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Application of Risk-Based, Adaptive Pathways to Climate Adaptation Planning for Public Conservation Areas in NSW, Australia

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Abstract: Globally, areas of high-quality wildlife habitat of significant environmental value are at risk of permanent damage from climate change. These areas represent social-ecological systems that will require increasing management intervention to maintain their biological and socio-cultural values. Managers of protected areas have begun to recognize the inevitability of ecosystem change and the need to embrace dynamic approaches to intervention. However, significant uncertainty remains about the onset and severity of some impacts, which makes planning difficult. For Indigenous communities, there are intrinsic links between cultural heritage and the conservation of place and biodiversity that need to be better integrated in protected area planning and management. In New South Wales, Australia, management of public conservation reserves and national parks is the responsibility of a State government agency, the National Parks and Wildlife Service (NPWS). This paper describes the outcomes of a participatory planning process with NPWS staff to, firstly, identify the options available, the available 'tool kit', to manage biodiversity and cultural heritage in protected areas; secondly, explore how the selection of management actions from the 'tool kit' is associated with the level of climate risk to biodiversity or cultural heritage assets; and thirdly, to understand how the form of individual management actions might adapt to changes in climate risk. Combining these three elements into a series of risk-based, adaptive pathways for conservation of biodiversity and cultural heritage is a novel approach that is currently supporting place-based planning for public conservation areas. Incorporation of the trade-offs and synergies in seeking to effectively manage these discrete but related types of values and the implications for conservation practice are discussed.

Keywords: biodiversity; cultural heritage; climate change; adaptation; risk; pathways; planning

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1. Introduction

Conceptualization of coupled human and natural systems as social-ecological systems enables the study of the interaction of society and the natural environment. Such studies emphasize the unique emergent properties of social-ecological systems as nonlinear dynamics with thresholds, reciprocal feedback loops, time lags, resilience, heterogeneity, and surprises that vary considerably across scale and in scope [1]. Protected areas, such as nature reserves and national parks, are recognized as social-ecological systems because they are natural areas managed for specific ecosystem service outcomes valued by society [2].

Fixed systems of protected areas (PA) are used in many countries to meet a variety of conservation and other objectives that include the management of species assemblages and ecosystems and the protection of significant socio-cultural values (e.g., important cultural sites) [3]. Globally, approximately 12 percent of Earth's land is designated as protected areas yet less than half of this land is managed explicitly for biodiversity conservation [4,5]. In New South Wales (NSW), Australia, there are 877 protected areas covering 7 million hectares of land (or 9% of the State) [6]. Despite the significant area under protection, the biodiversity and cultural heritage values in protected areas are considered increasingly vulnerable to changes in climate [7,8].

Climate change is widely recognized as a key threat to biodiversity as it alters the climatic variables of rainfall and temperature, which can disturb ecological systems and natural processes affecting species survival [9–11]. Some authors (e.g., [11]) estimate that up to 82% of physiological processes have been affected directly by climate change. Furthermore, climate change is recognized also as a threat multiplier because it amplifies other drivers of biodiversity loss including habitat degradation [12], soil loss [13], nitrogen cycling [14], and ocean acidification [15]. Concerns about biodiversity loss from climate change arise because present extinction rates are exceptionally high in comparison with background rates [16]. Each species fills an essential biological niche in an ecosystem that may perform specific functions, which work collectively as a whole [17]. Processes of adaptation in natural systems occur autonomously with capacity of ecosystems to adapt to climate change dependent largely on the physiological thresholds of individual organisms, the genetic diversity of individual species present, and the functional and response diversity of the species assemblages in the ecosystem [18–20]. Biodiversity enhances the resilience, function, and stability of social-ecological systems because functionally diverse ecosystems are more adaptable and can support response diversity among multiple species to a range of external shocks including extreme climate events [3,19–22].

In contrast to the impacts of a changing climate on biodiversity, these impacts on spiritual and cultural heritage values of significance in protected areas have been, to date, largely overlooked [8]. Adger [23] defined culture "as the symbols that express meaning, including beliefs, rituals, art, and stories that create collective out-looks and behaviors, and from which strategies to respond to problems are devised and implemented". Cultural heritage is often closely tied to places (physical spaces) that are given meaning by people and has both tangible (e.g., buildings and sites of historical importance) and intangible (e.g., locations of indigenous spiritual practices) dimensions [23]. Conservation of such places evokes a sense of continuation of culture, enriches people's lives, facilitates attachment to place and serves as a link with the past and to allow society to make sense of the present [24].

