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A precautionary tale: the consequences of, and remedies for, data deficiencies and uncertainty in conservation decisions related to the 2019–20 wildfires

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Summary

- Biodiversity is in decline; it is imperative we take a precautionary (risk averse) approach to uncertainty in management decisions.
- Uncertainty and data deficiencies cloud almost all decisions made about biodiversity conservation, and introduce biases against the most poorly known species. However, this problem was particularly pronounced in relation to the 2019–20 wildfires, because so many species were potentially so affected and because choices about conservation responses needed to be made so urgently.
- Uncertainty is likely to be magnified when considering the fate of biodiversity in, and making management decisions for, future fire regimes rather than responses to a single fire.
- Uncertainty can be overwhelming but need not be crippling; specifying uncertainty can help identify the need for, and help target, monitoring and research (e.g. through adaptive management) to resolve critical knowledge gaps. These knowledge gaps are those that, if resolved, will result in changed and more effective management.
- Much of the research and management effort made in response to the 2019–20 wildfires will enhance the knowledge base for comparable future events.
- Lack of empirical data does not always translate to lack of knowledge – Traditional Ecological Knowledge and those that hold it have been largely ignored in management decisions.

Introduction

Ecology is plagued by epistemic uncertainty, which is a lack of (or incomplete) knowledge or certainty about the relationships between organisms and their environment (Regan *et al*. 2002). The likelihood of major biodiversity losses in, and the need for urgent conservation responses to, the 2019–20 wildfires highlighted the extent of major knowledge (or information) gaps, which we specifically refer to as those that need to be factored into conservation decision making (Kujala *et al*. 2013). During and in the aftermath of the fires, managers and decision makers were working in the face of critical uncertainty; these gaps impeded the ability to make decisions about what management strategies were best (Runge *et al*. 2011), where, when, and for what duration, to ensure the response was as effective as possible. But the critical uncertainties exist not only in relation to decisions made about the type and efficacy of actions taken in and after fires – there is also very limited knowledge about the more pervasive strategic issue of how to build more resilience for biodiversity conservation in a landscape and future likely to be subject to increasing frequency and magnitude of wildfires and other threats.

The compilation of accounts in this book highlights that knowledge is critical for effective biodiversity management, before, during and after the fires. However, there are many knowledge gaps that constrain or potentially bias decisions about such management, and the form of its implementation. Many of these knowledge gaps affect most conservation decision making (Victor 2006; Bland *et al*. 2015, 2017), but were particularly important in response to the 2019–20 wildfires. These data deficiencies and uncertainties include:

- limited knowledge about the distribution of species and ecological communities (and hence of their overlap with fire);
- limited knowledge of the responses of species and ecological communities to fire, fire severity and fire regimes and their pathway to recovery post-fire (with this uncertainty magnified in this case because the available evidence was largely derived from studies of fires of far less magnitude than the 2019–20 wildfires);
- limited knowledge of the cocktail of other threats that may be imposing pressures on species and ecological communities, and of the manner in which these threats are affected by or compound the impacts of fire;
- limited knowledge of the effectiveness of management options for these threats, and of the conservation responses that can be made to support post-fire recovery;
- limited knowledge of the population size and trends of species (and hence their likely resilience or precariousness to fire impact);
- limited knowledge of risks and efficacy of actions that can be taken prior to, and in the interval between, fires to build the resilience of ecological systems in order to reduce the susceptibility of biodiversity to extreme events and chronic threats; and
- for some groups, marked taxonomic uncertainties (and comparably for ecological communities, some marked definitional uncertainties).

These uncertainties are uneven across taxonomic groups; such bias can be further reinforced when prioritising and implementing conservation responses after catastrophes such as the 2019–20 wildfires – for example, robust evidence is required for listing species as threatened, and this requirement disadvantages the conservation of poorly known species. In recognising these critical uncertainties, we do not seek to derogate the extraordinary research effort undertaken over many years by many researchers on the responses of Australian biodiversity to fire (e.g. see Bradstock *et al*. 2012). The evidence base accruing from that research was a critical foundation for understanding impacts of the 2019–20 wildfires and for the management decisions made in their wake – but it still has many critical gaps.

