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Some personal reflections on the present and future of Australia's fauna in an increasingly fire-prone continent.

Tein McDonald Editor of *Ecological Management & Restoration* interviews **Chris Dickman** Professor in Terrestrial Ecology, School of Life and Environmental Sciences, The University of Sydney.

Abstract: Australia already has the highest rate of species loss of any region in the world, yet the risks suddenly worsened in the spring–summer of 2019–20, with an unprecedented chain of wildfires covering 10 M ha of the nation's forest and woodland estate. Fires of this scale were unprecedented and not factored into recovery plans for Threatened Species or ecosystem management in general. EMR asks one of Australia's most pre-eminent ecologists what can be done to ameliorate the losses and better avoid and respond to such impacts occurring in the future?

TM: Chris, you were the researcher who broke the news to the world about the extent of predicted loss of native animals in the 2019–20 Australian bushfires – 800 M in NSW alone and over 1 billion Australia-wide. You are a highly published researcher holding many highly prestigious roles as a scientist and are not prone to exaggerated statements. Yet, you suggest this may even be an underestimation?

CD: The initial figure that I calculated was 480 million in New South Wales (NSW). That drew on data collated in 2007 for a report prepared for WWF (World Wide Fund for Nature), to estimate the effects on native animals of legally approved land clearing for development in NSW. The State of New South Wales had approved the clearing of 640,000 ha of land between 1998 and 2005, which seemed an extraordinary amount (Fig. 1).



Figure 1: Professor Chris Dickman is pictured here releasing an eastern quoll at Booderee National Park, NSW, with David Smith. Chris has been involved in studying fauna in Australian ecosystems for over four decades, guiding many cohorts of honours and post-graduate students and earning widespread recognition from his peers. His unequivocal statements regarding the potential impact of, and appropriate responses to, the 2019–20 Australian wildfires have been crucial in assisting agencies, organisations and communities prepare for timely post-fire actions and to work towards improved environmental disaster planning. (Photograph: Judy Dunlop).

To try to get a handle on it, we looked at as much of the published information and unpublished studies that we could find on the densities of mammals, birds and reptiles in forests and woodlands in the areas subject to clearing – and to synthesise it to produce some average density estimates for those three vertebrate groups. Once we had that, we could derive the numbers of animals killed by multiplying out the average density by the area approved for land clearing – and that turned out to be 104 million. With the bushfires going on and being as severe and intense and covering as much of the landscape as they were, it seemed that here was another huge disturbance event in many ways similar to land clearing. That is, the fire was likely to kill all the animals in its direct path and the extent of it gave little chance of animals that had survived the flames surviving in the post-fire environment (Fig. 2). Many animals are likely to die of starvation or predation.



Figure 2: Small mammals are among the many vertebrate species that are highly vulnerable to the immediate effects of fires as well as secondary effects of lack of food and increased predation that occur after fire. Widespread fire that leaves few unburnt refuges is likely to place populations of many fauna species, particularly those already listed as Threatened, at hugely greater risk of extinction. Much of the wet forest habitat of this Endangered silver-headed antechinus was burnt in early 2020. (Photograph: Gary Cranitch).

I came out with the initial figure of 480 million for NSW in mid-December 2019 when the fire had burnt 3 million ha in NSW – the vast majority of which was forest and woodland. I had to revise this up to 800 million when the fires had burnt 5 million ha by the end of 2019. When you add just the additional land burned in Victoria, let alone other states, the total area burnt came to 6.25 million ha. Assuming density estimates similar to those in NSW, particularly in similar habitats just over the border in Victoria, you end up with an estimate of over a billion mammals, birds and reptiles in the path of the fires. So the numbers were huge and certainly quite shocking when I first estimated them, but still an underestimate as more than 6.25 million ha overall had burned, and other animal groups were not included in the calculations.

TM: So this calculation is assuming that there would be few able to survive in refugia in the fire grounds, and if they did survive the fire, they would not be able to survive the post-fire lack of food and habitat?

CD: Yes. In the first statement I put out, I used the word 'affected'. The reason for doing that was to provide a little bit more nuance, because if you say that 480 million animals had been killed in the fires then everyone assumes that the fires had just incinerated the animals straight out. I wanted to avoid that impression. While some animals will be killed immediately in the fires, there will be a lot that had gone underground, into burrows, into cracks in the soil, maybe even some into tree hollows in the tops of trees. They will survive the immediate impact of the flames, but then they will emerge into a burnt landscape with no resources. Many of them are likely to starve or be preyed upon. I have been in post-fire environments prior to the current one and looked around and have seen the carcasses of newly dead animals, everything from kangaroos through to lyrebirds and even things like bush rats – not burnt but just dead, presumably having starved.

The key thing about these fires, occurring as they did in such dry conditions, is that they seemed to be so big that they were not leaving many unburnt patches in the landscape to act as refuges for fauna and sources of recolonisation after the fire (Fig. 3).