Climate induced changes in values of protected areas, whether through autonomous adaptation of ecosystems or damage to heritage artifacts, are problematical and require intervention [25] because conservation is traditionally the principal aim of protected area management [26,27]. Given the increasing likelihood of irreversible change to ecosystems under a changing climate, alternative methods of intervention have been suggested that accommodate some change and loss, that remain relevant and feasible under a range of future trajectories, and that seek to conserve multiple societal values [25,28]. Such approaches will require adaptation of the management 'tool kit', as the effort to maintain protected area values will likely increase as climate risk rises [29]. Approaches to planning that incorporate adaptive management pathways [30] enable flexible planning under deep uncertainty and help prioritize adaptation actions in complex social-ecological systems, such as protected areas, which perform a range of functions for society [31].

Jacobs [29] reported on a participatory process to incorporate uncertainty into climate adaptation planning for the NSW National Parks and Wildlife Service (NPWS). The findings of that research indicated that in the context of increasing climate risk, management practices will need to evolve due to likely resource constraints and discontinuities in management pathways that will emerge across a range of service areas within reserve areas including management of pests and weeds, fire and incident management, customer experience, and strategic planning. This paper expands on that work by focusing specifically on the adaptive management pathways developed for biodiversity and cultural heritage to support place-based planning for public protected areas.

2. Methods

The development of the adaptive pathways involved engagement with the NSW NPWS staffing responsibilities across two series of workshops. To ensure the full range of operational and policy expertise was captured in the workshops, field operational (i.e., park rangers), education officers, planning officers, fire management officers, policy officers, middle and upper management, and asset management staff participated (Figure 1). The first series of seven workshops engaged staff (n = 101) from each of the seven 'functional areas' of the agency: pests and weeds, nature conservation, strategy and services, park assets management, heritage, customer experience, and fire and incident management. These workshops gathered information on the broad suite of options available to each functional area to manage the minor to major impacts of a changing climate within protected areas in NSW. These workshops defined the breath of responsibilities of each functional area; visualized the impacts on NPWS functions of major climate drivers resulting from extreme events and incremental changes; developed a series of risk assessment matrices (Figure 2) and constructed a decision framework of adaptive pathways that incorporated the range of management options available to each functional area.

Risk was conceptualized as the product of the impact (or consequence) of an event combined with the likelihood (or probability) of an event occurring and detailed in a risk matrix [29]. For example, a moderate risk from a changing climate, such as increased bushfire frequency on biodiversity, may result in localized extinction of a species with a limited range, or injury to park visitors or staff. Whereas, for cultural heritage, a moderate risk may result in tangible impacts in the form of damage to or loss of access to an important cultural heritage site, and intangible impacts such as loss of connection to place. A more detailed description of the process through which adaptive pathways for biodiversity and cultural heritage management were developed is provided in Jacobs [29].

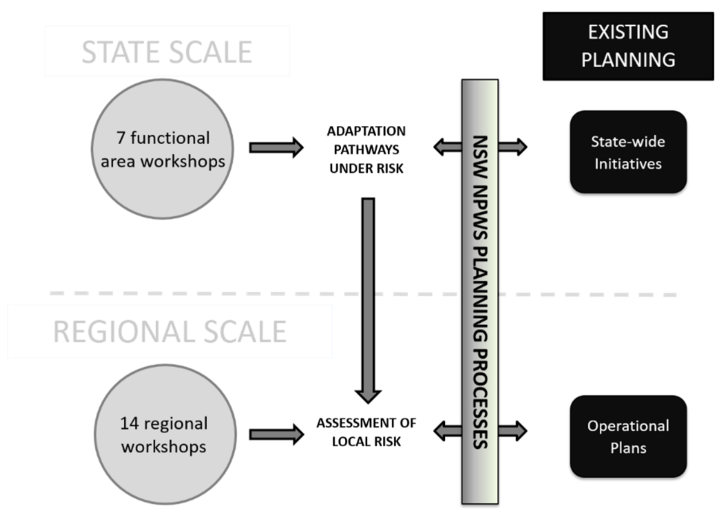

Figure 1. Process to elicit risk heuristics and adaptive pathways and its relationship to existing planning processes in the New South Wales National Parks and Wildlife Service (NPWS).

