Department of Planning and Environment

dpie.nsw.gov.au

Appendix 3 and 4

CPCP Research Program Implementation Strategy Draft

November 2022

Acknowledgement of Country

The Department of Planning and Environment acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

Published by NSW Department of Planning and Environment

dpie.nsw.gov.au

Appendix 3 and 4

TMP-MC-R-SC-V1.2

Contents

Appendix 3. Knowledge gaps and supporting information

This information was identified during workshops conducted as part of Cumberland Plain Conservation Plan draft Research Program Implementation Strategy supporting information. Participants identified 294 unique knowledge gaps and over 900 potential activities to address them. All identified knowledge gaps from the workshops have been listed below. Knowledge gaps have been presented with editing for clarity purposes only to ensure transparency. Common acronyms: Cumberland Plain (CP); Cumberland Plain Woodland (CPW); Climate Change (CC); Threatened Ecological Community (TEC); Biodiversity Stewardship Agreement (BSA); National Park (INP).

Workshop - Engaging with peoples and cultures

- What does Country need? Aboriginal-led research to establish the needs of Country and guide conservation/restoration.
- Ontological (in)compatibility.
- How can we incorporate traditional practice and culture into management for biodiversity outcomes?
- How can citizen science and cultural aspects of the CP be combined and what spaces could that activate to facilitate greater understanding of the aboriginal cultural landscapes that exist in their community.
- What are the cultural connections and aspirations for places with CPW, not only framed around biodiversity and conservation but the broader spiritual connection to Country?
- How do First Nations TO want to have a seat at the 'research' and restoration decision making and empowerment for both these areas to provide paid employment to care for Country.
- What is reciprocity vs giving back to aboriginal communities?
- Recognising Aboriginal science in western terms.
- How to respectfully share knowledge between Aboriginal and Settler (general) community.
- Two eye seeing approach Cultural/Western Science.
- Broader focus on education. There is a focus on birds and animals, but what about the invisible yet intriguing like fungi, insects, lichen. You capture a new group of people here.
- What do communities value? Do these values align with biodiversity and conservation?
- How do people value greenspace - both in terms of what is in their region and what they have access to? Will increased access help improve public perception of green space?
- What's the emotional relationship people who live and work within CPW have to those places e.g. what do they value, not necessarily framed around 'biodiversity'.

- How do residents evaluate the use of public funds for biodiversity offsets? Is a lack of access to restoration / biodiversity offset sites a barrier for appreciation of where the money goes?
- Community priorities and aspirations e.g. strategic plans.
- Capitalizing on the desire for recreational activities to encourage low impact experiences in natural settings.
- Link between "Urban Green Infrastructure" (in growth areas) vs ecological connectivity that CPCP will create.
- How do attitudes differ between different sectors of community?
- Attitudes and knowledge of migrants. Many share a love of land and to connect them to local environment would benefit both.
- What are people's attitudes to conservation and biodiversity in the CP?
- Forming long term connections and networks where once engaged people can continue to engage and welcome people.
- Incorporating cultural healing spaces within the proposed blue-green networks - new places that form song lines.
- For private landholders what are the core challenges and barriers for effective EEC conservation and what are the funding mechanisms to support this.
- What are the key areas of human-wildlife conflict and what are the options for managing this?
- What are the drivers of conflict concerning increasing green space?
- Barriers and limitations.
- Does increasing green space resulting gentrification?
- Ownership vs caretaker. Property rights vs shared resources.
- Understanding barriers and challenges or private landowners to support restoration and conservation.
- 'Plastic Panda syndrome': next generation preferring 4K high-res video of 'wild nature' vs real (uncomfortable, hot, dirty) outdoor experiences.
- Are we imposing artificial "western' timeframes or administrative barriers on Indigenous communities' if so, how we manage this?
- Knowledge and understanding of actions that promote/support biodiversity?
- Cannot assume any interest or knowledge of the natural environment.
- How do we translate successful community engagement projects to CP? e.g. Wooli NP.
- Hegemony of 'Western' thinking and conservation practices.
- What do landowners know about conservation and what don't they know.
- What is the value of BSA or other private / government conservation land with no public access to the community?
- What incentive / information / assistance is needed to get landholder involvement in conservation outcomes.
- Benefits for locals - health, cooling etc.

- Cost benefit analysis of restoration from different starting levels of degradation versus conservation of pristine areas.
- Is there a conflict between public access and use with management for conservation?
- Understanding what the barriers are to engagement and conservation.
- The dynamics of CALD attitudes, do they/ have they changed over time?
- Make (better) use of narrative, storytelling (about meanings of cons & biodiversity to people, communities), to complement quant indicators.
- How can multilevel school, council, Landcare networks be leveraged for effective TEC conservation?
- How to better engage with migrants not familiar with the Australian bush in Western Sydney.
- How does the media affect and shape community attitudes to conservation? Which media channels are most effective?
- What are the cultural factors that influence behaviour change in Western Sydney?
- How to improve messaging to the community about what we are doing - how to get people on board or that they have a forum to express their opinions.
- How do local residents perceive rewilding projects? Will access to spaces where they can (potentially) observe rare species improve perceptions?
- What's the understanding between people seeing nature and understanding and interest in healthy ecosystems and services?
- What are community attitudes to controls on domestic animals - cats, dogs.
- What are community attitudes to critically endangered species that they will never encounter themselves.
- Engagement fatigue.
- How to reengage disenfranchised groups e.g. koala interest groups in Wollondilly?
- Potential of financial compensation mechanisms (payment for what? Traditional Knowledge, Ecosystem Services, etc).
- How to best engage with stakeholders we know are impacting on biodiversity e.g. waste dumpers, BMX trail bike riders?
- How to balance the benefits of people engaging with nature through recreational use and damage to environment.
- What methods can we use to educate residents using the bush for illegal activities such as motor bikes, 4WDs, bike jumps and tracks.
- How are restoration activities perceived within local and regional contexts?
- Who are the community leaders in non-English speaking cultural groups who can engage and educate?
- Knowledge holders and leaders within community.
- How do we identify/ attract community champions who lead others to create community change?

- Are there community volunteers/groups with local knowledge/expertise/relationships that can be drawn on/leveraged?
- Increase volunteering for conservation.
- Financial incentives for landowners to engage in BSAs.
- Empowering communities.
- Who are the community already aligned to loving nature in areas with CPW? Who and why do others not love it?
- How do diverse cultural groups receive their local news and conservation knowledge - social media, foreign language newspapers.
- How to give more social weight to conservation programs - should this be used more when determining projects.
- What are the limitations of citizen science to capture monitoring data for restoration activities, is there any?
- Overlaps between song lines and biodiversity corridors?
- Can we link song lines and aboriginal trails with landscape connectivity for biodiversity and conservation?
- Song lines and Cultural protocols.
- Significance of and connection to place/Country.
- Kinship to Country.
- What are culturally significant species and places in the CP that could be better managed by Aboriginal custodians.
- Critical assessment of the financial costs of implementing cultural activities and beneficiaries.
- How/ where do aboriginal people see their role in the restoration of ecological and cultural spaces within the CP.
- How can we use Caring for Country to create a sense of belonging for a diverse community?
- How can Indigenous relational knowledges genuinely lead effective CPW biodiversity conservation in an operation environmental of neoliberal management regimes and expectations.
- How do we provide indigenous leadership for research in biodiversity and conservation?
- What assistance do Aboriginal people need to be involved in conservation on their Country.
- How does cultural burning compare with ecological and hazard reduction burning practices in terms of biodiversity and conservation gains?
- Can cultural burning be used to improve management but also community engagement.

Workshop - Conserving threatened species and ecosystems

- Identifying locations within the Cumberland Plain that are disproportionately important in terms of the species population viability or climate refugia. Focusing on sites with endemism.