Figure 3: Much of Chris's ecological work has been carried out in the sand dunes of the Simpson Desert where faunal diversity is one of the highest of any known areas in inland Australia. His research across a range of ecosystems has provided insights into processes of faunal recovery after drought and fire, adding substantially to our capacity to predict extinction pressures arising from large-scale ecological disturbances. Pictured here is Chris with a thorny devil. (Photograph: Stephanie Yip).

We know from other fires that there are probably two groups of survivors, those that survive in situ in the burnt areas and those that can survive by fleeing into unburnt areas. Those that survive in situ are going to be the less mobile things, small mammals perhaps, lizards with deeper burrows. They are the ones that will emerge into the burnt landscape and face the prospect of no resources. Already at the end of a long drought, they were stressed to begin with and, particularly after the fires had been through and removed food, water and shelter resources, they were not going to last long.

There is an additional factor for those survivors and that is that red foxes and feral cats move into burned areas very quickly. They are much more mobile than all of these smaller or medium-sized native species, and they will come in to pick off the survivors. We know this from previous studies in forest environments and in open desert environments; these predators are very active and very mobile, taking advantage very quickly after the fires have gone through.

The more mobile survivors that might be able to flee are going to be the birds and the larger more mobile animal groups like kangaroos. While some individuals may escape the flames, many will be disoriented in the smoke and flames and die in big numbers. There were images from the beach areas down the south coast and at Mallacoota showing large numbers of dead birds, for example. But for those birds that do flee the flames, it is going to be very difficult for any to find a place to settle. Studies of land clearing have shown that's exactly what happens with birds. They don't all die when the bulldozers come through with chains. Some will fly away to a neighbouring bush block, but very few will survive because the resident birds, particularly the territorial ones, won't have a bar of it. So the 'survivors' just die later. This is likely to be the case for many other escaping animal groups, who already would not have been in great shape due to drought.

TM: And what was going through your mind at the time when, like all of us, you were watching the fire authorities' online maps that repopulated daily with all these extended fires. You would have had a sense of growing alarm. How did having to make such a statement feel?

CD: It was pretty bad really. Yeah, I think one of the things that stimulated me to make this statement was seeing all the coverage of koalas that were being rescued or wandering amidst the flames while the fires were still burning and kangaroos that were fleeing the fire front. The images themselves were horrible, and some of them went viral on social media. These were telling the world that there was an event that was happening here that was really quite terrible. But for all the horror associated with these images, there was a whole lot of other animals that were not being seen – animals that are less charismatic, maybe smaller, maybe underground and still being burnt, or being burnt inside logs or tree hollows. It was thinking about all of these other unseen animals that motivated me to draw people's attention to the greater extent of the catastrophe. It was not just the cute and charismatic ones that were dying, tragic though that must be. It was everything else as well. It was about the impact on all the other species and on the ecosystems they belong to.

TM: The loss of genetic diversity among some fauna species is extremely concerning. When we already have under-represented fauna and conservation requires as much genetic representation in as many populations as possible, this rings enormous alarm bells.

CD: Yes, it is a loss all round. There was a study some years ago looking at a very wide range of taxa, plants and animals, and it found that each species comprised, on average, about 220 populations.

Even for species that may not go extinct, and there'll be a lot in that category (e.g. koalas won't go extinct in these fires, despite some of the media that has been out there) many will lose populations. So it is the cumulative death of lots and lots of populations that will lead to erosion of genetic diversity and ultimately species extinction.

Of the listed Threatened Species, the ones of most concern are going to be the ones that are sensitive to the immediate and secondary effects of fire and that have had most of their ranges burnt. That is, those sensitive to the fire itself or sensitive to the effects that come after fire (e.g. such as being picked off after the fire by predators or being short of food) and for which the greater part of the population is in the path of the fire.

Again, our earlier estimates were that anywhere from 20 to 100 species would be in that category, that is of being threatened with extinction. The Commonwealth announced more recently that of 331 species listed under the federal Environment Protection and Biodiversity Conservation Act (EPBC Act), the majority, about 270, were plants, and these had had a greater or lesser amount of their geographical ranges burnt. While many of the plants are likely to have adaptations to fire, we do not yet know whether the intensity of these fires in some areas may have exceeded that capacity for some species. Furthermore, it is safe to say that some of these plant species will be under increased pressure from herbivory when they start to recover after fire as well as where they occur in unburnt refuges.

One example of a Threatened animal of most concern would be the Kangaroo Island glossy black cockatoo – which can fly away from the fires but has no food when it returns because the canopy-borne seed of the casuarinas it depends on will have been released or burnt. Habitat that is suitable and has casuarina is going to be occupied by other glossy black cockatoos, and in the case of the Kangaroo Island glossy blacks, the nearest populations are in East Gippsland. Those populations (which are a different subspecies) probably didn't do terribly well because of the fires there. So it is really not clear where displaced glossy blacks would go.

Another example is the Kangaroo Island dunnart. It is likely that many would have died immediately in the fires, but if any of them were able to get underground they will have come back into an environment where there was no food and no protection from feral cats.

TM: And I guess there even may be a reconsideration after this as to whether other species may need to join the lists of Threatened Species?