		Consequence				
		Catastrophic	**Major**	**Moderate**	**Minor**	**Insignificant**
Biodiversity		Extinction/Death of a staff member/ Government dismantles National Parks	Rare/ Significant injury to staff/ Loss of agency credibility	Localised extinction / minor staff injury (e.g. broken arm) / reduction in resources & funding	Population decline / redirection of funds	No detectable impact / failure to optimise outcomes
Cultural Heritage	**Tangible Impact**	Loss of multiple significant cultural sites & access to sites / loss of totem animal / WH site delisted	Substantial loss of sites / landscape change / loss of historic buildings or collections / WH site damaged but recoverable	Temporary loss of site access / place disrespected / minor or temporary damage to WH site	Minimal impact on cultural sites / minor damage to a historic building or collection	Little or no loss of place or culture
	Intangible impact	Loss of culture / no underpinning identity / no spirit in the landscape	Lack of interest in cultural practices & knowledge / loss of connection to place	Landscape change but culture continues / temporary loss of connection to place	Acculturation (adoption of other cultures) / dilution of culture	Little or no loss of place or culture
Likelihood	**Almost certain** Event will occur in most to all situations	Extreme	Extreme	High	Medium	Medium
	Likely Event expected to occur in the majority of situations	Extreme	High	Medium	Medium	Low
	Possible Event might occur or might not occur equally	High	High	Medium	Low	Low
	Unlikely Event expected to not occur in majority of situations	High	Medium	Medium	Low	Negligible
	Rare Event theoretically possible but expected to not occur in most to all situations	Medium	Medium	Low	Negligible	Negligible

Figure 2. Risk management matrices used to develop adaptive management pathways for biodiversity and cultural heritage. Adapted from [29].

The information from functional area workshops was then used in a second series of 10 workshops with operations staff (n = 208) drawn from 14 NPWS regions throughout NSW [29]. The regional workshops identified key park values (such as priority species, built-heritage assets, sites of cultural importance or rare landscape features or ecosystems) at risk from a changing climate, assigned a current level of risk to these park values, and identified the range of management actions that could be implemented to protect those values. Using the adaptive pathways decision frameworks (Figures 3 and 4) developed in the functional area workshops participants then explored the change in management options required to protect the park value if the level of risk rose from the current level to the next highest risk level. This information was then used to inform a park planning process that anticipates the heightened impacts of future climate change.

In this paper, we use the pathways developed for biodiversity and cultural heritage to explore the implications for adaptive management, with increasing climate risk, of these types of protected area values.

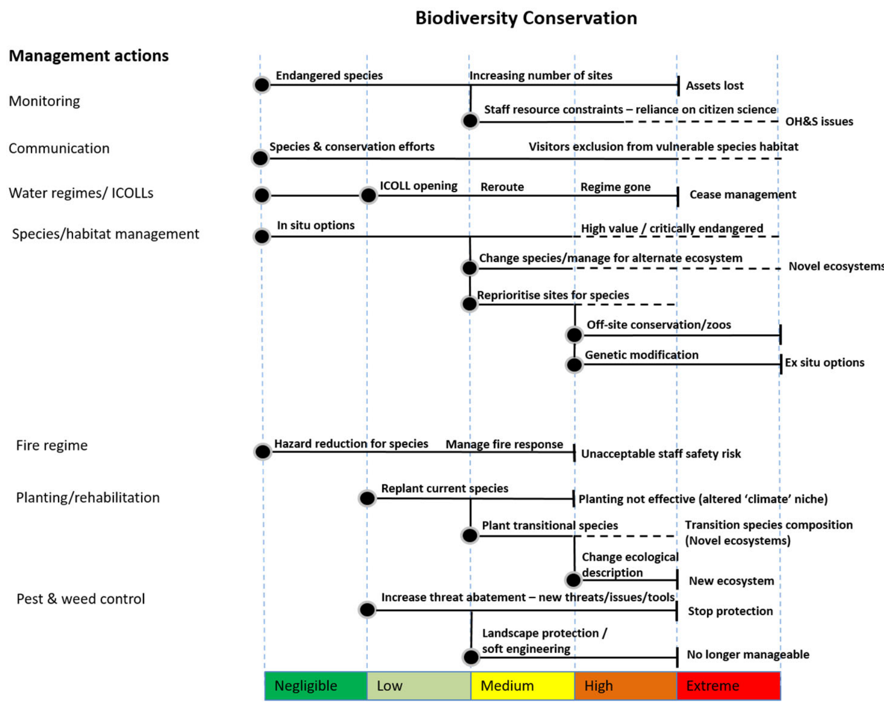

Figure 3. Adaptive management pathways under dynamic risk developed for biodiversity conservation. Black circles represent the beginning of a pathway or result from a disjunction along a pathway. Dotted lines represent uncertainty about the continuation of a pathway at a certain risk level.