- What constitutes a viable patch for investment into conservation/research.
- Where are the microrefugia from climate change? For each threatened species, what microhabitat conditions buffer climate effects?
- Mapping of threatened species distributions at high resolution to make regional risk assessments, including exposure to threats.
- How can indigenous knowledge be meaningfully grounded through the research including participation in the research process and outcomes?
- What role did and do Aboriginal custodians have in managing parts of the CP?
- Understanding that Country needs people and the impacts of 200 plus years on traditional owners' continuous in-depth knowledge systems and the effects and contemporary barriers to Caring for Country though lead through authentic Traditional Owner leadership.
- Switching the viewpoint to indigenous, what are the culturally significant species and places in the CP that could be better managed by Aboriginal Custodians.
- What are indigenous approaches to fire and landscape resilience.
- How does soil biodiversity influence ecosystem functional resistance and resilience and how this is impacted by global change?
- Understanding how plant-soil microbe interactions change in response to global change drivers.
- Understudied species and understanding of lichen and fungi. Which species are necessary for healthy ecosystems and how will they be affected by climate change?
- Enhanced plant performance through management of soil biotic and abiotic properties.
- Relationship between belowground biodiversity and function with aboveground community and function. To guide management of belowground that can support whole ecosystem health.
- Disease - phytophthora etc. invasion, alternative hosts.
- Invertebrate richness and abundance.
- Understanding the interaction of soil biota with plant community types.
- Mycorrhiza susceptibility to heat, *Pterostylis saxicola*.
- Do we have any knowledge of soil seed bank dynamics for threatened species and how can we effectively test for resilience of this important resource?
- How to optimise fire management, such that conservation outcomes are maximised and risk to local/regional communities is minimised.
- There is a knowledge gap around seasonality of fire. Prescriptions for more southern grasslands and grassy woodlands favour spring as the 'best' season to burn. This may not apply on the Cumberland Plain, which is further north, and with less seasonality in rainfall. Linked to this is fire intensity, which can have major effects on eucalypt populations via mortality of the sapling and young tree stages. We know that lack of fire in CPW can lead to encroachment of the shrub Bursaria; if fire intensity increases with climate change, this may favour the open woodland state, mediated by the mortality of the eucalypt sapling stage.
- What is the best fire regime for CP communities to support its resilience?

- Effect of hazard reduction burning on homogenization of the landscape/ managing time since fire.
- Understanding interactions between fire and other ecosystem processes (e.g. seed dispersal, seed predation and pollination).
- Understanding how fire influences species and TEC's and how we can use fire to manage threatened species as well as invasive species.
- Long-term multiscale monitoring of species, populations, ecosystem function using standardised protocols and central database.
- How do organisms move throughout the landscape? What are the barriers? Which components of the landscape are harder/softer barriers?
- Minimum population size and dispersal requirements for threatened species identified in the CPCP.
- How do fauna move across the Cumberland Plain - corridors for residents & seasonal altitudinal migrants?
- Connectivity needs to be considered for mobile species e.g. birds not just for terrestrial species, and the movement cost of moving through non-reserved parts of the matrix.
- Fragmentation effects on fauna, how to maintain connected, sustainable populations.
- Explore the possible corridor links across various community types for passage of fauna and plant movement, plus fire management strategies across the broader CP communities.
- Investigating the value of railway corridors as connective corridors for biodiversity.
- What kind of landscape connectivity works to assist with migration of species?
- How are invertebrate communities affected by habitat area and connectivity?
- Does habitat connectivity enhance adaptive capacity within the CP for threatened species and those in TECs?
- Mammal habitat augmentation to permit dispersal.
- Connective patch gap distance for dispersal barriers for various mammal species.
- How do corridors effect connectivity and habitats?
- Pollinator needs of *Pterostylis saxicola*.
- Understanding the relationship between site quality and structure/composition of tree stands.
- What do we want to achieve in terms of biodiversity, authenticity, threatened biota, cultural heritage?
- Defining what we're aiming for - conservation of what's there now or what the future climate may support, or what was once there.
- What are the vegetation structure requirements of threatened flora species (e.g. canopy benchmarks)?
- Understanding barriers for private land holders to support threatened species and ecosystem resilience.
- The impact that small landholders have on biodiversity.

- Getting all levels of government, community and other groups involved and on the same page - and how can this be done.
- How to deal with the difference between traditional owners and DALC (these parties have different ideas and agendas).
- Quantifying threatened species assets on private curtilage.
- How are restoration activities perceived within the local/regional and national context.
- Interactions/ partnerships between adjacent local government areas.
- The current state and future trajectories of remnants is affected by legacies (e.g. fertilizer application, grazing, fire history). How can we quantify these such that appropriate management can be planned?
- Remnant size may be poor indicator of conservation value and future viability because the degree to which biodiversity and conservation values are represented is context dependant. How can we devise better metrics for conservation value?
- Land use history effects on current biodiversity and ecosystem function.
- Interactions between threats: fire, climate, fragmentation, habitat degradation.
- How does climate change interact with other threats such as fire and disease?
- What threats does climate change potentialize the most? In order to focus efforts on management).
- Adaptive capacity to changing disturbances, particularly in fragmented landscape.
- Threatening processes with impacts on many species include increasing deer numbers and noisy miners. How will climate change affect these and what are the scenarios under different levels of management.
- Adaptive capacity of species under different (and interacting) threat scenarios.
- What are the key non-climate related anthropogenic disturbance factors?
- Changing disturbances e.g. drought/heatwaves/fire.
- What are the risks or perverse outcomes of the conservation intervention?
- What is the physiological tolerance to heat and drought of threatened species in the CP?
- Understanding of the sensitivity to climate change esp. warming, as well as exposure. Need for fine scale climate projections for CP microclimates.
- Adaptive capacity of threatened species populations to a warming/drying climate.
- Impacts of climate change on food quality for herbivores.
- How will interactions between species change with predicted CC. e.g. competition, predation, mutualism.
- Use of supplementary watering to mitigate drought mortality.
- Effect of temperature on hollow breeding species.
- Effect of changing climate on expected vegetation community trajectories (will the expected forest types change in certain aspects).
- What is the level of exposure to heat and drought in the CP? Are there areas of high/low exposure? How much variation is there within sites and among sites and areas.

- How do native herbivores impact Cumberland Plain flora/ What does an optimal grazing regime look like?
- How to calculate parameters that inform ecological triage. How to define the associated ethics.
- Which species and ecosystems and in what condition will recover by removal of threats alone (assisted natural regeneration).
- Which species and TECs will be the next to be listed as threatened?
- Successions processes, especially in regenerated sites.
- Recovery (succession) from extreme events - crown fire, prolonged drought, outbreaks of insect herbivores etc.
- Succession within and between ecological communities - are trajectories fixed or random.
- Effect of changing climate on expected vegetation community trajectories (will the expected forest types change in certain aspects).
- Importance of species and/or functional diversity.
- Is there genetic variation for climate change held within populations, areas and the CP for threatened species? If not, can we pull in populations for genotypes with enhanced tolerance?
- For foundation/ecosystem dominant species such as eucalypts, as well as for threatened, restricted range species, there is a need to understand patterns of genotypic and phenotypic diversity, and how these influence resilience to climate change and ecosystem function.
- Establish genetic knowledge infrastructure to support restoration practices (e.g. seed production areas) across multiple representative TEC species.
- Viability, vulnerability and adaptive potential of threatened species. Genetic knowledge to support long-term survival, prioritisation and translocation strategies.
- Genotype augmentation in restoration and management planting.
- Identify suitable climate resilient sources and develop genetic mixes that enable climate responses as well as ensure overall fitness and adaptability across multiple target species.
- Halting declines in distributions is predicated on offsetting future clearing - what do the current trends in the way offsetting is undertake suggest about future conservation status?
- How might phylogenetic and functional diversity be lost while technically achieving no net loss to biodiversity under the offsets scheme.
- Remnant size to provide resilience against threats and climate change.
- Impact of islands throughout the CP and ways to reduce these impacts. What is the smallest viable patch size to manage a population?
- What potential exists for reversing fragmentation in a highly cleared and urbanised context.
- Connectivity and potential resilience of remnant patches of TEC need to be quantified and monitored using targeted genetic studies on representative species (within and outside CP).
- Where are the current drought refugia for peri urban species, how do we protect this during the CPCP?
- Factors determining translocation success for threatened plants.

- Commitment to long-term monitoring the outcomes of biodiversity.
- State-and-transition models for EEC's and understanding of thresholds.
- Given that we generally only measure veg - test assumptions about the use of veg metrics as surrogates for faunal habitat quality.
- Can habitat be improved to assist existing spp. And possible future translocated species.
- What management actions are most effective for enhancing species persistence?
- How do we manage weed infestation when restoring landscapes?
- Can cultural burning be used to improve management and community engagement?
- Re-engagement with cultural burning.
- Do cultural burns benefit any threatened species or communities?
- Is the lack of cultural burning impacting on species and community engagement?
- How to find out what all the different projects are - hard to even find within one's own department - so many different entities within one department.
- Interactions with existing policy frameworks (i.e. local development plans).