CD: Indeed, another group that really hasn't received a lot of attention and has few species currently listed as threatened comprises the aquatic species that occur literally downstream of fires. We know from previous wildfire events – and also sadly, from recent events in eastern Australia – if you get heavy rain afterwards, a lot of ash and other material washes into the river systems and that can be toxic to the aquatic invertebrates; it reduces oxygen in the water as it rapidly decomposes. So you are losing both the invertebrates directly – for example a lot of the caddis flies and chironomids – and, either directly or indirectly, a lot of higher order organisms including endemic crayfish (as they have narrow ranges), fish (e.g. galaxids in Victoria), turtles (there are some Endangered turtles that each occur in only one catchment on the north coast of NSW or southern Queensland) and, according to some recent analyses, quite a lot of populations of platypus. So these are not in areas that necessarily have burnt but they will feel, literally, the downstream effects of the fires, when the rain washes the debris into the systems.

TM: You were an author on the Threatened Species Recovery Hub's document 'After the catastrophe: a blueprint for a conservation response to large-scale ecological disaster' (Dickman et al. 2020). I notice this HUB blueprint calls for more formal study to calculate the true impact of these fires at a detailed level.

CD: Yes, it is difficult to know what the true fire impact might be because our monitoring in Australia is really quite poor. Resourcing for it has been wound back progressively over the years. So we really don't have adequate monitoring set up to allow us to look at how populations of various species are tracking before a disturbance event, to then be able to go in afterwards and say OK, well here's a drop in Species A, here's the change in Species B, here's the loss of ecological function and so on. If we had this monitoring, we'd be in a much better position to understand how things were tracking prior to when the fires went through and we would be in a much better position to be able to quantify recovery afterwards and to improve the situation for the future. We just don't have the monitoring capacity – and we should have it (Fig. 4).