Biodiversity knowledge gaps (or at least ready accessibility to relevant information) were highlighted in post-fire inquiries as shortcomings that constrained decision making (Chapter 30), with some recommendations made to redress them. But those recommendations made by the inquiries were vague and aspirational, and did not describe specifically how to resolve these gaps. So, in this chapter we attempt to synthesise the knowledge gaps that contributed to epistemic uncertainty, describe the likely consequences of this uncertainty on fire management decisions, and provide a series of recommendations to aid targeted research and treatment of uncertainty in decision making. We do not delve into the assortment of epistemic uncertainties or linguistic uncertainties (see Regan *et al.* 2002). However, we do attempt to highlight the uncertainty that is fundamental to seeking improvements for the future. Accordingly, some of the uncertainties documented in this chapter form the basis of responses provided in the 'Recommendations' chapter (Chapter 35).

A synthesis of knowledge gaps

A synthesis of key biodiversity knowledge gaps, with their relevance to the 2019–20 wildfires and suggestions to remedy associated uncertainty, is provided in Table 32.1. In Table 32.2 we synthesise which of these gaps were considered to be a concern in the chapters describing impacts to biodiversity. These knowledge gaps do not constitute a systematic account of uncertainty, nor do they tell us definitively which knowledge gaps are most important to resolve; they are those highlighted by the contributors to this book. However, Table 32.2 provides a useful capture of the different ways in which our knowledge, which varies across taxa and systems, is lacking, and provides a useful basis for targeted and critical research. Some knowledge gaps may take decades and many resources to redress, so it is important to identify which are most consequential, and then to adopt a longer-term strategic approach to resolving them.

There are some striking discrepancies in knowledge highlighted throughout this book. The information base/uncertainty is systematically biased; for taxa, our knowledge base is thinnest for invertebrates and fungi, starting with large-scale gaps regarding the identification of species and their distribution. For ecological systems our knowledge of how soils (Chapter 5) and ecological processes (Chapter 8) respond to fire is generally poor, with such ignorance most profound for marine and freshwater systems (Chapters 6 and 7), and rarely burnt vegetation types (Chapter 4 and 8). This is critical, because an understanding of how (and if) we can manage species, communities and entire systems in the long term requires an understanding of how systems and processes respond to fire regimes, against a backdrop of other threats, including climate change.

These knowledge gaps and uncertainties probably compound in their consequences for decision making. For instance, if a species has uncertain distribution (and thus uncertain fire overlap) *and* we know little of its response to fire, then we know almost nothing about fire impacts on it. It is likely the unprecedented wildfire conditions, plus this compounding of different forms of uncertainty, leads to a commonly recognised shortfall: a lack of knowledge of what management is effective (Table 32.1).

Of course, there is much more nuance required in the categorisation of management uncertainty. For instance, many chapters refer to a need to build resilience for biodiversity

Table 32.1. Different epistemic uncertainties, data deficiencies and biases affecting conservation of potentially fire-affected species, ecological communities (EC) and ecological function (adapted from compilation in Woinarski *et al.* 2021)

Type of knowledge gap	Description	Relevance to 2019–20 wildfires	Action
Linnean shortfall	Species/EC not identified or described	There may have been major losses of species that are not yet described ('dark extinctions'), or cases where taxonomic review will partition species (with some suffering major impacts not detected in the taxon considered before splitting) (e.g. Jolly *et al.* 2022). Linnean shortfall and subsequent under-reporting of actual impacts will be most likely for poorly known taxonomic groups.	Surveys and taxonomic research (including eDNA and other developing technologies).
Darwinian shortfall	Phylogenetic information (evolutionary history and potential, species classification) poorly understood	Probably limited immediate consequence, but in the longer term, important for defining (and hence protecting) sites of biodiversity significance (e.g. where many old endemic species co-occur), and possibly for sites encompassing critical genetic diversity that may be important for ongoing evolutionary potential.	Phylogenetic analysis. Assessments of sites of biodiversity significance that incorporate some measure of phylogenetic history.
Wallacean shortfall	Uncertainty about species/EC distributions	Results in major uncertainty about assessments of the extent of fire overlap and the likelihood of finding important surviving populations post-fire. Introduces biases in favour of better-known species. Also, this shortfall renders it more challenging to identify, delineate and prioritise sites of biodiversity significance that should be priorities for protection during and after fires.	Ideal: systematic landscape-wide surveys, especially for poorly known species. Short-term: structured expert elicitation, followed by validation (surveys); better harmonisation across jurisdictions in EC classification and mapping.
Movement shortfall	Uncertainty about species dispersal	Limited information about species' capability to flee fires and for species moving from burnt areas to survive in new areas. For highly dispersive species, introduces uncertainty about assessment of fire impact (because of uncertainty about whether or not populations were in burnt areas at the time of fire) (e.g. Crates *et al.* 2022); limited knowledge of responses of how fires impact at landscape scale the resources (e.g. nectar) that govern the movements of dispersive species, and on which they depend (Baranowski *et al.* 2021).	Landscape-wide, repeated surveys of dispersive species, the resources that govern their movement patterns and the responses of these resources to fire. Short-term: structured expert elicitation, followed by validation (surveys).