Workshop - Restoring and reconstructing ecosystems

- Is it possible to create small top-quality cores and manage natural spreading and regen? what size cores? effective over what distances?
- How to rationalise competing demands, e.g. lots of trees for Koalas vs true community restoration.
- What soil conditions lead/prevent restoration success? Can they be promoted/counteracted? In particular, are there specific plant-soil feedbacks (influence of previous plant communities) that prevent recovery? These can involve nutrient and carbon availability, pH, soil microbiome, others.
- How important is invertebrate diversity to successful restoration?
- Can we identify microbes that enhance the establishment of key species for restoration?
- How can we support the soil to address dominant pastural weeds when planting natives?
- Models for soil recovery: what are the necessary inputs? (other than herbicide).
- What are the belowground chrematistics for a functional resilient ecosystem - microbial, invertebrates, chemistry, properties?
- Potential for soil translocation from good condition remnants to poor condition sites.
- Once sites are restored, fire should be an essential ecosystem process. Previous work gives some idea of fire frequency effects. Knowledge gaps here include: best season of fire (spring vs autumn), what range of fire frequencies will best maintain biodiversity (determined by experiment, not observational approaches).
- How can we use fire, incl cultural burns, to manage invasive species / biodiversity?
- Once sites are restored, fire should be an essential ecosystem process. Previous work gives some idea of fire frequency effects. Knowledge gaps here include: best season of fire (spring

vs autumn), what range of fire frequencies will best maintain biodiversity (determined by experiment, not observational approaches).

- How best do we include fire to maximise restoration success? What are the risks of perverse outcomes?
- Climate change will lead to more frequent and more intense fires. Fire intensity effects are known from other systems, but not for CPW. Intensity effects on CPW eucalypt populations are likely to be similar to other systems.
- How does ecological connectivity influence restoration?
- What is the value of restoration in enhancing population holding capacity and landscape connectivity?
- What options are available to improve connectivity or facilitated movement between patches where vertebrates.
- Where are our baseline remnants? OR what are our targets/benchmarks.
- What should a mature, climax phase CPW look like in terms of tree stocking and age /size classes?
- What is a minimum area that might be considered 'resilient'? What are the common features of these areas?
- Reconstruct to what previous condition?
- What stem density of tree cover should we be 'aiming' for in different areas?
- What are the variations in structure and species composition of CPW across environmental gradients?
- We need to model progression of restoration sites towards reference or desired states. This will guide intensity and mode of additional active interventions.
- No control over inappropriate use of natural areas e.g. rubbish dumping, informal tracks.
- How to incentive the uptake of restoration on private land.
- How can the community be engaged to best assist with long term monitoring capacity?
- Be cognoscente of the land tenure and level of protection-Is the study location protected in perpetuity?
- The largest challenge will be to encourage private landholders to set aside land for conservation.
- What are the most robust indicators of ecosystem function which are cheap and simple to measure?
- Given uncertainty, how do we allocate funds to maximise success.
- Cost-benefit analysis of restoration from different starting levels of degradation vs conservation of pristine sites.
- Cost effective and ecologically effective methods / techniques for large scale restoration projects e.g. 1020 ha of land.
- Can we calculate $ value of particular sites/bio values based on irreplaceability, opportunity cost etc.

- Long term thinking needs to be adopted for restoration grants. For example, let's not do what happened with the 20 million tree funding. Which equated to 20 million plastic tree guards in the environment and no funding in the future to remove the guards. species selection will be very important when thinking about future climate change conditions.
- How do you take a pasture improved paddock and get it to a state where you can start restoration? Would be good to have accessible guidelines.
- How does historical land use affect restoration methods and outcomes?
- Comparing the restoration outcomes in terms of the BAM improvement values in areas with varying soil-chemistry histories.
- How best to manage/control invasive exotic plant species and other pests (insects, pathogens, etc.).
- What changes occur between urban edge and bushland that influence establishment/ naturalisation of invasive species.
- What are the most important reasons for restorations failing? What are the risks that can predict these failures?
- We don't know how well the conservation areas (BSAs) will be placed within the Strategic Conservation Areas.
- How to assess resiliency? how to assess self-sustainability? is it even possible?
- How do we embed research programs within proposed restoration and rewilding projects to value-add and implement adaptive management based on the outcomes?
- Planning policy does not allow for the best possible ecological outcome - Ecological Restoration in the private sector (Part 4) is hamstrung by Planning Policy. Conditions of Consent typically have a 1-year time frame for all weeding and planting works followed by up to 5 years maintenance. 12 months to remove all weeds, collect provenance seed, propagate and install does not allow for the best possible ecological outcome. The 12-month practical completion timeframe is a mechanism to grant construction/occupation certification.
- Assuming restoration is feasible, recent surveys tell us that the restoration sector does not have the capacity or structure to undertake large CPCP-type targets. How can we address this in Sydney?
- Can we respond with monitoring when natural events act to test resilience? What happens if these events occur before we're ready?!
- Private land set aside for conservation may not be connected.
- Public support for conservation will underpin success.
- Ensure that vision is not limited to CP, but that relevant communities and distributions are also considered in research project. This will value add to the outcomes and also better facilitate long-term resilience across natural systems.
- How do we ensure short term gains are translated to long term success?
- Creating suitable habitats to support species to adapt to climate change - Evolutionary potential.
- Enhance the capacity of species and ecosystems to withstand or respond to environmental change

- What is the role of mammal herbivores in controlling Bursaria encroachment?
- What are the roles of native and exotic herbivores in limiting restoration success? Including largely locally extinct macropods such as RN wallabies, are possible reintroductions like.
- Restoration species complexity (genetics, diversity) to maximise adaptive capacity (in response to expected climate influences for 50 - 150 years from now). Which species to we choose and which model of community?
- Should we focus less on recreating certain TECs and focus more on creating functional, self-sustaining ecosystems that provide the functions and services that we desire?
- What level of diversity is required to build a functioning ecosystem? genetic, species, functional, trophic. Above and belowground
- What ecosystem functions are contributed by different vertebrates, including non-threated species currently sparsely distributed in CP e.g. wombats.
- Are there critical associations among organisms microbial-plant-animal required for functional resilience?
- Develop restoration practices that go beyond the focus of single vegetation types, but that focus on shared diversity and functional representativeness.
- Ameliorate loss of specific ecological functions.
- Sue Prober's work in White Box woodland showed Themeda was a keystone species, reducing soil nitrate via high-C litter. Are there other C4 grasses in CPW with this property?
- How is functional resilience measured and can a common metric be developed.
- Utilisation of 'micro-habitat' components in establishing functioning patches.
- Supporting species from being functionally extinct due to climate change?
- Biota of the CP require various habitat requirements to maintain diversity in the CP, how can we make generic recommendations that can be applied to many habitats.
- If a full diverse seed mix cannot be sown at a site, getting a native C4 grass mix going would be a good initial step to take to return plant-soil interactions toward low-N status. Other species can be added subsequently.
- What vertebrate species are absent but 'belong' in these CP? have/can the causes of extinction be addressed.
- Where are we at in understanding the effectiveness of artificial tree hollows and their use by different fauna groups, including native versus introduced species?
- Define strategy for establishment of 'novel ecosystems' (from gene to species). what are we trying to achieve and what is the best way to define, assess, and monitor success?
- How novel is too novel for ecosystem reconstruction.
- Support the establishment of genetically informed seed production areas across a range of key species to facilitate the sourcing of adequate source material across CP and beyond (local and future proofed).
- Establish genetic knowledge infrastructure to support restoration practices (e.g. seed production areas) across multiple representative TEC species.
- Genomic adaptation.