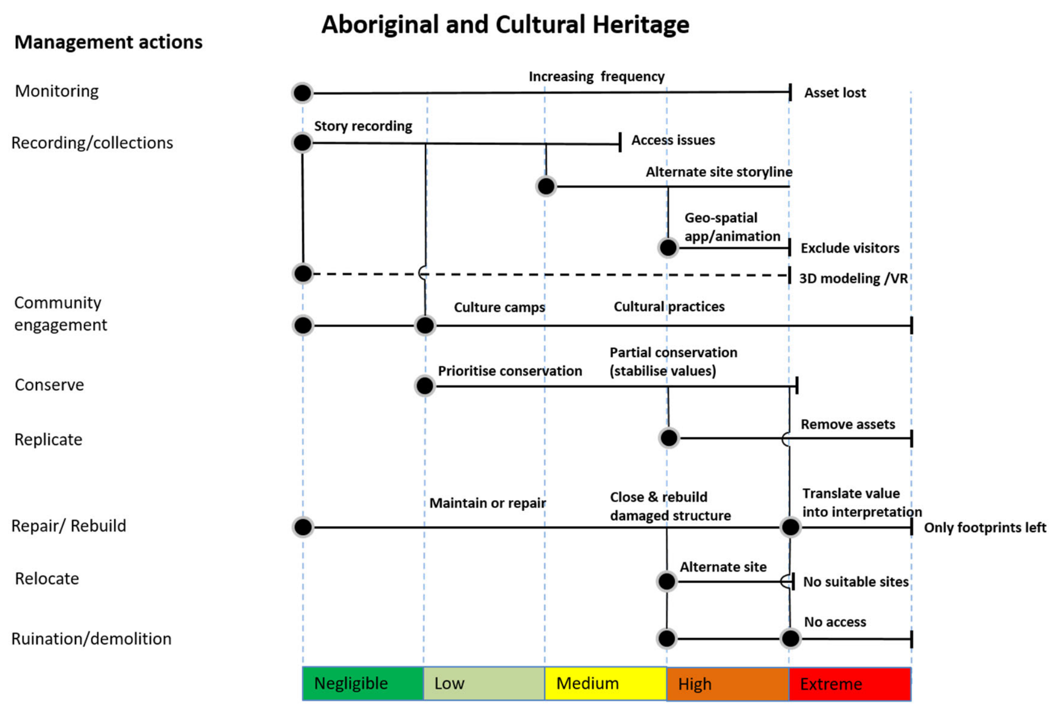

Figure 4. Adaptive management pathways under dynamic risk developed for Aboriginal and cultural heritage. Black circles represent the beginning of a pathway or result from a disjunction along a pathway. Dotted lines represent uncertainty about the continuation of a pathway at a certain risk level.

3. Results

3.1. Adaptive Management Pathways

3.1.1. Biodiversity Conservation

Figure 3 depicts adaptive pathways constructed from the range of actions available to manage biodiversity in a protected area. The suite of management actions to respond to changes in the climate, effectively the adaptation 'tool kit' for biodiversity conservation, is listed on the left-hand side of the figure. These actions include monitoring, habitat management, fire regimes, and planting and rehabilitation among others. Risk, from a range of climate impacts, increases from negligible to extreme summarizing the likelihood by consequence matrix shown in Figure 2. Each management action is represented as a single or branched pathway variously spanning the levels of risk. The pathways have clear starting points that relate to the need for progressive implementation of selected management actions as risk levels increase. For example, five pathways are implemented at negligible risk: monitoring of vulnerable or endangered species, communication (within NPWS and with the public), management of Intermittently Closed and Open Lakes and Lagoons (ICOLLs), species/habitat management, and management of fire regimes. These actions represent the routine operations performed by managers of public protected areas.