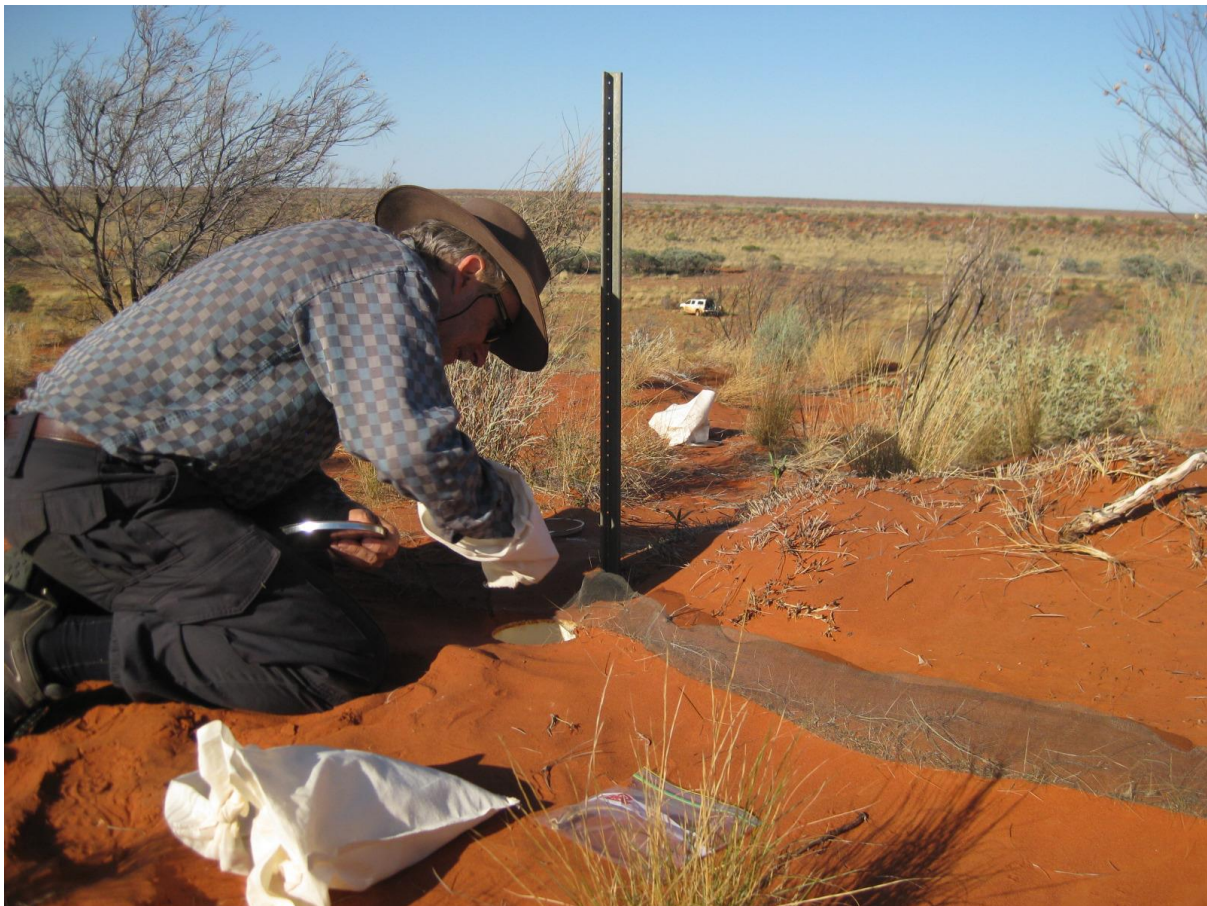


Figure 4: One of the factors limiting Australia's capacity to respond to large-scale environmental emergencies such as fire and drought is the dearth of long-term ecological research in Australia. The trend of defunding long-term programmes needs to be reversed, establishing well-designed long-term research across the full range of our nation's bioregions. Pictured here is Chris retrieving captured animals from a trap line on a permanent plot on top of a sand dune at a site in the Simpson Desert. (Photograph: Emma Spencer).

As an example, the Long Term Ecological Research Network was shut down in 2017. It cost only about \$1.5 M per year, which in the grand scheme of things was incredibly cheap. And it was a great investment, but yes, it was cut. We need to revisit that, not only revisit it but get long-term

monitoring up and running I think in every bioregion – maybe one or two sites in small ones while you'll need multiple sites in the bigger ones. At the moment, we are just looking at a very small handful of sites, and often they are not even statutory, but just driven by individuals.

It can't just be left to individuals, no matter how committed, as they will not be around all the time. You need to carry it forward as part of legislation. It needs to be built into your structures going forward. We accept such monitoring for a whole variety of other aspects of life. The Bureau of Meteorology monitors every day and its predictions have been fantastically valuable. We look at them every day to work out whether we will be going to the beach or getting out our umbrellas. But we don't do that with our natural environment and we absolutely need to.

We have had fire studies in the past, of course, but fires of this intensity really are unprecedented, and we don't have such a clear idea of what to expect and how management might be able to assist post-fire recovery. So what is absolutely crucially important is to get into some of the burnt areas now – and find some of the unburnt areas as well so that they are effective controls – and look at the trajectory of recovery and what we can learn from it. This monitoring should also capture responses of biota to different fire management regimes in a range of ecosystems – to better inform future management approaches.

TM: Speaking of recovery, you've done a lot of work looking at recovery of fauna in arid zones after drought and fire. What are the main lessons from science?

CD: Yes, one of the things that has come out of much of that previous work is that, for recovery to be relatively speedy and across the broader landscape, you need unburnt patches across the landscape that contain refuge populations, remnant populations representative of the broader landscape before. If you don't have these, then the recovery is going to be much, much slower. And in areas where forest has been fragmented and entire blocks have burnt, then we have situations where many species will never get back.

One example is Royal National Park, south of Sydney. It is isolated from other surrounding bushland. To the north is Sydney and to the south is Wollongong and to the west is a lot of housing development and really big arterial roads. In 1994, a fire swept through Royal National Park and knocked out a fairly well-known and well-studied population of the greater glider. There has been one possible sighting of gliders going back about 5 years now. But effectively that population was knocked out, and we are looking at a population extinction. Gliders won't be able to get back in – unless we translocate them from somewhere else – because they can't migrate across all the development and roads that we have placed in the way.

There are other remnant vegetation blocks up and down the coast that have been similarly fragmented by developments and roads and other infrastructure. Where they have burnt it may be very difficult for the less mobile species to get back in, whether plants or animals. That process of ecosystem recovery may be further slowed if some of the species that have been affected are some of the pollinators, seed disperser or spore disperser organisms. Animals like flying foxes, for example, were already doing it tough before the fires went through – simply because they don't do very well in long-term droughts. When the temperature gets to 42 degrees celsius, then they drop out of the trees; dead. When you go to colony sites and see piles of dead bats at the end of hot days, it is just heartbreaking. And when you lose species like that, you lose the opportunity for pollination and seed dispersal between fragmented blocks. So all these things are adding up to being not just a

numerical catastrophe but very much an ecological one across the board in terms of ecological function and ecosystem integrity

TM: So it is all about fragmentation – and emphasises why connectivity is a mantra for those seeking to conserve and restore ecosystems.

CD: Yes, what we need is more connectivity, not less of it. And some of the social media commentary is saying we need to chop up the forest even more. There is a lot of weird stuff happening at the moment, but if these ideas were to go ahead it would be even more catastrophic for biodiversity.

TM: Another recommendation of the Hub blueprint has to do with improvements when fires are actually burning – that is, to work closer with the fire authorities to set up processes for extinguishing a fire once threat to life and property was over.

CD: Yes, that's right. There are some situations where fires have been allowed to continue to burn across the landscape when they are no longer posing any further risk to people or communities. Understandably, the priorities are people, communities and infrastructure, but there needs to be another layer there that, once those imperatives are taken care of, attention can be turned to ensure that biodiversity remains. I don't think we do that very well. There was one exception, however – the planning that went into making sure that the Wollemi Pines didn't get burnt. That was very impressive and was done because the Wollemi Pine is so well known. But there are lots of threatened ecological communities out there that don't get the same priority because they are not so well known. If there was an ecological response team to call upon, it should be possible to say 'OK – what we really should be thinking about is this ecological community over here. It is totally unique and it is only 10 ha in area, we really should try and stop this fire getting through'. It worked for the Wollemi Pine. That was a great precedent.