- Promote in situ genetic adaptation.
- As foundation species, eucalypt foliar chemistry is a regulator of ecosystem processes, including herbivory, nutrient cycling and koala habitat quality; how does foliar chemistry vary across the CP, esp. with soils; how will global warming affect it? Can we select genotypes for restoration plantings to produce favourable, resilient outcomes?
- Develop empirically based guidelines on how to genetically improve currently isolated and bottleneck population to increase viability, self-sustainability and resilience (as well as facilitate between remnant connectivity).
- What would target-based ecological compensation look like for the Cumberland?
- How do we know when active restoration is NOT required - i.e. may lead to perverse outcomes at offset sites?
- Should we be making it easier to propagate threatened species for restoration.
- Is restoration more successful when done in stages e.g. do, we focus on more common species first or try to plant the full complement of species in a community.
- Scalping topsoil and re-sowing with diverse seed mix is best approach to restoration. There may be site where this is not possible, and other, more low-key approaches may start the restoration process.
- Social research- impacts on restoration success.
- What are the ecological constraints and their threshold values prohibiting successful restoration?
- What site prep / land management can be done in advance of restoration to make restoration successful.
- What are the socio-economic constraints and their threshold values prohibiting successful restoration?
- Is there a role for ecological thinning to overall CPW restoration (e.g. overplanting trees and shrubs then felling and leaving in situ?
- How can we improve successful use of landscape wide tube stock plantings?
- What meta-analysis has been conducted recently for successful restoration - what are the key variables this would address.
- Where do you source material? how far away from the site before it is not locally adapted.
- The efficacy of using supplementary watering to support restoration in the event of extended dry periods relating to climate change.
- How to define/select the best restoration approaches for specific conditions and outcomes.
- How do we assure that biological propagation material is available for all restoration programs, from plant genetic to soil biodiversity?
- The impact of absent or enhanced growth form groups in restoration.
- Testing the model - rates of increase and enhancement of growth forms in management.
- How does coarse woody debris contribute to restoration success (and natural regeneration)?
- 'Gated communities' - assessing the response of natural and restored areas to animal re-introductions.

- Fire and cultural burning: there is an excellent opportunity to test results from cultural burning against more conventional fire treatments, or other management options.
- Assessments of historic restoration (techniques and approaches) from across SE Australia will be important to informing approaches.
- Assess representativeness and relative success of existing restoration programs. What are the learnings, how can they be improved?

Appendix 4. Prioritisation process information

A: Engaging with peoples and cultures

Table 1 Identifies the knowledge gaps and desired outcomes from research. Table 2 details the research needed to fill the knowledge gaps listed in Table 1.

Table 1. Knowledge gaps and desired outcomes – Engaging with peoples and cultures

Gap no.	Knowledge gap	Desired outcome
A1	Who has a cultural investment in the Country? (Move beyond land council to community groups etc) If the research has some element of being indigenous led it needs a veto body. Each project that is proposed has to come before an independent review body.	Know who has knowledge of Country. And know how to approach them (reciprocity comes into play - trust building exercise - protect their rights).
A2	We lack an understanding of how the community (residents, landowners, Aboriginal groups, conservation practitioners) value biodiversity and conservation.	Achieve a benchmark for community values to build from. Positive values can be leveraged off; negative values can be changed.
A3	How do Song Lines and Aboriginal trails relate to important connectivity values in the CP and how can ecosystems be connected via existing Song Lines, waterways and Aboriginal trails?	Create more biodiversity corridors from traditional song lines and their connections to waters.
A4	How can landowners be encouraged to participate in conservation on their land within and outside of the biodiversity offset market? How can landowners participate in the conservation of country?	More landowners participate in conservation and restoration.

Gap no.	Knowledge gap	Desired outcome
A5	How can values from a diversity of communities in Western Sydney be shaped over time to respect and appreciate nature and native assemblages rather than simply greenspace?	More appreciation of native plants, animals and communities and thereby improved biodiversity outcomes. More native plants in green areas and gardens to attract insects and pollinators and conserve genetic resources.
A6	What are the key areas of conflict between public use of the conservation areas and managing these areas for restoration and threatened species? Public use can be positive in the sense that it increases appreciation, such as hiking, and negative in that it results from a lack of appreciation (dumping). It can also be in the middle such as BMX biking.	Less damaging behaviour such as dumping; more respectful behaviour from non-passive use of conservation areas.
A7	How can we protect spiritually significant sites while protecting country? What are the culturally significant species and places in the CP that could be better managed by Aboriginal custodians and the broader sense of connectedness and implications for value.	Improved management of culturally significant species and places.
A8	How can we protect spiritually significant sites while protecting country? Monitor advertising of CPCP work. Everything is significant.	Improved management of culturally significant species and places.
A9	How does cultural burning compare with ecological and hazard reduction burning practices in terms of biodiversity and conservation gains and the community's connection to Country?	Both cultural and ecological outcomes. Cultural burning has its own aims and objectives. Improved biodiversity outcomes is a secondary desirable.
A10	How can we value and cost restoration and conservation actions and therefore prioritise actions efficiently?	Prioritised conservation and restoration actions are more "efficient"; that is, actions get more bang for their buck (are more cost-effective). Where valuation is possible, conservation and restoration actions can be justified on the basis of benefits exceeding costs which improves the allocation of government funds.

Gap no.	Knowledge gap	Desired outcome
A11	How does the community value offset sites relative to in situ ecosystems/species and publicly accessible conservation reserves?	Achieve an understanding of how offset sites (Biodiversity Stewardship Agreements on private land and planned conservation reserves) are valued relative to in situ biodiversity. This would improve prioritisation of project sites and provide evidence for policy initiatives around the amount of offsetting to be done and accessibility to offset sites.
A12	How can the community be involved in monitoring conservation and restoration actions, both to enhance community appreciation and ensure long-term adaptive management and conservation success?	Improved monitoring of restoration outcomes; greater appreciation of biodiversity values.
A13	What is the role of narrative, storytelling and the media in changing community values over time and how can this be leveraged and improved upon?	Greater appreciation of diverse biodiversity values and cultural appreciation.
A14	How do different cultural groups value biodiversity and conservation in the CP and how can values be changed to appreciate and experience biodiversity?	Achieve a benchmark of community values to build from with specific reference to CALD communities. Positive values can be leveraged off; negative values can be changed.
A15	What are the best ways to engage the community to participate in conservation activities?	Greater participation in conservation and restoration activities; improved appreciation of biodiversity values.
A16	How can Indigenous methodologies be best incorporated into the CPCP research implementation strategy?	Improved conservation and restoration outcomes; increased knowledge of Indigenous methodologies in science and social science researchers.
A17	Is the governance model right for delivering the CPCP in terms of responsibilities of State and Local governments and community groups? What are the possible governance approaches and how does the current model compare?	Improved governance arrangements and conservation/restoration outcomes.

Gap no.	Knowledge gap	Desired outcome
A18	What condition/ species/ecosystem structure are we restoring to.	Improved conservation and restoration outcomes through understanding the desired future state
A19	How do we rebuild song lines etc severely impacted by Sydney colonisation?	Rebuilt song lines
A20	How do we build a new cultural understanding of country?	Improved cultural understanding of country
A21	How do we restore the cultural relationship to country, rather than just wildlife?	Improved cultural relationship to country