Type of knowledge gap	Description	Relevance to 2019–20 wildfires	Action
Prestonian shortfall	Uncertainty about abundance of species and its variation in time and space	Lack of pre-fire population data means that it is almost impossible to determine proportion of population lost in fires, and hence also target levels for recovery. Such uncertainty may also make it difficult to assess priority of fire management relative to management of other threats that may be having greater impact.	Ideal: landscape-wide monitoring. Short-term: structured expert elicitation, followed by validation (surveys).
Extinction deficit shortfall	Extinction rate or conservation status of species/ECs uncertain	Rates of loss in wildfire may be difficult to contextualise in relation to other factors; this makes modelling of impacts (and extinction rates) of future fire regimes challenging.	Ideal: targeted surveys especially of poorly known species that may have suffered major fire impacts; modelling of impacts across potential future fire regimes. Short-term: structured expert elicitation, followed by validation (surveys).
Hutchinsonian shortfall	Species ecology and sensitivity or response to disturbance poorly known	Limited knowledge of response of biodiversity and ecological function (e.g. soils) to fire reduces capability to evaluate impact of individual fires, and of fire regimes. Limited knowledge also constrains ability to impose preferred fire management, and preferred post-fire recovery actions. Major bias among taxonomic groups – there is far more knowledge of responses to fire for birds, mammals and plants than for other groups.	Ideal: long-term monitoring, research on impacts of fires on individuals, populations and ecological function, including use of experimental manipulation of fires. Modelling indicating plausible ranges of responses to future fire regimes. Short-term: inference from similar species/traits.
Raunkiaeran shortfall	Uncertainty around ecological traits and functions or processes (of ECs)	Limited knowledge of life history and ecological traits constrains our ability to understand why species may be variably affected by (and recover from) fires of varying severity and regimes. Major bias among taxonomic groups. Also, limited knowledge of the responses to fire of many ecological processes, and of how biota recovery post-fire is affected by and affects recovery of ecological processes. Critical uncertainties relating to capability to build resilience in biodiversity (e.g. systematic program of translocations) to better enable it to withstand future pressures.	Ideal: fundamental research on species and traits, and/or ecological processes. Short-term: structured expert elicitation; inference from similar species/traits or ECs.
Poirot shortfall	Causes of decline (including compounding threats) and relevant effective actions poorly known	Limited knowledge of how threats (other than fire) are affected by fire, and how they may compound impacts of fire. Limited knowledge of the efficacy of post-fire recovery actions or how long they will need to be implemented to achieve recovery. As a consequence, management responses post-fire may be poorly directed or prioritised. Also, limited knowledge of other threats (and their management) constrains capability to build resilience in the system before and between fires.	Ideal: long-term monitoring especially in relation to threat management. Short-term: structured expert elicitation; inference from similar species/traits or ECs.

Table 32.2. A synthesis of knowledge gaps described by the chapter authors, leading to uncertainty relating to the 2019–20 fires.

This is not intended to be a systematic review, and it is acknowledged that some gaps may be missing. EC = Ecological communities.