Escalating risk generally adds greater complexity (branches) to the pathways as more actions need to be implemented to protect biodiversity. At low risk, pathways for planting/rehabilitation and pest and weed control begin, triggered by information from routine operations about ecosystem change, such as the analysis of information from biodiversity monitoring. At higher levels of risk (medium and above) four pathways branch (monitoring, species/habitat management, planting/rehabilitation and pest and weed control) as additional or alternative management actions are implemented.

Pathways may terminate at high or extreme risk levels as many management actions were considered likely to be ineffective, owing to ecosystem transformation through breaches of ecological thresholds, or were operationally too dangerous for staff or public visitation. Some branches of pathways terminate in dotted lines, which implies uncertainty around the effectiveness of a particular action at high levels of risk.

Some pathways formed complex branched structures that illustrate the need for adaptation to increasing risk within individual biodiversity management actions. For example, species/habitat management moves from in situ options at negligible risk to ex situ options at high and extreme risk levels through a multi-branched 'decision framework'. This framework incorporates new forms of management for the emergence of alternative/novel ecosystems, the reprioritization of sites to better match altered climatic conditions for key endangered species, or the reliance on zoos, genetic storage banks or potential genetic modification of species under threat of permanent loss.

3.1.2. Aboriginal and Cultural Heritage

For Aboriginal and cultural heritage, the adaptive pathways mirror those of biodiversity conservation, albeit with a set of management actions appropriate to heritage conservation tasks (Figure 4). As with biodiversity, a set of routine operations is in place at negligible levels of risk, which includes monitoring, recording/collections, and general repair of heritage sites. At low risk levels, the heritage tool kit includes conservation activities on priority values. More management actions, represented as the pathway branches, are implemented as risk levels rise because protection of heritage values requires intervention that is both different in mode and more intensive.

In contrast to the biodiversity pathways, for heritage, with the exception of monitoring, management actions were grouped into two interlinked decision frameworks. The first was an interaction between recording/collections and community engagement. This pathway moves from recording and collection of place-based stories at negligible risk, through identification of alternate sites for storylines at medium risk levels to the use of geo-spatial applications and animation of stories at high risk levels when access by the public becomes increasingly dangerous. Three-dimensional modelling of sites and their rendering into a virtual environment is represented as a dotted line across the range of risk levels because the application of extended reality technology to heritage is currently under investigation by NPWS staff. The connection between recording and community engagement at low risk levels, reflects the need for ongoing dialogue between protected area managers and, in particular, Indigenous communities on their requirements for the preservation of specific place-based cultural and spiritual values.

The second group of pathways formed a decision framework that linked a set of physical interventions of increasing intensity driven by the likelihood that a heritage value could be lost as risk levels rise. These pathways included management of in situ conservation, repair and rebuilding following damage, relocation of an asset to an alternative safer site, replication at an alternative site, and, finally ruination and demolition where a site might become a public hazard under extreme levels of risk. Many of the management actions in this set of pathways related specifically to tangible and built heritage values.

4. Discussion

Baron [32] defined three principles to underpin the management of anticipatory adaptation for protected areas under climate change: (1) Climate patterns of the past will not be those of the future; (2) climate defines the environment and influences future trajectories of change in ecosystems; (3) specific management actions may help increase the resilience of social-ecological systems, but fundamental changes in species and their environment may be inevitable. In adopting an adaptive pathways approach to planning for the impacts of climate change in public protected areas, we identified two principal ways in which the management of biodiversity and cultural heritage would respond to a dynamic risk environment. Firstly, the selection of interventions from the management tool kit will change, with the level of intervention (number and intensity of actions) increasing as risk levels rise. Secondly, the mode of delivery of some management actions will change. For instance, remote monitoring of change in protected area values through the use of drone technology will likely become part of routine operations (e.g., [33]) to reduce both risk to field staff and accommodate the need to monitor more sites more frequently [34]. These changes, however, raised deeper questions about the effectiveness of a traditional conservation approach in a climate changed world, in particular for biodiversity, given the likely need to accommodate change and loss within social-ecological systems [21,35].