Table 2. Research types and approaches for each knowledge gap – Engaging with peoples and cultures. See Table 1 for explanation of Gap no.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
A1	Indigenous led methodologies	Indigenous ethics and protocol (AIATSIS, NHMRC) - trust building.	0-5 years	Very High	<$10K	High	Interactive research approaches. Bring Aboriginal groups together first to get everyone on the same page and build an understanding of cultural values of country and then aspirations for active management of Country towards a "healthy balance". Start with conversation about what we know a healthy balance to look like
A1	Indigenous led methodologies	Local community preferences in terms of communication and methods such as storytelling, yarning, participatory values).	0-5 years	Very High	$100-1000K	High	Very high impact. Resisting development to preserve country. If we can get aboriginal groups on board in would have a ground up support.
A1	Indigenous led methodologies	Exploring maps (varying opinions on worth). Participatory mapping. Identifying areas of significance.	0-5 years	Very High	$10-100K	Moderate	Question around importing knowledge. Depends on local community groups.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
A2	Community activity/ engagement	Community group meetings and elect reps to attend Community Hub meetings	16-35 years	Very High	>$1000K	High	No comment.
A2	Online survey/ interviews	Large scale survey of community values	0-5 years	Very High	Not identified	Low	No comment.
A3	Indigenous led methodologies	Not identified	Not identified	Not identified	Not identified	Low	Question mark - sovereignties. The community can decide how these relate to the project.
A4	Online survey / interviews	Semi-structured interviews with landowners.	Not identified	Not identified	Not identified	Moderate	No comment.
A4	Online survey / interviews	Focal groups.	Not identified	Not identified	Not identified	Low	No comment.
A4	Policy / literature review	Not identified	Not identified	Not identified	Not identified	Low	No comment.
A5	Community activity / engagement	Shared values workshop - shared learning.	0-5 years	Very High	$10-100K	High	No comment.
A5	Community activity / engagement	Sharing stories - with permission, greater awareness of the significance of the native plants.	Not identified	Not identified	Not identified	Moderate	No comment.
A5	Community activity / engagement	participatory action research.	Not identified	Not identified	Not identified	Low	No comment.
A6	Policy / literature review	Build off existing knowledge such as the NPWS behavioural change campaign.	0-5 years	Low	Not identified	Low	No comment.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
A6	Field surveys	To understand where impacts occur.	0-5 years	Medium	Not identified	Low	No comment.
A6	Citizen science	To understand impacts and monitor behaviour.	6-15 years	Medium	Not identified	Low	No comment.
A6	Policy / literature review	Policy evaluation at the Local Government level focussed on monitoring and preventing damaging behaviour. (Social change via banning practices that impinge on nature - rights of nature approach).	0-5 years	High	Not identified	Low	No comment.
A7	Policy / literature review	Approaches to indigenous understandings of entities and country (their interrelatedness). Beyond their individual value. Understanding indigenous standpoints.	0-5 years	High	$10-100K	Very High	No comment.
A8	Indigenous-led methodologies	Indigenous led and methodological approach to understand interrelated species and places and Country (yarning, storytelling, how they are told on country) IRM.	0-5 years	Very High	$100-1000K	High	Relevant throughout the CPCP lifespan and beyond
A9	Policy / literature review	Comparative research	Not identified	Not identified	Not identified	Not identified	Knowledge gap aligned with priorities elsewhere and not detailed here

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
A9	Community activity / engagement	Participatory action research - experience	Not identified	Not identified	Not identified	Not identified	No comment.
A10	Policy / literature review	Build off existing DPIE valuation methods of valuing green space. Combine with the BAM. Analyse existing BCT and DPIE databases for costs and the determinants of conservation success.	Not identified	Not identified	Not identified	Moderate	No comment.
A10	Online survey / interviews	Not identified	Not identified	Not identified	Not identified	Low	No comment.
A11	Online survey / interviews	Non-market valuation (contingent choice) approaches to compare (1) offset site to (2) public reserve to (3) in situ.	Not identified	Not identified	Not identified	Low	No comment.
A12	Policy / literature review	Not identified	Not identified	Not identified	Not identified	Moderate	No comment
A12	Citizen science	Not identified	Not identified	Not identified	Not identified	Low	No comment.
A12	Community activity / engagement	Not identified	Not identified	Not identified	Not identified	Low	No comment.
A13	Policy / literature review	Sand talk? DPIE's behavioural insights team.	Not identified	Not identified	Not identified	High	No comment.
A13	Indigenous-led methodologies	Intergenerational indigenous knowledge sharing.	Not identified	Not identified	Not identified	Low	No comment.
A13	Indigenous-led methodologies	Culture camps.	Not identified	Not identified	Not identified	Moderate	No comment.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
A14	Online survey / interviews	Large scale survey of community values.	Not identified	Not identified	Not identified	Moderate	No comment.
A15	Policy / literature review	Not identified	Not identified	Not identified	Not identified	Low	No comment.
A15	Online survey / interviews	Not identified	Not identified	Not identified	Not identified	Low	No comment.
A16	Indigenous-led methodologies	Has to be indigenous led.	Not identified	Not identified	Not identified	Moderate	No comment
A17	Policy / literature review	Not identified	Not identified	Not identified	Not identified	Moderate	Multifunctionality; need for co-design
A18	Community activity / engagement	Not identified	Not identified	Not identified	Not identified	High	Need to distinguish restoration from regeneration
A19	Indigenous led methodologies	Walking contemporary Indigenous song lines as public pedagogies of country	Not identified	Not identified	Not identified	Very High	No comment
A20	Indigenous led methodologies	Not identified	Not identified	Not identified	Not identified	Very High	No comment
A21	Indigenous led methodologies	Not identified	Not identified	Not identified	Not identified	High	No comment

B: Conserving Threatened Species and Ecosystems

Table 3 Identifies the knowledge gaps and desired outcomes from research. Table 4 details the research needed to fill the knowledge gaps listed in Table 3.

Table 3. Knowledge gaps and desired outcomes – Conserving threatened species and ecosystems

Gap no.	Knowledge gap	Desired outcome
B1	What locations within the Cumberland Plain have high diversity - community - species - genetic (endemic/unique) for conservation or sources for restoration? [sub knowledge-gap] How to determine high value and assess state for different vegetation types?	Identify areas for priority conservation and/or high-quality sources for regeneration/restoration. list of location of significant value. High diversity / low degradation sites.
B2	What are the best indicators of biodiversity and conservation values at local and regional scales? [sub knowledge-gap] What are the indicators that best describe the value of assets and can be translated into an asset register?	Deploy cost effective methods that provide improved indicators of biodiversity and conservation values?
B3	What locations and habitat features within the Cumberland Plain may act as climate / habitat refugia (or areas of high exposure)?	Identify landscape and habitat features for priority conservation and/or restoration.
B4	What is the minimum viable population size able to persist into the future within the Cumberland?	Target active management on patches to enhance holding capacity/connectivity.

Gap no.	Knowledge gap	Desired outcome
B5	How to enhance connectivity and population holding capacity in the Cumberland? [sub knowledge-gap] What are the current/future connectivity metrics for the region and different biota? What are the dispersal mechanisms, pathways and barriers for key biota and their spatiotemporal timescales? How well do corridors or other dispersal aids improve connectivity for key biota?	Inform active management through knowledge of landscape features that as barriers and corridor attributes that facilitate to movement and persistence, along with patch size and features that support greater population size and health in the future. Quantitative information of how and where the landscape features create variation in connectivity for different biota under a range of future scenarios. Better quantification of the assumptions underpinning the connectivity analyses, and validation of the connectivity analyses.
B6	How to monitor effectively to detect long term changes in populations, species and community diversity and function? [sub knowledge-gap] what to monitor (e.g., threatened vs. common species? species vs. communities? psyllids? healthy vs. impacted communities?)	Inform monitoring programs to be able to detect change in the status of species and ecosystems associated with land use, management and climate change. Implementation of monitoring program to inform management.
B7	What are the key threats facing target threatened species and TECs in the Cumberland (at a resolution appropriate for unground management, e.g., which invasives, which fire regimes)?	Objective prioritisation of key threats for the persistence of threatened species and TECs in the CPCP. Prioritise the assets (population, species, TEC) for conservation.
B8	Interactions between threats: fragmentation, habitat degradation, fire and climate change.	Inform and prioritise management of threats with greater certainty into the future.
B9	What is the sensitivity to heat and drought of threatened species and dominant species in TECs within the CP?	Determine species sensitivity to extremes to inform scientifically based objective decision making for the prioritisation of conservation efforts.
B10	What is the capacity of threatened species and ecosystems to adapt to climate change?	Capacity to climate change through genetic and environmental mechanisms to inform vulnerability and active management strategies (e.g., translocation, assisted gene migration).

Gap no.	Knowledge gap	Desired outcome
B11	Importance of species and/or functional diversity for ecosystem resilience.	Determine thresholds of diversity required for ecosystem function and resilience into the future.
B12	What are the states and transitions for CP ecosystems with different land use histories, disturbance regimes and current management?	Inform and prioritise active management actions with greater confidence in the ecosystem state and trajectory in the future.
B13	Determinants of successful adaptive management strategies, including translocations and assisted migration for threatened species.	Inform and prioritise active management of threatened species with greater confidence in the most likely outcomes.
B14	How do you effectively manage fire in the Cumberland to minimise risk to biodiversity (in the context of constraints on protecting life and property)? [sub knowledge-gap] Does fire need to be introduced to long unburnt areas in this peri-urban environment, and if so, what type of fire regime?	Inform fire management and enable burns to enhance biodiversity and conservation values. Minimise risk of loss to biodiversity.
B15	How do cultural burns and indigenous practices contribute to biodiversity and conservation?	Provide mechanism for Caring for Country, community engagement and indigenous led cultural practices to be supported in the CPCP.