Uncertainty	Icons	Soils	Aquatics	Marine	ECs	Plants	Fungi	Inverts	Frogs	Reptiles	Birds	Mammals
Identification and description (Linnean shortfall)					+		+	+	+	+		
Phylogeny (Darwinian shortfall)												
Distributions (Wallacean shortfall)			+		+	+	+	+	+	+	+	+
Movement (movement shortfall)										+	+	
Abundance and variation in time and space (Prestonian shortfall)			+			+		+	+	+	+	+
Extinction rate or conservation status (extinction deficit shortfall)			+		+	+	+	+	+	+	+	+
Ecology and sensitivity or response to disturbance (Hutchinsonian shortfall)	+	+	+	+	+	+	+	+	+	+	+	+
Ecological traits and functions or processes (Raunkiaeran shortfall)						+	+	+				
Causes of decline and efficacy of actions (Poirot shortfall)	+	+	+	+	+	+	+	+	+	+	+	+

in relation to fire, which is likely to involve a strategy of actions such as translocation, *ex situ* population establishment, threat (pest animal and weed) management, and fire management. If there are no precursors to act as a guide, resolving uncertainty may involve trials of risk-informed programs of translocations of insecure species, and trials relating to establishment of *ex situ* populations (or germplasm material). There are risks involved due to the precarious state of species requiring protection, and planning and research that integrate multiple management options and scenario planning (e.g. to account for climate risks) are important. Threat management is undeniably part of this suite of actions, but arguably the benefits of intensive and broad-ranging ongoing management of other threats (before and after fire), such as weed and feral animals, are relatively well known. Yet there are always questions of efficiency (such as intensity, timing, duration and location), particularly when resources are limited.

A path forward for management, underpinned by greater recognition and incorporation of Indigenous fire practices, has been outlined in Chapter 33. In a discussion of uncertainty, it is necessary to acknowledge that the approaches and resulting evidence base used to inform management has to date largely ignored Traditional Ecological Knowledge held by Indigenous people. The reliance on empirical data derived from current scientific practice to justify management may be misguided, given this bias (Fletcher *et al*. 2021). While the underpinning knowledge held by Indigenous people is critical to guide management of biodiversity into the future, approaches to research and monitoring require collaboration at all phases of knowledge acquisition (Fletcher *et al*. 2021) and of implementation of the actions informed by that knowledge. Importantly, it is here that the barriers to implementation of actions (the 'implementation gap') are more critical than any knowledge gaps. These barriers need to be resolved (Chapter 33) so that Indigenous people are able to fulfil their right to self-determination, and manage Country at scale.

When does uncertainty matter?

Uncertainty matters most when lack of knowledge leads to failure to prioritise effective conservation responses where they are most needed. Following the fires, impact assessments at a national scale were undertaken for vertebrates, invertebrates, plants and ecological communities to guide allocation of resources to action (https://www.dcceew.gov.au/environment/biodiversity/bushfire-recovery/bushfire-impacts/expert-panel). With the fires either still burning or just passed, it was critical to use whatever information was available to assess potential impacts to species and communities, for inaction or misplaced actions might have compounded losses and subverted possible recovery. Given the uncertainties described above, decisions needed to be taken on the basis of incomplete information. As a result, expert elicitation was used to redress some knowledge gaps.

A key question that should be asked is: were those assessments of impacts and (hence) prioritisation of species and recovery actions right? This is an entirely valid question about how data quality impacts decision making. However, it requires more nuance. The question is more usefully refined to: which species (or ecological communities) were erroneously not classified as a priority despite being highly impacted and needing recovery support following fire, but received little or no management attention? This is a false negative or Type II error (Fig. 32.1) and is the error most environmental managers seek to avoid (Burgman 2005). False positives, where it is falsely assumed a species or community is impacted and needs conservation support, and such action is taken, have far less consequential outcomes (except perhaps to those managing inadequate budgets). As an example of avoidance of Type II error, the impact of the fires on, and susceptibility of, the slender myoporum (*Myoporum floribundum*) was difficult to assess, due to limited records and understanding of the species. However, the plant was prioritised for survey effort, and a new population was uncovered in a severely burnt area, enabling cuttings to be taken for *ex situ* conservation.

Type II errors are most likely to be made, and hence to have adverse consequences, for poorly known species. For those species about which we know next to nothing, or indeed nothing (i.e. they are data deficient), their fate is mostly left to chance and possible benefits arising from actions taken for other co-occurring species, where management