TM: Importantly, the Hub blueprint also notes that there is no pre-existing national plan to guide a national post-fire environmental response and that how we manage this post-fire emergency will help us be better prepared to respond to future ones. Two needs strike me – one is the ability to coordinate a response with many, many players and second is the ability to identify priorities that those players can then move on.

CD: I think that the task of coordination is a work in progress at the moment. In at least the first month after the national scale of the disasters became clear, I hadn't seen anything functioning as a central coordinating authority that was providing advice and that is something that is desperately needed. All the organisations I know who are doing anything about it have been fielding two or three orders of magnitude more calls and emails, and it has been tough. Organisations are working largely in the dark about what their role might be, without knowing whether there is duplication or potential for synergies. I think things will improve as time goes on, but this is something that we must have in place immediately after the next bush fire.

On the task of identifying priorities, the federal Environment Minister, Sussan Ley, has been taking a lead in conducting Ministerial Roundtables with researchers and non-government organisations (NGOs) as well as meeting directly with the state governments. She has been closely advised by the Threatened Species Commissioner, who in turn is advised by an Expert Panel of Threatened Species

ecologists. They have pulled together a robust set of general priorities around species rescue, feral animal management (particularly in unburnt patches) and protecting waterways, moving later to the intermediate and then longer term tasks.

That is, there is a need to prioritise where the unburnt patches are in the landscape and to prioritise those to go and look at on the ground. That will be particularly important where those patches contain Threatened Species or Endangered Ecological Communities. And then, when you've got those priorities organised, ensure appropriate management depending on the species that happen to be left in those patches. For example, if it's anything small and furry, the major risk is going to be cats and foxes; if it is anything medium-sized and furry, it's likely to be foxes; if it's something like rock-wallabies that already live in reasonably predator-proof habitats, then it's probably going to be the availability of food. And food is going to be, of course, a longer term concern for any of the other mammals and birds that manage to get through, irrespective of immediate predation problems, which is why so much of the focus of fauna rescue groups has been on establishing food and water stations in some key areas. Good examples of where supplementary food has helped already are the vegetable drops for brush-tailed rock-wallabies in NSW and the provision of 'bogong bikkies' for the Critically Endangered mountain pygmy possum in the alpine region. Longer term efforts include planning to respond to the need for reintroducing the food plants of some Threatened Fauna, for example, restocking the fire-sensitive mountain plum pine in some burnt areas as it is the main food plant for the mountain pygmy possum.

This experience is showing us that we have been caught somewhat unprepared, as this sort of fire disaster has not been factored into Threatened Species recovery plans. The Hub blueprint suggests that we use the device of a Prospectus, prepared in advance, for either particular areas where you know there is a particular species under risk or a particular ecological community.

TM: Predator management and herbivory management around those Threatened Species have to be really well targeted.

CD: It really does. And I think that there are some great opportunities now to think of pest management more broadly. The fires most likely will have reduced the populations of pest species anyway, but also it is likely that many pest species will be congregating around unburnt patches in the landscape. For many of the bigger ones like deer, they will be more visible, so it is an opportunity to reduce their populations before the vegetation starts to regrow and it becomes harder to spot them as they begin to disperse away again from the unburnt patches where there is some food. Although it may be unpalatable, especially in the wake of huge faunal losses, any overabundant native animals, such as macropods, that are presenting risk to vegetation recovery may need to also be considered for management.

TM: Do you think it's an important opportunity to do some aerial shooting of some of these species? That is going to be difficult with respect to feral horses, given the social context.

CD: I think it is a great opportunity to aerially cull deer. Absolutely, and there needs also to be action on feral horses. Horses are of course a flagship species for stirring controversy about their values and impacts, and this makes effective management difficult. But for me, and I think for many ecologists who are aware of the immense damage that feral horses are doing to our fragile ecosystems, the current situation represents a great opportunity to humanely reduce horse populations.

Cat control is problematic because they don't like baits and baits are the standard thing that have been used to try and get rid of them. You can do it of course by shooting and trapping but that is very intensive and you can only do it over small areas. It might be worth thinking about some exciting new technologies, and the innovative 'Felixer' traps spring to mind here as being one really good opportunity (Fig. 5).



Figure 5: With so few animals surviving extensive fire (and some of those being native predators), control of introduced pest predators is an essential step in the short-term response to fire. Pictured here is the Felixer trap, an innovative device targeting feral cats that depends upon their fastidious grooming behaviour and size and shape detection beams. This is one of a number of innovative approaches that could be rolled out for pest predator control at the interface between burnt areas and unburnt refuges. (Photograph: John Read).

TM: What do those traps do?