Table 4. Research types and approaches for each knowledge gap – Conserving threatened species and ecosystems. See Table 3 for explanation of Gap no.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B1	Analyse existing data	Compile existing plot-based data	0-5 years	Medium	$10K-100K	Very High	Work done by CPCP mapping conservation layer - check inputs and develop models.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B1	Field surveys	Conduct new field surveys including Structured Regional Fauna Surveys	0-5 years	High	$100-1000K	Very High	Attributes vary by vegetation type.
B1	Genetic analyses	Estimate genetic diversity, species diversity, functional diversity and uniqueness across the greater Sydney region.	0-5 years	High	$100-1000K	Moderate	No comment
B1	Indigenous practice	Incorporate Aboriginal Cultural Heritage with work led by appropriate Aboriginal knowledge holders.	6-15 years	Medium	$100-1000K	Low	Local Aboriginal leadership essential.
B2	Policy / literature review	Current approaches for valuing natural assets (standardised priority matrix for biodiversity assets) and how objective/repeatable are these?	0-5 years	Not identified	Not identified	Low	How can a land manager be sure that that a biodiversity priority matrix is actually effectively identifying the most important assets for management?
B2				identified	Not identified	Low	Value should be based also on investment required to manage.
B2	Indigenous practice	Not identified	Not identified	Not identified	Not identified	Low	No comment
B2	Field surveys	Ground truthing valuation matrix effectiveness.	Not identified	Not identified	Not identified	Low	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B3	Modelling / simulation	Not identified	Not identified	Not identified	Not identified	High	No comment
B3	Mapping / remote sensing	Not identified	Not identified	Not identified	Not identified	Low	No comment
B3	Implement sensors / imaging	Not identified	Not identified	Not identified	Not identified	Low	No comment
B3	Field surveys	Not identified	Not identified	Not identified	Not identified	Low	No comment
B4	Field surveys	Demographic data, including reproduction and recruitment.	6-15 years	High	$100-1000K	Low	Long term study minimum 3-year best 20+ year. Combined with modelling.
B4	Modelling / simulation	Pop viability analysis, transition models including disturbance and threats.	6-15 years	High	$100-1000K	Low	Some immediate outputs but limited by data inputs. Maybe combined with field surveys to share costs and outputs.
B4	Genetic analyses	Determine effective pop size, diversity/structure.	0-5 years	High	$100-1000K	Low	No comment
B4	Field experiments	Adding new material to test improved viability, habitat/resource/pollinator.	6-15 years	Medium	$100-1000K	Low	Application to target species with development of methods for other species TECs.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B5	Analyse existing data	Not identified	Not identified	Not identified	Not identified	Low	No comment
B5	Mapping / remote sensing	Classic landscape ecology patch metric analysis and mapping, using existing data such as aerial photos, DEMs, and other GIS layers; analyse where new connectivity measure make biggest impact in overall connectivity for all components of biodiversity; Need to objectively identify which biota groups are crucial? Identify dispersal barriers as well as potential perverse outcomes (e.g. predation, invasive species).	0-5 years	Very High	$100-1000K	Low	No comment
B5	Field surveys	Field surveys to assess and refine predictive models of the habitat corridors of key biota, the habitat & barriers influencing movement of these biota and identification of priority corridors for conservation & restoration investment.	6-15 years	High	$100-1000K	Low	No comment
B5	Field experiments	Introduce novel techniques to improve connectivity. Compare to existing links using comparative experiments on key biota.	6-15 years	High	$100-1000K	Low	No comment
B6	Analyse existing data	Not identified	Not identified	Not identified	Not identified	Moderate	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B6	Mapping / remote sensing	Remote sensing useful for psyllid dieback (in combination with ground surveys) and land use change / what patches most vulnerable to clearing.	0-5 years	Not identified	Not identified	Moderate	No comment
B6	Field surveys	Leverage and build on existing studies, e.g. Mt Annan, Hoxton Park, Scheyville and probably others. Existing Bionet survey sites from late 90s/early 2000s which could be re-surveyed. Leverage recent field plots established under Commonwealth research funding for fire recovery. Key Q.s: how well do sites retain their biota? how do individual spp. vary from year to year (prob. related to rainfall), which introduced spp. are increasing? Bird and invert component important for fauna.	Not identified	Not identified	Not identified	High	No comment
B6	Citizen science	Scope to analyse citizen science platforms, if enough people are engaged. To be successful, need group of engaged people, strategic workshops could be helpful here to build local ownership (e.g. Agnes Banks).	0-5 years	Not identified	$10K-100K	Low	No comment
B6	Genetic analyses	Not identified	Not identified	Not identified	Not identified	Low	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B7	Analyse existing data	CPCP, SOS, BCT, RBG existing work.	0-5 years	Very High	$10K-100K	Low	Collated at generic level in SOS program.
B7	Mapping / remote sensing	CPCP maps (BIOSIS).	0-5 years	High	$10K-100K	Low	Climate change and land clearing are not addressed.
B7	Modelling / simulation	Based on field validation.	0-5 years	Medium	$10K-100K	Low	No comment
B7	Field surveys	Field validation across seasons / conditions. Confirm population data.	0-5 years	Very High	$100-1000K	Low	Survey of private land is a key outcome required.
B8	Analyse existing data	Not identified	Not identified	Not identified	Not identified	Moderate	No comment
B8	Indigenous practice	Not identified	Not identified	Not identified	Not identified	Low	No comment
B8	Field surveys	Not identified	Not identified	Not identified	Not identified	Low	No comment
B8	Field experiments	Not identified	Not identified	Not identified	Not identified	Moderate	No comment
B9	Modelling / simulation	Climate niche / SDM. Application of mechanistic models with physiological tolerance.	0-5 years	High	$10K-100K	Low	MQU existing SDM work. Greater time/costs required for mechanistic models.
B9	Mapping / remote sensing	GIS + flow accumulation models combined with satellite imaging and flight data.	0-5 years	Medium	$10K-100K	Moderate	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B9	Field surveys	Observe dieback / failures. Incorporate sensors. Consider exposure and microhabitat.	6-15 years	High	$100-1000K	Moderate	No comment
B9	Controlled growth / laboratory experiments	Determination of physiological tolerance to heat and drought to estimate threshold traits (Tmax, P50).	0-5 years	Very High	$100-1000K	Moderate	All species possible. reduced costs for target species.
B10	Field surveys	Not identified	Not identified	Not identified	Not identified	Low	No comment
B10	Genetic analyses	Not identified	Not identified	Not identified	Not identified	Low	No comment
B10	Field experiments	Not identified	Not identified	Not identified	Not identified	Low	No comment
B10	Controlled growth / laboratory experiments	Not identified	Not identified	Not identified	Not identified	Low	No comment
B11	Modelling / simulation	Not identified	Not identified	Not identified	Not identified	High	No comment
B11	Field surveys	Not identified	Not identified	Not identified	Not identified	Low	No comment
B11	Field experiments	Not identified	Not identified	Not identified	Not identified	High	No comment
B12	Online survey / interviews	Not identified	Not identified	Not identified	Not identified	Low	Consider use of superphosphates, fire, flood.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B12	Indigenous practice	Recognise and respect different objectives.	Not identified	Not identified	Not identified	Low	No comment
B12	Field surveys	Define and characterise reference states.	Not identified	Not identified	Not identified	Low	No comment
B12	Mapping / remote sensing	Detect transitions (regrowth, dieback, clearing, olive invasion etc.	Not identified	Not identified	Not identified	Low	No comment
B12	Modelling / simulation	Development of conceptual models with drivers to predict. Data required from field surveys and experiments.	Not identified	Not identified	Not identified	Low	No comment
B12	Field experiments	Manipulations for model validation.	Not identified	Not identified	Not identified	Low	No comment
B13	Analyse existing data	Not identified	Not identified	Not identified	Not identified	Low	No comment
B13	Field surveys	Not identified	Not identified	Not identified	Not identified	Low	No comment
B13	Other approach	Not identified	Not identified	Not identified	Not identified	Low	No comment
B13	Genetic analyses	Not identified	Not identified	Not identified	Not identified	Low	No comment
B14	Analyse existing data	What has fire history been in recent times? and traditional management?	Not identified	Not identified	Not identified	Low	No comment
B14	Field surveys	Not identified	Not identified	Not identified	Not identified	Low	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
B14	Field experiments	Questions around alternative fire management options, e.g. fire seasonality? Bursaria management? Other types of disturbance?	0-5 years	Very High	$100-1000K	Very High	0-5 years to establish, but longer-term monitoring will yield greater value. Establishment phase costing ~$100k/year, but longer-term funding/monitoring highly desirable.
B15	Indigenous practice	Not identified	Not identified	Not identified	Not identified	Low	No comment
B15	Community activity / engagement	Not identified	Not identified	Not identified	Not identified	Low	No comment
B15	Field surveys	Not identified	Not identified	Not identified	Not identified	Low	No comment

C: Restoring and Reconstructing Ecosystems

Table 5 Identifies the knowledge gaps and desired outcomes from research. Table 6 details the research needed to fill the knowledge gaps listed in Table 5.