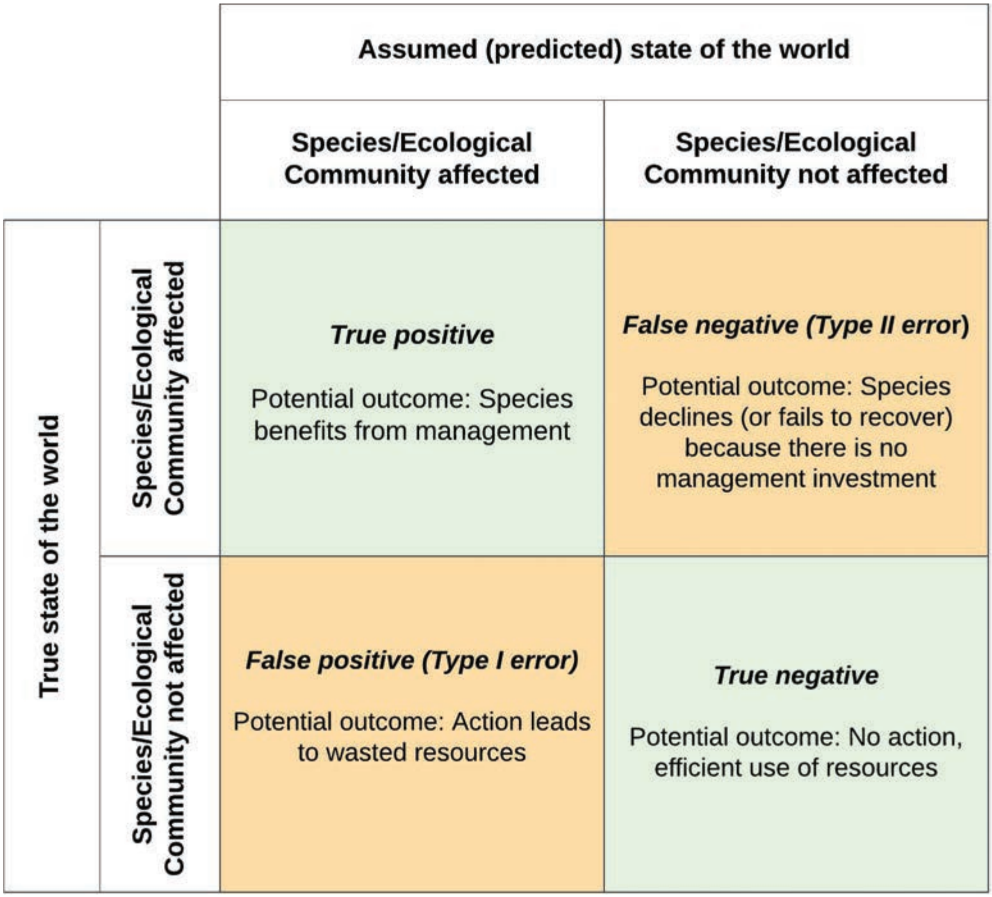

Fig. 32.1. An outline of the potential outcomes of Type I and Type II errors related to susceptibility assessments after the fires.

intervention happens to be applied where they occur and has some benefit to assist recovery. For those that are poorly known but imperilled, the potential consequences of a Type II error are dire, especially if they require targeted intervention (i.e. translocation or *ex situ* management). For example, ~400 described invertebrate and ~100 fungi species had all of their known ranges burnt in the 2019–20 fires (Chapters 11 and 10), but all of these are known from only one or two records. Some of these species may have been rendered extinct by these fires; the continuing existence of others may now be extremely tenuous, and there is some urgency in conducting on-ground surveys to assess whether any populations have survived the fires and, if so, to implement recovery actions. Given the uncertainty about the distribution and fire response of such species, there is major uncertainty about how many extinctions may have been caused by these fires: it is somewhere in the unacceptably wide range between one (the only 'confirmed' extinction of the *Banksia montana* mealybug: see Chapters 11 and 34) and perhaps 500 species. Even this larger figure may be an underestimate given that there are many more undescribed than described invertebrate species, and many of these undescribed species may have had complete overlap with fire.

Accounting for uncertainty and risk is perhaps embodied by the substantial federal and state government investment in strategic landscape-scale interventions (Chapters 22 and 23 respectively), such as feral pest and herbivore control. For researchers (and their funders), there is a need to focus effort on resolving uncertainty for those species for which the risk of imperilment is greatest, and which a change in management would benefit most.