CD: They are multiple use; that is, they can kill many cats once set up. Imagine something about the size of a suitcase, standing on its end. You can put the device on the ecotone between the burnt and unburnt parts of the environment. We know that cats like to patrol ecotones, picking off animals that are moving in between the burnt and unburnt areas and will then move from there into burnt areas to pick off any further survivors there. The Felixer traps emit infrared beams in a particular combination. The idea is that the device will fire only if a cat passes in front of the beams and breaks a particular combination of them – and then, it sprays a poison gel on the shoulder or flanks of the cat. The device really exploits the fastidiousness of cat grooming behaviour. If the cat feels the gel – ooh what's that on my shoulder – it will turn around and lick it off and then will get a dose of the poison. If it is a swamp wallaby or something else that passes by it'll break a different combination of infrared beams and the device won't fire. It's been field-tested and modified to get it just right.

The Felixer trap came up as being one of the possibilities of the post-fire emergency response through the Ministerial Roundtable. The Minister and Threatened Species Commissioner's office

know about them. Whether they are going to be rolled out in particular critical areas, I am not sure, but the information is out there.

TM: These unburnt areas will hopefully allow colonisation in a nucleating pattern after the fire. And in areas where weeds have been a problem, weed removal work to advantage natives over weed can also be very fruitful – but that would need to be prioritised on the basis of urgency or Endangered ecosystem or Threatened Species presence.

CD: Yeah, that's right. It is really one of the big potential problems to keep an eye on. There are so many environmental weeds out there. Even in some of the most remote forest areas, the first things that pop up are blackberry or lantana. In some of the more open areas, serrated tussock grass and other things will come up. In Kosciuszko, there are a number of environmental weeds that have just popped up, partly after other kinds of disturbances such as grazing or trampling by horses, and of course the firefighting effort itself may well have brought in more weeds. It is one of the big problems. Weeds, of course, do the job of exploiting disturbed areas so well. When the early post-fire colonisers are introduced species, we have a real problem on our hands.

TM: So managing these ecosystems really does need an understanding of disturbance ecology and an ability to time responses to get maximum return on investment.

CD: Yes, given the vast areas that have been burnt, getting the expertise and even (clean!) boots on the ground into all the areas where management is going to be most effective and beneficial is not going to be easy. That is the sort of thing we have talked about in the Prospectus and will be really very valuable to build into Recovery Plans for Threatened Species in the future. But we don't need to wait; I think we can start writing them now.

And we need to bear in mind that Threatened Species of course only cover a small proportion of the species that are sliding; many others just haven't been necessarily listed yet. We have not really worried very much about the more common species, but many of these also need special attention.

TM: Will reintroduction of fauna play a role in the recovery, whether for Threatened Species or more common species? Are rescued animals going to play an important role in maintaining or rebuilding gene pools?

CD: Yes, I think they will. It's likely to vary between species. For example, with possums, I suspect it is unlikely that most of the possums that are put back will survive because we know from past work that these animals are highly susceptible to predation from feral cats and foxes. But, for wombats and koalas that are bigger and better able to hold their own, the chances of restoring and returning many individuals of these species are probably much better.

TM: Is there also potential for captive breeding to ensure conservation of any genetically unique populations?

CD: That sort of genetic rescue is going to be potentially quite important for some species – but it will be probably just a small subset of all the species we could do it for. It will be the ones that we know a little bit more about and the ones that are a bit bigger and charismatic. Genetic rescue is one

thing that we haven't explored much in the Hub blueprint as yet, but there is a lot of potential for it to ameliorate the genetic effects and fragmenting effects of the fires. We could ameliorate these effects, potentially by bringing individuals from selected populations into captivity and making sure they survive and using them as insurance populations and as seeds for either restocking the same areas or bolstering other populations elsewhere. It is really quite important. That is what zoos will often try to do, particularly when species are down to their last few individuals.

The northern and southern corroboree frogs are probably good examples. When their sphagnum bog habitat was being chewed up by the fires in 2003 and the species were suffering from Chytrid fungus as well, they would have gone to the wall had it not been for captive breeding programmes. The ACT government, Taronga Zoo and Zoos Victoria were instrumental in keeping the corroboree frogs going. Individuals have since been reintroduced to fenced areas in the species' original habitats that were burnt during these fires, with good proportions surviving, demonstrating the value of this approach.

TM: The Hub blueprint also referred to potential for some populations of some Threatened Species being translocated into areas where they previously haven't been, emphasising the need for contingency planning to avoid those actions having an impact on the receiving ecosystem. This would allow for ex situ conservation 'in the wild' as it were.

CD: That's right – and of course there are some really good guidelines prepared by the IUCN that provide a recipe for all the things that you would need to tick off before you do such translocations. It wouldn't be a matter of just grabbing animals, or plants, and putting them over here and hoping for the best. There should be a process that is followed. Ideally that would be something that is in the Prospectus – to have already identified some areas where a translocation may be possible and desirable to pre-empt the effects of a really big disturbance like a bushfire going through.

