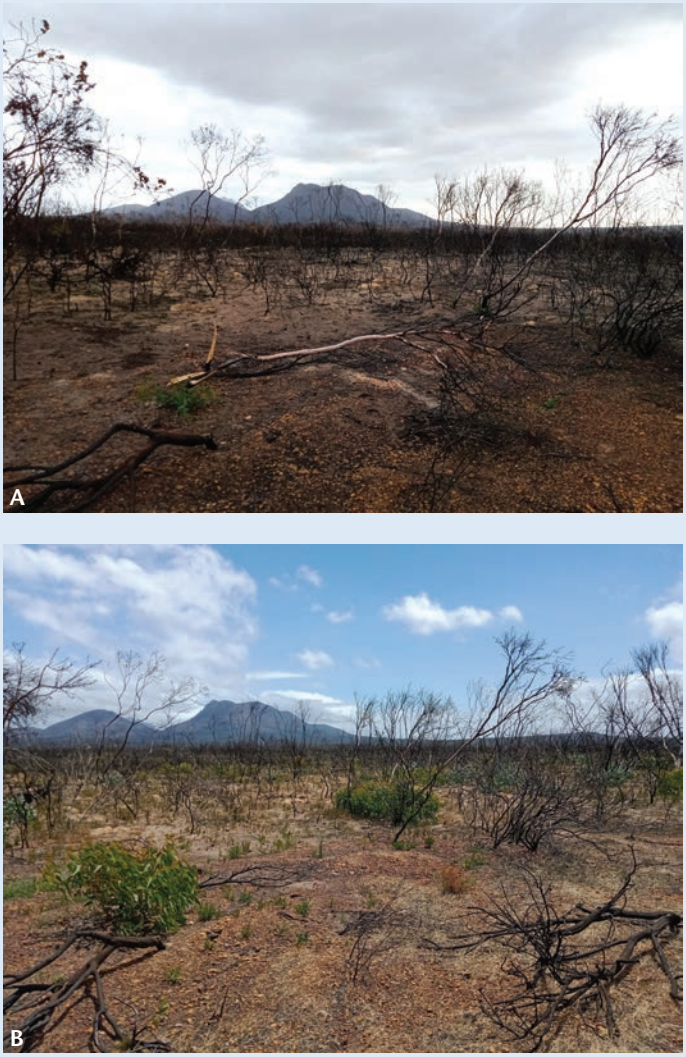

Fig. 4.6. Stirling Range KBA 3 months post-fire (A) and one year post-fire (B) showing severely burnt areas are slow to recover. (Photos: Vicki Stokes)

intact (BirdLife Australia 2021), and breeding hollows were confirmed active in spring and summer 2020 (V. Stokes, *pers. comm.*). Other species did not get away so lightly. The fire sensitive wheatbelt western whipbird (*Psophodes nigrogularis oberon*), for which Stirling Range KBA is one of two remaining strongholds (McNee 1986; Birdlife International 2016), had ~30–40% of its habitat burnt in 2019, mostly with high severity. Record densities of calling whipbirds found in habitat adjacent to burnt areas suggests individuals immigrated from severely burnt areas, now uninhabitable (Stokes *et al.* 2021). Unfortunately, these refuges are unlikely to sustain whipbirds in the long term and burnt areas will take many years to regrow suitable whipbird breeding habitat.

Patterns of fire

We explored the patterns between forest integrity, measured using the global 'forest integrity' metric (Grantham *et al.* 2020) and 2019–20 wildfire severity for each protected area, World Heritage listing and KBA. The statistical analysis suggests that for every unit increase in forest integrity, the odds of an increase in fire severity decreased by 13.7% (CI: 13.5–13.8) in KBAs and 3.1% (CI: 3.0–3.2) in protected areas (Fig. 4.7A, C). More simply, the higher the forest integrity in a KBA or protected area, the less likely that area will experience very high severity fires.