Incorporating uncertainty to support decisions

For the 2019–20 fires, some assessment and response approaches explicitly recognised uncertainty and implemented mechanisms to deal with it. Often, these approaches required use of expert judgements and assumptions about system dynamics, whether that be through expert elicitation (Marsh *et al*. 2021; Legge *et al*. in press), or modelling (Gallagher 2020; Gallagher *et al*. in press). This is inevitable and – at least until the knowledge gaps are filled – appropriate; existing data are spatially and temporally piecemeal, biased information derived from previous research on fire may not necessarily be extrapolatable to fires of the unprecedented magnitude of those in 2019–20, and the data we have now might not tell us much about a changing future.

A specific post-fire vulnerability assessment approach was developed for invertebrates (Marsh *et al*. 2021; Chapter 11) to guide decisions about management responses and conservation listing while accounting for an overwhelming lack of knowledge about the majority of species. In this work, a trait database relevant to fire susceptibility and recovery potential was compiled using expert input on life history characteristics, threats and management needs. Critically, this trait compilation (and hence assessment of susceptibility) was not restricted to well-studied species, but experts also assigned likely traits based on knowledge of species in the same genus or family, with explicitly stated level of confidence to their assessments. This information was collated with fire overlap information, for > 1000 species, to identify species likely to be most affected by the 2019–20 fires and most needing recovery support. Although this process allowed prioritisations to be made for many poorly known species, it could not be used for the majority of invertebrate species, which are not even described. However, this structured approach provides a path forward; it will be an accessible database that can be updated and, importantly, the type of uncertainty (Table 32.2) is attributed to each taxon to inform future research needs.

Legge *et al*. (in press) expanded on the initial post-fire vulnerability assessment for vertebrates and spiny crayfish using the IDEA protocol (Hemming *et al*. 2018): a structured, repeatable, consistent approach to eliciting information that captures uncertainty and minimises bias for a large number of species. Experts were asked to predict post-fire population change over time, providing realistic upper (best case) and lower (worst case) bounds. Uncertainty from expert judgments was used to assess if population change over time crossed the population reduction threshold for a species to be considered Vulnerable, Endangered or Critically Endangered. This is illustrated in Fig. 32.2. For example, due to the impacts of the 2019–20 fires and other threats, the gang-gang cockatoo (*Callocephalon fimbriatum*) will potentially cross the Vulnerable threshold over time, when accounting for uncertainty (i.e. when using confidence limits around projected future population). Other species were predicted more unequivocally to have declined as a result of the fires such that they meet Endangered criteria (e.g. Kangaroo Island southern emu-wren (*Stipiturus malachurus halmaturinus*)). Likewise, some species do not meet listing criteria, even when factoring in uncertainty (e.g. black-faced monarch (*Monarcha melanopsis*)). This

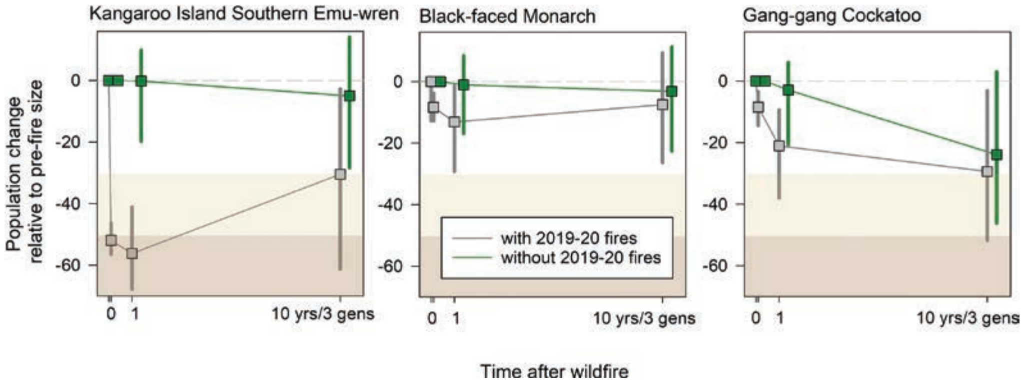

Fig. 32.2. An excerpt from the Legge *et al.* (2021) assessment for birds, highlighting how uncertainty was used to assess whether population changes (at the national scale) due to the 2019–20 wildfires met thresholds for listing as Vulnerable (light brown) or Endangered (darker brown).

structured elicitation process was used to inform national conservation assessments for threatened species listing under the *Environment Protection and Biodiversity Conservation Act* 1999.

