# NSW Koala Research Plan 2019–28

A 10-year plan under the
NSW Koala Strategy

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# 1. The need for a koala research plan

The NSW Koala Strategy (NSW Office of Environment and Heritage 2018a) includes as an action the preparation of a koala research plan. But why is such a plan needed, and what should it include? A lot is known about koalas, sufficient in many cases to allow action relating to their conservation; however, there are many situations where the information is incomplete. In **parallel** with taking action, there is a need to know more about koalas, effective mitigation of threats, and the social and economic opportunities for successful implementation of koala recovery strategies. The knowledge base should be continually updated (McAlpine et al. 2015), and this need is heightened as koalas react to a changing environment (e.g. a changing climate).

In general, these knowledge gaps can be addressed through research. While it is recognised there must be a balance between responsive mode research and targeted research (see Box 1), and that in some cases a program of targeted research can limit technical excellence (House of Lords Science and Technology Committee 2010), in the case of research required for a specific conservation outcome, the balance should be towards targeted research. Determining how research should be targeted, and prioritised, is a primary driver for developing a research plan.

### Box 1

**Responsive mode research**

Proposals are driven wholly by what the applying investigator wants to research. Each proposal is considered and assessed on its own merits.

**Targeted research**

Proposals fit within a pre-defined specification for a narrow research area.

Further, the research plan should make clear the linkages between research and koala policy. Koala policy must be related directly to sound knowledge and research and where possible, koala research should be clearly directed towards policy and conservation outcomes. Where management actions are undertaken, outcomes must be monitored and learnings applied to modifying future actions (i.e. an adaptive management framework).

The research plan should have long-term goals and programs and accommodate the various research funding cycles. After the initial plan, subsequent updated plans should build on the earlier plans and refresh the content. The research plan should not inhibit curiosity driven research, but rather direct limited funds for koala conservation to research topics that will have the greatest benefit.

## 1.1 Objectives and aims

The NSW Koala Research Plan is a 10-year plan. It is a dynamic document that will be reviewed, evaluated and updated at regular intervals throughout its life.

The objectives of the NSW Koala Research Plan are to:

- increase our overall knowledge of koalas and their threats in a targeted manner
- coordinate research and data collection on koalas within New South Wales in a manner that facilitates both research and policy development/actions

- foster engagement and understanding between koala researchers and policy makers so that the best possible outcomes are achieved for koalas (see Gibbons et al. 2008; McAlpine et al. 2015; Hogg et al. 2017), and
- engage the community in the development of the plan and participating in the research program.

The overall project logic of the koala research plan is shown in Figure 1.