Table 5. Knowledge gaps and desired outcomes – Restoring and reconstructing ecosystems

Gap no.	Knowledge gap	Desired outcome
C1	What are the soil physical-chemical and biological barriers associated with past management or site conditions to restoration success?	Information to inform appropriate site preparation actions that improve restoration outcomes that takes into account past land use.
C2	What management actions most effectively overcome soil physical-chemical and biological barriers to restoration success?	An assessment of management outcomes relative to site characteristics to inform management actions, including cost-benefit trade-offs and long-term restoration outcomes.
C3	How does soil biodiversity influence ecosystem function and resilience under current and future conditions?	Ecological knowledge of species interactions that can improve restoration outcomes, including improved resistance and resilience.
C4	How can restoration projects be managed to reduce the threats associated with fire, climate change, fragmentation and habitat degradation and their interactions?	Knowledge that allows adaptive management that consider primary management needs (reconstruct / rehabilitate), secondary fire / vandalism, and finally extremes and climate change.
C5	How do native and exotic vertebrate herbivores influence biodiversity, ecosystem structure and function? How can these effects be taking into account in restoration projects to enhance outcomes?	Total grazing pressure is managed to maximise restoration outcomes (What are the optimal grazing regimes for CP ecosystems in the cycle of restoration?)
C6	Can we identify microbes that enhance the performance and resilience of key plant species used restoration?	Identify individual microbes, or consortia, which improve ecosystem function, including resistance and resilience of plant species to disturbance.
C7	Can microbial symbionts be used to enhance the production, establishment, growth of key plant species used in restoration?	Knowledge of microbial symbionts associated with key species used in restoration outcomes which will enhance restoration success. Similar principles can be applied for priority conservation species.

Gap no.	Knowledge gap	Desired outcome
C8	What diversity from genetic to species, aboveground and belowground, is required to enhance adaptive capacity in restoration projects given likely future climate scenarios?	Guideline for biodiversity targets to improve the long-term restoration outcomes.
C9	What is the role of succession in restoration projects and how can we use this as a tool to promote restoration outcomes?	Evaluate successional patterns on degraded land, and in restoration programs, to identify opportunities to allow 'natural' or improved (through management) successional trajectories.
C10	What are the thresholds for ecological communities to transition to desired states naturally, with minimal inputs or active management?	Better knowledge of potential tipping points beyond which existing management practices are unable to support certain outcomes.
C11	How can we manage plant-soil microbial interactions to enhance restoration success under current and future conditions?	Ecological knowledge of species interactions that can improve restoration outcomes, including improved resistance and resilience.
C12	What management actions can be implemented to most cost-effectively manage invasive or pest species?	Information on how effective management actions are at controlling exotic species in the longer term and establish guidelines for when to implement certain actions. Recognize that control require up-front costs as well as ongoing maintenance to ensure the long-term outcomes.
C13	What is the desired trajectory or outcome of restoration projects for the Cumberland Plain?	Better knowledge of what the broader range of stakeholders' desire in terms of green space throughout the CPs in the long term (clear link with the community theme).
C14	What skills, capacity, access to material is required to maintain genetic diversity of seed production areas relevant to the CPCP?	Identify industry needs critical to ensuring restoration practices can be implemented.

Gap no.	Knowledge gap	Desired outcome
C15	What are the effective time frames for restoration success?	Better guidelines for monitoring, evaluating and managing restoration programs that take into account the long-term nature of restoration.
C16	How do we develop and secure the capacity of the restoration sector to undertake the projected levels of reconstruction and restoration required to support the CPCP outcomes, including access to seed/propagule sources, facilities to grow material, and the know-how and capacity to implement in practice?	Identify industry needs critical to ensuring restoration practices can be implemented.
C17	What is the role of fire in population dynamics of species relevant to restoration outcomes?	Knowledge to inform the use of fire to manage restoration outcomes.
C18	What is the potential role of existing seed banks in bush regeneration and how do we assess when it is valuable to maintain this resource?	Knowledge relevant to establish industry-wide guidelines for site preparation that can reduce costs of sourcing plant material while maintaining local populations.
C19	Where should restoration be prioritised? Based on knowledge of spatial location to meet conservation needs, ecological constraints that might limit outcomes and management and cost effectiveness given constraints.	Framework to prioritize areas for restoration and desired restoration outcomes, incl. ecological and social/cultural; Decision tree based on quality, past experience, needs / values.

Table 6. Research types and approaches for each knowledge gap – Restoring and reconstructing ecosystems. See Table 5 for explanation of Gap no.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C1	Field surveys	Establish benchmarks for soil physical-chemical and biological properties for target species and TECs, including existing restoration.	0-5 years	High	$100-1000K	Very high	This knowledge can also be used to determine (prioritise) if a site is even worth (cost wise) to restore, i.e. perhaps not a target for restoration if the conditions are too poor.
C1	Field experiments	Evaluate restoration outcomes associated with individual management actions given contrasting site conditions.	6-15 years	High	$100-1000K	Very high	No comment
C1	Controlled growth / laboratory experiments	Pot experiments to evaluate establishment, growth, performance etc in soils with different conditions.	0-5 years	Medium	$100-1000K	Low	Field surveys can inform experiments in the field and lab.
C1	Analyse existing data	Draw on previous work in field, combined with field surveys.	0-5 years	High	$10-100K	High	No comment
C2	Field experiments	experimental (both field and lab) approaches taking advantage of the existing range of soils, health conditions and existing vegetation to test what suite of conditions are more/less conducive to allow response to particular restoration efforts.	Not identified	Not identified	Not identified	Not identified	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C2	Other approach	Need a feasibility study - both in terms of implementation (i.e. large areas) and in terms of cost/ socio-economic study (inputs v outputs).	0-5 years	High	$10-100K	High	Ongoing - Need the data first so probably a longer-term outcome.
C2	Controlled growth / laboratory experiments	Test effects of specific actions - resistance and resilience to disturbance / stress.	0-5 years	High	$100-1000K	Low	No comment
C3	Field surveys	Develop benchmarks for soil biodiversity for i) individual species, ii) TECs - to develop understanding of relationships of soil biodiversity with "healthy" and "unhealthy" ecosystems including spatial and temporal heterogeneity.	0-5 years	Medium	$100-1000K	Moderate	No comment
C3	Field experiments	Assess linkages between soil biodiversity / belowground community composition and functioning - community/ecosystem scale. (1) Is our understanding of "healthy/unhealthy" correct, and (2) can we shift unhealthy -> healthy.	6-15 years	Medium	$100-1000K	Moderate	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C4	Mapping / remote sensing	Establish (semi-)permanent monitoring within, and targeted observational studies of, sites with different management.	16-35 years	Low	>$1000K	Low	very different threats, that need different management and solutions (i.e. may require knowledge based, political/social/governance or on-ground action). They also operate at different spatial and temporal scales
C4	Field experiments	Embed experimental manipulation within existing and planned restoration projects with different management practices.	6-15 years	Low	$100-1000K	Moderate	Knowledge framework/infrastructure that draws together and integrates research, data, policies etc from all other research themes and programs.
C4	Online survey / interviews.	Consultation with practitioners and land managers.	0-5 years	High	$10-100K	Low	No comment
C5	Field surveys	Assess the effects of native and exotic herbivores on ecosystem structure and function in TECs.	6-15 years	Medium	$10-100K	Low	No comment
C5	Field experiments	Assess the effects of native and exotic herbivores on ecosystem structure and function in TECs.	6-15 years	Medium	$10-100K	Low	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C6	Field surveys	Surveys of rhizosphere soil associated with species commonly used in restoration programs, including species targeted in conservation projects, to identify microbes associated with healthy populations.	0-5 years	High	$100-1000K	High	No comment
C6	Controlled growth / laboratory experiments	Isolation and cultivation of microbes associated with Cumberland Plain plant species and follow up experiments to test their potential benefit to plant establishment and growth.	0-5 years	High	$100-1000K	Moderate	Need information from the field surveys to identify target species.
C6	Field experiments	Can we change conditions to manage soil microbes?	6-15 years	Medium	$100-1000K	Low	Opportunity to build on information from the field survey (if those surveys microbial communities at a relevant scale).
C7	Field experiments	combination of lab and field to assess the potential of combing symbiont with other seed treatments, e.g. pellets. Using direct seeding. Keep cost-effectiveness in mind, not just ecological/biological feasibility.	0-5 years	High	$100-1000K	Low	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C7	Field surveys	approach must contain assessment of microbial treatments effect on seed germination but also long-term establishment and growth and resilience to environmental stress.	6-15 years	High	$100-1000K	Low	No comment
C7	Other approach	Develop guidelines for the use of microbial inoculants in restoration programs.	6-15 years	High	$100-1000K	Low	No comment
C8	Analyse existing data	Come up with a narrowed list of high priority species, and form categories for others in terms of how they compare.	0-5 years	Very High	$10-100K	Low	Analysing data to determine what is actually happening on ground across groups that undertake restoration.
C8	Field experiments	Determining the survivorship and contribution of genotype to restoration outcomes.	6-15 years	High	$100-1000K	High	Short to longer term with different outcomes.
C8	Field surveys	Genomic surveys of climate adaptation.	16-35 years	High	$100-1000K	Low	Ongoing - can assess outcomes relative to disturbance, extreme events, increasing pressures on ecosystems; should be informed by field survey below.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C8	Field surveys	Validate / benchmark what a healthy system is to develop guidelines.	0-5 years	High	>$1000K	High	Fit with outcomes Knowledge Gap 1 and 2 - design field survey to address additional knowledge gaps (i.e. whole of system approach).
C9	Field surveys	Compare the outputs of different trajectories of successional change of existing projects implemented over the past decades (in terms of species type, diversity etc). Measure the time it takes for communities to become established. Assess how established restoration projects have developed given the diversity inputs.	0-5 years	High	$100-1000K	Very High	Pioneer species often implement given that they perform well but how does this influence the establishment, conditioning for the later successional species? Need to develop approaches to balance the role of seeding vs natural immigration.
C9	Field surveys	Observational studies to enhance our understanding of successional patterns in target TECs.	16-35 years	Medium	$10-100K	Low	How do early successional influence the establishment of exotic species? What species could be implemented to suppress undesired species establishing.