The approach shows how the precautionary principle can provide a framework for dealing with uncertainty to inform policy. Currently, it is little applied but, given the rate of biodiversity declines in Australia and the current paucity of data, this needs to be rectified. Not incorporating and accounting for uncertainty means ignoring risk (Burgman 2005). Of course, the data can, and should be, validated, but the approach allows us to make urgently required decisions in the face of critical uncertainty, and then target knowledge acquisition where uncertainty is most critical.

Many uncertainties remain unresolved. Two metrics were pivotal in the assessment of the conservation impacts of the 2019–20 wildfires on wildlife – the extent of species' distribution that overlaps with fire, and the likely proportional mortality rate in burnt areas. However, such an evaluation is based on the presumption that animals in unburnt terrestrial areas are largely unaffected by fire – indeed, unburnt areas within or near the burnt areas are widely assumed to form crucial refuges and to be critical source areas for re-population of burnt areas. There is at least one major uncertainty in this assessment, relating to the extent to which impacts of fire on terrestrial wildlife species extend beyond the burnt area, notably due to the impacts of smoke (Chapter 16).

Uncertainty can be overwhelming, but it need not be crippling. There are existing frameworks that help us understand whether uncertainty is critical to resolve before a management decision is made, such as structured decision making (Gregory *et al.* 2012; Hemming *et al.* 2022). These approaches require clear specification of objectives, alternative management options, and evaluation of the consequences of these options with available data (with uncertainty) to explore whether a decision can be made. If the preferred (or optimal) alternative does not change after consideration of uncertainty (i.e. would you make the same decision when considering the worst case scenario?), then uncertainty is not critical to resolve in that context. A relevant example of such a process can be found in the PACES tool (NESP Threatened Species Recovery Hub 2021), which guides users through a structured process to help guide decisions about whether or not to initiate or continue an *ex situ* management plan for a species. Of course, research may be required to refine knowledge on management effectiveness, and monitoring to verify the predicted outcomes of the chosen strategy.

Conclusions

Uncertainty clouded assessments of biodiversity impacts of the 2019–20 wildfires. In some cases, these uncertainties may not have been knowledge gaps, but simply reflect lack of appropriate transfer of knowledge from experts (or data custodians) to those who needed such information (e.g. fire control centres). In either case, these gaps may have resulted in some suboptimal conservation responses. Whether that is true will only be revealed with monitoring, and time, but the 2019–20 wildfires catalysed an extraordinary spate of conservation management responses, establishment of monitoring programs, and research; and this effort should result in major knowledge gains and resolution of some key uncertainties.

Even more challenging will be uncertainties relating to future *fire regimes*, rather than individual fires, as regimes and their impacts are far more complex than single fires. In addition, many of the issues concerning uncertainty raised in this chapter are likely to be transferable: many of the same uncertainties constrain or subvert other decisions about conservation, and many of the approaches to resolving uncertainties will be applicable to other situations.

Recognition of uncertainty, and making an explicit attempt to factor it into responses, is likely to provide better, more robust, more flexible and more justified decisions and outcomes, and ready alignment with adaptive management. Critically, it allows decision makers to exercise their risk attitude; given our current declining baselines for biodiversity and an uncertain future, a precautionary approach is warranted. Approaches developed and applied after the 2019–20 wildfires demonstrate how uncertainty can be integrated into risk assessments to inform management. Yet we need to be much more proactive. The scale of the 2019–20 wildfires showed that we shouldn't have been so accepting and complacent about knowledge gaps: it should not need such catastrophic triggers to recognise and redress uncertainties.

Recommendations

- Explicitly recognise and incorporate uncertainty into risk assessments and planning, to enable decision makers to understand and moderate the risk associated with management options. Apply options and scenario analysis in planning for management, to explore the risks of an uncertain future associated with climate change and more frequent fire.
- Enable Traditional Owners to take a leading role in planning, management and research; Traditional Ecological knowledge is so often missing from decision making.
- Be specific about which type of uncertainty is critical to resolve to improve management decisions.
- Where data are lacking (particularly about the future), structured expert elicitation should be used to supplement existing data, to understand uncertainty, and to target research and monitoring to where they most affect decision making.
- Overcome some of the bias in the knowledge of biodiversity, by resolving substantial knowledge gaps for invertebrates, fungi, and ecological processes.
- Improve understanding and research about the impacts of repeat fires (fire regimes) on biodiversity.

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