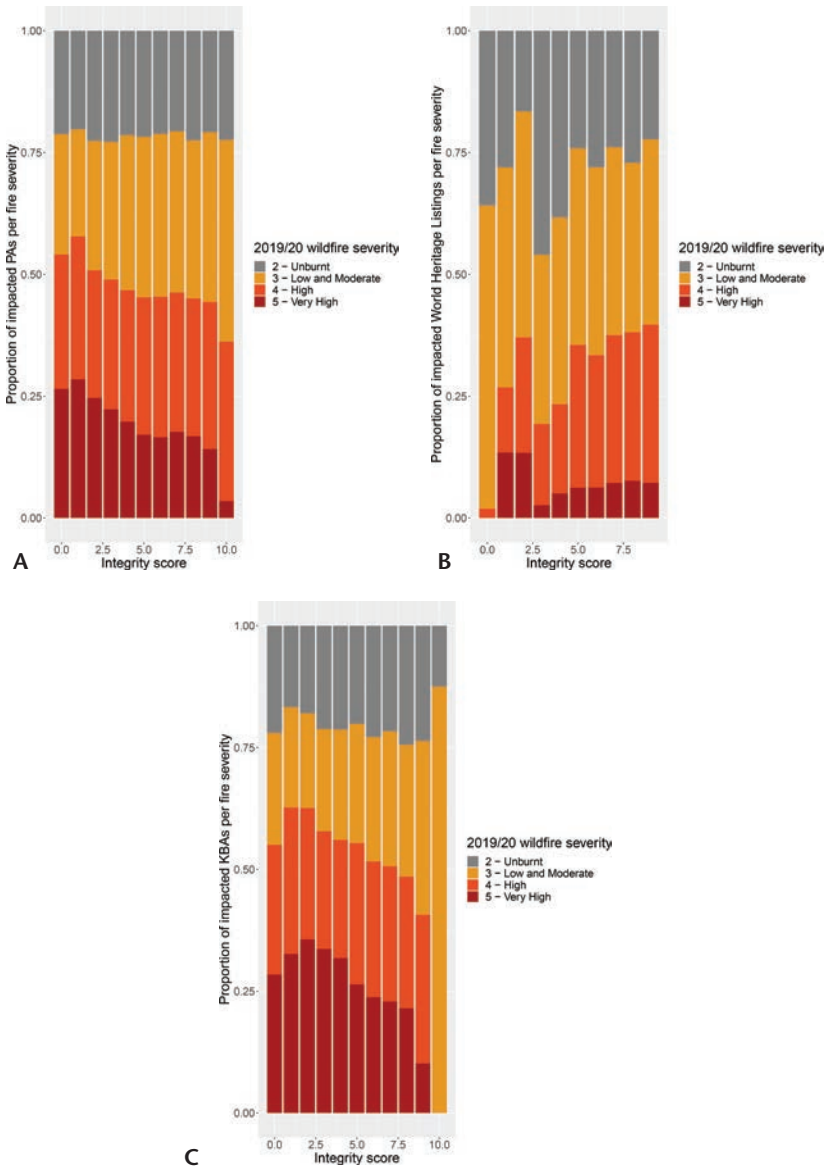

Fig. 4.7. Broad patterns between forest integrity and 2019–20 wildfire severity for each protected area (PA), World Heritage listing and KBA.

In contrast, for every unit increase in forest integrity within World Heritage listings the odds of an increase in fire severity increased by 8.4% (CI: 7.9–8.7) (Fig. 4.7B). A possible reason for the difference between protected area and KBA results, and World Heritage results is the small sample size of the World Heritage Listings relative to the size of the 2019–20 wildfires, meaning the results could be based on the particular characteristics of the six affected World Heritage areas. While many complex and interacting variables drive fire severity within the landscape, these initial exploratory patterns require further investigation, as they indicate that protected areas that are well managed and recovering from past degradation and fragmentation processes, and as a consequence have higher 'integrity', may be able to buffer megafire events like those experienced in 2019–20. In comparison, the fact that higher integrity places in World Heritage areas had higher odds of being more severely burnt raises concern for the resilience of these particular areas and the future value of such areas as ecological refugia from anthropogenic threats.

Conclusions

The 2019–20 wildfires had a devastating impact on many important Australian sites of high conservation value. Recovery for many of these places will require targeted effort and resources, which include actions to reduce the likelihood of future fire, as well as increase resilience in the face of other catastrophic climate events. However, as illustrated in the examples (Boxes 4.1 to 4.3), the achievement of such an objective will be challenging, given the large variety of threatening processes these sites face. The fire management objective is also unlikely to be successful unless the fundamental drivers of such fires, anthropogenic climate change and mismanagement of landscapes, are mitigated effectively. Without ambitious climate action and appropriate large-scale management, catastrophic fires will recur, and important conservation sites will continue to be diminished.

Recommendations

- Targeted management to support the recovery of all important fire-affected conservation sites must be resourced and implemented immediately, to prevent cumulative threats from worsening impacts.
- Long-term investment and commitment are needed to ensure full recovery of species, ecosystems and key ecological processes.
- The main objective of management should be to mitigate all known and likely threats to species and ecosystems within important conservation sites in a climate sensible way, to increase resilience in the face of future catastrophic climate events, as well as reduce the likelihood of future megafires.
- Investigation of the link between forest integrity and wildfire impacts, to test our preliminary evidence that higher integrity areas potentially buffer megafire events and act as species refugia under anthropogenic climate change, is of high importance. Such evidence would help allocate funding for new protected areas towards higher integrity areas that are refugial habitats of at-risk species. They also inform wider landscape scale forest management and forestry and agricultural policy when it comes to vegetation management.
- Long-term monitoring programs in important unburnt and fire-prone conservation sites that enable adaptive management are essential to ensure recovery of species and

ecosystems. These need to occur alongside protected area designation in those particularly important unprotected fire refugial habitats of at-risk species.
- Early warning systems and resourced response scenarios must include important conservation sites.
- Programs to ensure that species' habitat is available both on and off reserves for species that move over large areas are essential as this would ensure landscape-scale fire management is practised, rather than being restricted to local scale efforts.

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