One really good example is Gilbert's potoroo in Western Australia. That was a really rare species when it was rediscovered in the 1990s, and only had about 40 or 50 individuals (at most) in one small population at Two People's Bay near Albany. The habitat at the site was very dense, which is why the species had survived as well as it had; cats and foxes couldn't get into it as it was too dense for them to get in to hunt. But the habitat was also really vulnerable to being burnt, and if it did burn, then the whole population would go. Only a few years ago, the Western Australian government captured some Gilbert's potoroos and put them onto Bald Island. They went through the IUCN process of making sure that there was nothing else on Bald Island that would be affected (quokkas also occur on the island, but use different habitat) and that it was a suitable environment, that there was enough food, and so on. They went ahead with the translocation, and the animals are doing very well there. Soon afterwards, in 2015, a huge fire went through Two People's Bay and the mainland population was wiped out. So that was a great example of positive, forward-thinking conservation action.

TM: The need for temporary enhancement of habitat is another point made in the Hub blueprint – including the idea of installing artificial shelter structures in some of the habitats of Threatened Species around the refugia and unburnt areas. How useful could that be to protect wildlife from predation?

CD: I think it can be very useful, if well designed. I received some funding 7–8 years ago to install some artificial shelters post-fire in the desert (Fig. 6), and these worked pretty well. So I put in for funding through the Australian Laureate Fellowships programme, two years in a row, to expand the idea to look at providing post-fire protection in a wide range of other habitats. The reviews came back saying ‘This isn't very original. Why do you think fire is going to have these dramatic effects anyway?’ So, I couldn't get the money, but I think the idea is still valid and I have been talking to people about it. Artificial shelters are now being used by researchers and managers in the Otway Ranges in Victoria post-fire, in Western Australia, in Boolcoommatta in South Australia, and I think also in the Cooktown area post-fire. Artificial refuge structures are also being used in the post-fire environment on Kangaroo Island to protect remnant populations of the Kangaroo Island dunnart. Of course, any materials that are used to create these structures need to be clean to be sure we don't bring in weeds or diseases.



Figure 6: Immediate post-fire actions to support Threatened Fauna emerging in a barren landscape need to be part of a prepared response to large-scale environmental emergencies. One such action is the installation of artificial shelters to protect small animals from predation. These structures on Ethabuka Reserve in western Queensland have inspired other trials of such artificial shelters in other ecosystems post-fire. (Photograph: Chris Dickman).

We could also do better at leaving whatever natural structure remains after a fire. The tendency is to 'clean up' but, rather than going out and just cleaning up after a fire, I think we need to leave whatever burnt logs are there for the structure they provide. Leaving existing structures and, if possible, adding to them so that we can provide continued protection for small species that otherwise we know will be vulnerable to cat and fox predation, has got to be a key part of post-fire recovery.

TM: The very big question is what can be done to avoid a repeat of the tragedy? The Hub blueprint states that 'the only long-term solution is climate change mitigation at a scale that reduces the risk of severe post-fire droughts'.

CD: Yes, there are many considerations surrounding the level of fossil fuel burning, all the narratives at the moment being about whether we should continue to dig up coal or whether we should be exploiting gas to a greater extent, and the whole renewables debate. Clearly, we should be going down the renewables route to a much greater extent than we are. In fact, Australia is not doing too badly in this regard, but it is simply because people are doing it rather than the government providing any leadership.

But beyond that, and what I think we should be looking at much more carefully, is our management of the forest and woodland estate. We still clear land at a breathtaking rate. For a developed country to be land clearing at the rate that we do is just stunning. There are so many studies now that show that when you take away tracts of woodland or forest, you have local and then regional effects on the climate. The more forest you have the more likely you are to get rainfall when the conditions are right. So land clearing is a really big issue.

There is also talk about increasing salvage logging at the moment in some of the burnt areas. We know that salvage logging post-fire can be very damaging to the environment. You are going in there with heavy equipment, taking out the trees and causing all kinds of problems from an erosion point of view, so that catchments clog up in the wake of the salvage operations. So it is not great.

Another of the ideas going around is that we need to be reducing the fuel loads by thinning forest habitats. But as soon as you thin the forest, you let in more light through the canopy and that helps to dry the leaf litter, as does the increase in wind speed: with a reduction in wood density, you have greater wind speeds. So those two factors are likely to increase the rate of drying in thinned forests and, in addition to any effects that there might be on the local climate, you are much more likely to get fires in thinned forests than in forests that have never been touched.

Another aspect of this is that, where you have more intact forests you've got greater likelihood of more animals like bandicoots working over the forest floor, turning the leaf litter and organic material back into the soil. So you are both increasing carbon storage and reducing the fuel load if you have increased numbers of these engineering species. Sometimes, these suites of interactions are not well appreciated, but the bottom line is that we need more conservation, not less.

There is also talk that we need to be burning much larger areas more frequently. That'd be just awful from a biodiversity point of view; and it wouldn't stop the big fires anyway. The NSW Fire Commissioner, Shane Fitzsimmons, made that point right at the start. He said 'look we have been doing cool season burning. These fires come right over the top and there is nothing you can do to stop them in that situation'. Strategically placed control burns during the cooler times of year will continue to be important as part of the 'tool kit' for fire management, but are likely to be most effective in years that are not exceedingly dry and hot, as was the case in 2019.