For the two types of assets considered in this paper, biodiversity and heritage, there was considerable overlap in management options and in the actions along adaptation pathways suggesting some synergies in management interventions might be possible. Increasing monitoring effort was common two both asset types, and there would appear to be obvious synergies in the adoption of technology by protected area managers to enable a change from in situ to remote sensing of assets. Similarly, a progression from rehabilitation to relocation to ruination/cessation of management appears in both sets of pathways at extreme risk levels. In this case, rather than in the technical aspects of management, synergies may be possible in the processes to resolve conflict over trade-offs in environmental, economic and social values, which are likely to be subject to intense political lobbying from dispersed communities of interest in addition to local, place-based concerns [36,37].

Social-ecological resilience theory [35,38] is widely applied to the management of protected areas, although its operationalization can encompass a range of approaches. Dudney [39] summarized these under the term Resilience Based Management (RBM) as: 1. management of the drivers of change, 2. management to increase adaptive capacity, or 3. management to enable transformation. These three aspects of RBM are apparent within the adaptive management pathways developed here for biodiversity and cultural heritage.

RBM that focuses on management of local or regional drivers of change represents a business-as-usual approach to biodiversity conservation, through the reduction of threats to iconic species or communities (e.g., [40]), to enhance resilience to broader scale changes in climate [41,42]. However, the effectiveness of such approaches has been questioned [43,44], and this is reflected in our pathways as a shift away from management of in situ threats to a wider landscape-scale view of protected area management as risk levels rise. This approach seeks to increase adaptive capacity of protected areas by increasing species diversity (e.g., planting of transitional species, Figure 2) and facilitating the movement and migration of biodiversity, or the relocation of cultural heritage assets, in the landscape along topographic and climate gradients [45]. To date, landscape-scale approaches to public protected area management have suffered from the fragmentation of the public reserve system. Alternative models of landscape management call for the integration of conservation on public and privately-owned lands 'to blur the distinction between land management on reserves and the surrounding landscapes in a way that fosters widespread implementation of conservation practices' [46] (p1), improves landscape connectivity [47], and reduces the risk of extinction from spatial isolation of species [48].

Finally, at high-risk levels, our adaptive pathways embrace the likelihood of transformation in social-ecological systems with the emergence of novel ecosystems, which may fundamentally change biodiversity and intangible heritage values of protected areas as resilience thresholds are breached [49]. Management of these transformations calls for new approaches to conservation. Functional transition of ecosystems to conserve ecosystem services rather than native biodiversity [50], human-assisted evolution (e.g., to conserve coral reefs [51]) and genome editing [52] are among the controversial techniques currently under consideration as additions to the biodiversity conservation tool kit. Similarly, for intangible heritage values, the retention of cultural and spiritual values for Indigenous communities within an extended reality environment (e.g., [53]), in the absence of the original site, has yet to be fully explored and raises questions related to the authenticity and integrity of the experience to support Indigenous cultural practice [54], and of the protection of Indigenous peoples' intellectual property [55] in an age of mass digital reproduction.

5. Conclusions

There is an urgent need to identify and adopt strategies to limit further climate change to avoid permanent change to social-ecological systems [56]. However, in the absence of successful global attempts at mitigation, adaptation to the impacts of climate change remains the only approach to the conservation of biodiversity and heritage values in protected areas. An adaptive pathways approach to protected area management for climate risk allows managers to anticipate the need for changes in intensity and form of interventions to biodiversity and cultural heritage conservation. These changes have implications for resources and knowledge needed to support management action [29]. Adaptive pathways approaches allow management to anticipate change and identify adaptation solutions even though the timing of the onset of climate impacts may be uncertain. We believe the novelty of our process lies in the combination of management pathways and risk heuristics into a practical planning tool for protected area management. The next step in the implementation of these pathways as a decision support tool requires protected area managers to identify specific place-based triggers as indicators of a change in risk and therefore level of intervention. However, where climate impacts trigger multiple, and perhaps contradictory, management interventions for a range of asset types, some form of prioritization will be required, which traditionally falls within the discipline of ecological economics to resolve. Alexandrakis [32] provides a recent example of an economic appraisal technique that accounts for both market and non-market values to aid in prioritization of intervention at cultural heritage sites.

Clearly, under pressure to conserve protected area values and ecological systems more generally, managers may need to consider novel techniques as part of the management tool kit. The use of many of these techniques, such as assisted evolution of species and digitization of intangible cultural heritage, is experimental and contested. However, the survival, in some form, of biodiversity and cultural heritage values may well depend on society's ability to resolve the complex ethical and moral issues related to the use of these novel technologies [57,58].

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