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C9	Field experiments	Manipulative studies to assess how interactions among species change during succession - short term could assess establishment of both native and exotic species, longer term studies could assess whole system development.	0-5 years	High	$100-1000K	Low	Assess how individual species influence trajectory v limiting the establishment of other desired species.
C10	Field surveys	Community specific (prioritizing the most threatened) field experiments to understand response to management with a range of starting conditions and different management intensities and with controls, long to medium term, spatially controlled.	6-15 years	High	$100-1000K	Low	No comment
C11	Field experiments	Targeted experimental work to understand plant-soil interactions that support plant community and species persistence.	Not evaluated	Not identified	Not identified	Low	Similar to set 7 (gap no. C8, Line 4). Scenario testing - could assess how the likely future conditions affect plant-soil microbial interactions, and the broader microbial assemblage, and whether this improve / impairing restoration outcomes

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C11	Controlled growth / laboratory experiments	Assess how plant-soil interactions are modified by edaphic properties, such as high nutrient levels, and whether this limits restoration success.	Not evaluated	Not identified	Not identified	Low	Overlaps with plant-microbe interaction, place that one withing this one?
C11	Field experiments	Experiments that implement mechanisms that enhance microbial diversity / composition relative to a known target.	Not evaluated	Not identified	Not identified	Low	No comment
C12	Field surveys	Establish (semi-)permanent monitoring within current and planned restoration projects with different management.	16-35 years	High	$100-1000K	Very High	No comment
C12	Field experiments	Embed experiments within existing and proposed restoration projects.	6-15 years	High	$100-1000K	Low	No comment
C12	Field experiments	Experimentally test the effectiveness of management actions to manage exotic species.	6-15 years	High	$100-1000K	High	No comment
C12	Other approach	understand ecology and management of high threat invasive perennial weed species.	6-15 years	Very High	$100-1000K	Low	No comment
C13	Online survey / interviews	Stakeholder surveys and expert knowledge.	0-5 years	High	$10-100K	Low	No comment
C13	Analyse existing data	Cost-benefit analyses of the likely long-term feasibility of 'forcing' restoration projects to mimic specific TECs.	0-5 years	Medium	$10-100K	Low	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C13	Online survey / interviews	Assess what the community value.	0-5 years	High	$10-100K	Low	No comment
C14	Online survey / interviews	Consult stakeholders in the sector to assess shortcomings and develop mechanisms to overcome these.	0-5 years	Very High	$10-100K	Very High	No comment
C14	Policy / literature review	Establishing guidelines / mechanisms to ensure the industry is supported throughout the CPCP.	0-5 years	Very High	$10-100K	Low	No comment
C14	Modelling / simulation	Identify needs for which species will be required where.	0-5 years	Very High	$10-100K	Very High	No comment
C15	Online survey / interviews	Develop mechanisms that better account for the long-term nature of restoration programs.	16-35 years	Medium	$10-100K	Low	Requires clear articulation of what success looks like and appropriate benchmarks.
C15	Analyse existing data	Reviewing areas that have had activity to determine outcomes.	0-5 years	High	$100-1000K	Low	No comment
C15	Modelling / simulation	Determining trajectory and management practices to support intended outcomes.	0-5 years	High	$10-100K	Moderate	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C16	Online survey / interviews	Consult stakeholders in the sector to assess shortcomings and develop mechanisms to overcome these.	0-5 years	Very High	$10-100K	Very High	Lots of knowledge but have failed to bring it all together and develop clear end goals; often failure is highlighted while success is not always measured / 'advertised'; Capacity is available, but knowledge need to be integrated with practice, research, etc; How can we use this knowledge to inform policy.
C16	Policy / literature review	Develop guidelines for best principles that establish a sector wide approach to CP restoration incl propagule collection, propagation, and access to support the proposed works.	0-5 years	Very High	$10-100K	Very High	No comment
C16	Policy / literature review	Develop mechanisms that better account for the long-term nature of restoration programs.	0-5 years	Very High	$10-100K	Moderate	No comment
C17	Policy / literature review	About where and when and how it can be achieved in western Sydney to use fire as a management tool.	0-5 years	High	$10-100K	High	No comment
C17	Field surveys	Biomass / fuel load management.	16-35 years	High	$100-1000K	Low	No comment
C17	Field experiments	Alternative mechanisms that may / will give the same outcomes.	6-15 years	High	$100-1000K	Low	No comment

Gap no.	Research type	Approach	Timeframe	Potential	Likely cost	Priority	Comment
C17	Field experiments	Management for species - complexity of communities and target taxa / growth forms.	6-15 years	High	$100-1000K	Low	No comment
C18	Controlled growth / laboratory experiments	Systematic surveys to collect soil seedbank followed by germination trials to understand exotic weed load and native species abundance and diversity.	0-5 years	Very High	$100-1000K	Very High	No comment
C18	Controlled growth / laboratory experiments	Understanding germination cues of priority species. Seed burial trials to understand seed longevity in the soil.	16-35 years	High	$10-100K	Low	No comment
C19	Policy / literature review	Analyse existing information, provide guidelines for decision making based on prioritization, that is adapted based on new information coming through.	0-5 years	Very High	$10-100K	Very High	Short to long term / ongoing - need to adapt to changing conditions, needs, other changes; hierarchy of decisions - where do you restore (prioritize relative to conditions / outcomes), what do you do, how does management change through time.
C19	Community activity / engagement	Test decision tree formally through interaction with stakeholders but validate using data.	0-5 years	Very High	$100-1000K	Very High	Ongoing.