TM: Perhaps ways could be found to create patchiness without creating more fragmentation. Whatever the case, broad brush generalisations are unlikely to be useful. The situation needs to be considered in much finer level.

CD: Yes, it really calls attention to the need for much more targeted monitoring in a much wider range of systems. But creating effective patchiness also shows we should re-engage with Indigenous

people to a much greater degree about cultural burning practices. It's not to say that cultural burning or something like it would be the be – all and end – all solution – it probably wouldn't stop the really big fires going through when very dry and very hot conditions prevail, and it could be very hard to apply in some contexts. The key thing here, though, and what distinguishes cultural burning from extensive cool season fuel reduction burning, is that each burn is on a small scale and doesn't result in very large areas of homogeneous burned country. That's one of the problems that can arise with cool season burning. Cool season burning doesn't really have the effect of stopping very big fires such as those in the current fire season, but it can have the effect of reducing biodiversity. Mosaic burning in strategic areas would seem a much more sensible strategy than what the Victorian government did after the Black Friday fires, mandating 5% of the state's public land to be burned every year, which essentially meant most of the conservation estate being burned most of the time.

The complexity of the situation probably suggests a need for a national authority that reviews the available evidence and helps direct targeted research to make the picture a lot clearer and advocate for doing the right thing. At the moment, there are so many calls to let livestock into national parks, thin the forests or burn all the time – but it makes no sense. We probably need an authority that can really counter these sorts of opinions much more forcefully than we currently are able to do, using good science as the most effective counter.

TM: If we get the confluence of extreme dryness and extreme heat as we had last year, and we are being told this is more likely under climate change, we'll get these fires again. What will we do next time when they come around? What have we learned from these fires?

CD: Over the next year or two, we can probably learn a lot from the current fires. Once it is safe to go back into the burnt country, we can identify where the unburnt patches are and we might be able to identify attributes about those patches. Perhaps they were in areas where there was a more shallow water table. Perhaps they didn't burn because they were already moist – along riparian strips, for example, or had particular aspects or topographic features. Can we replicate any such features in the future? If we can't, are there things we can do to manage future fires – and their impacts – better?

One example of proactive management might be with respect to flying foxes. We know that these animals get incredibly stressed by high temperatures; they can't lose enough heat and die. But in western Sydney, there is some predictive mapping going on that allows researchers to identify where and when climatic hot spots are going to be. They have sprinklers set up so that they can cool the bats down by watering them. Obviously, that is at a very local scale, but it may be that we have to look at taking those sorts of actions for particular species at particular risk. For example, that might extend to koalas in some areas. Then, when the big fires do come, provided we have been able to get some parts of the landscape that are less likely to be in the way of the really big fire fronts, we will be able to go straight in with recovery actions. We should be able to identify them quickly and go in and assess what's there, using whatever detection method is appropriate to the species of concern, and then, we should try to make sure that whatever additional threats they are likely to face (whether lack of food, or predation), we can protect the species to the degree that we can. And that will mean having these plans in place before these big fires come through. Now, we are just improvising. But we need to be prepared with rapid response teams and contingency plans for this sort of thing in the future.

Another thing that we have learned as a consequence of these fires is that everyone wants to help. On the one hand, this is a very positive response. On the other, it brings some challenges. There are very many separate efforts to help going on at the individual level (people knitting kangaroo pouches, building nest boxes), at the community level in organisations such as WIRES, at the institutional level in universities, the Academy of Science, the natural history and zoological societies, the Hub, CSIRO, and at different levels of government. So everybody is doing things but we are not necessarily talking to each other. And we really do need to have effective coordination in place.

Coordination needs to be a federal response simply because these fires, this time round, are multi-state, multi-territory in their extent and impact. It should be part of the portfolio responsibilities of the Environment Minister, linked to the Emergency Services Minister. And environment needs to be seen as a really important portfolio, standing on its own, in terms of status in Cabinet. When it is combined with Water or Agriculture, as it is currently, it is very likely that these portfolios will take precedence over anything environmental.

Bushfire response linkages need to also come down to the State level, of course, because that is where the recovery actions will be largely undertaken. There is already some great experience in this regard. In Victoria, for instance, the response to the fires was really swift. The state government produced a really good, detailed report, in draft form, on the 8th January, saying what they were going to do in their response to the effects of the fires on wildlife. They'd got the fire mapping under way, they had got predictions of how much of the range of all of their state-Threatened Species were likely to be affected, and they had begun to list a series of recovery actions. This alacrity was probably due to the experience they had had with previous fires. The Victorian response to the fires was immediate and very impressive, in contrast to other States that had not had this prior experience.

It's now time for all levels of government, non-government organisations and communities to do the best we can to optimise our collective response to these fires – and to learn from that experience so that we can be better prepared for next time. There will be a next time. And the maintenance of our precious biodiversity demands nothing less than that we are ready – with the appropriate levels of planning, personnel and resources – for the challenges to come.