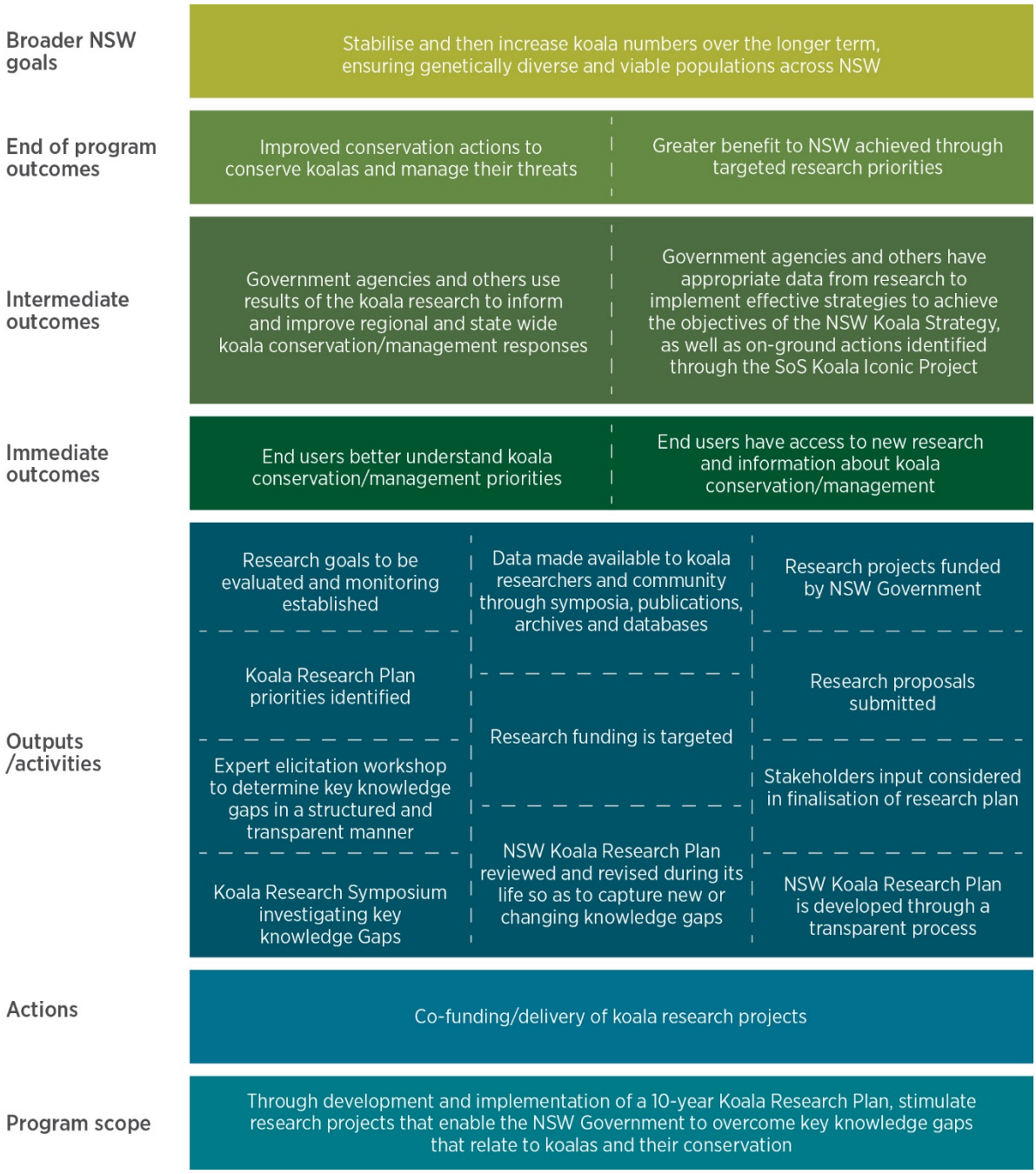


**Figure 1 The overall project logic for the NSW Koala Research Plan**

To this end, the research plan will:

- Identify and prioritise key knowledge gaps. In the context of this plan, a key knowledge gap is one that, as a result of being addressed through research, will likely increase the effectiveness of koala conservation actions and/or their likelihood of implementation.
- Outline the process by which research grant applications will be sourced, including assessment criteria.
- Outline how progress and outputs of the individual research projects will be monitored and evaluated.
- Outline how progress and outputs of the overall research plan will be monitored, evaluated and revised over the life of the plan.

The NSW Koala Research Plan is a dynamic document that will be accompanied by several supporting documents. It is expected the plan and supporting documents will change over the life of the plan so anyone using the plan should ensure they are using the most recent version. All documents relating to the research plan can be accessed at: www.environment.nsw.gov.au/koalas

# 2. Background to the Koala Research Plan

The concept of the Koala Research Plan has been recognised as an important part of koala conservation planning throughout the development and implementation of the NSW Koala Strategy. The two distinct stages that have most led to the development of the Koala Research Plan (including identification of knowledge gaps) are detailed below.

## 2.1 The NSW Chief Scientist and Engineer's Report

In 2016 the then NSW Chief Scientist and Engineer, Mary O'Kane, undertook a review of the decline of koalas across New South Wales. The review resulted in a report presented to the NSW Minister for the Environment, which included 11 key recommendations, all related to the key recommendation of developing a NSW Koala Strategy (NSW Chief Scientist and Engineer 2016).

The report highlighted the importance of knowledge and research in the conservation of koalas. In particular, the report highlighted that while many threats to koalas are well known 'there is still much to learn about many of these existing threats and the most effective actions to mitigate them.' The report states that as a result of the recommended NSW Koala Strategy, 'our scientific knowledge of koala populations, dynamics and health will be substantially increased'.

Recommendation 8 of the report relates specifically to a koala research plan:

### Recommendation 8

> That Government, through the Office of Environment and Heritage, convenes […] within 12 months of receiving this report [a symposium] for scientists active in koala research and land managers to develop a koala research plan.[1]

The report then elaborates on the recommendation and highlights some knowledge gaps and research priorities:

> The koala research plan should build on the koala research priorities identified in the strategy and provide seed funding to support researchers to build collaborative grants applications such as Australian Research Council and Environmental Trust bids.
>
> A biennial symposium, organised and facilitated by the NSW Office of Environment and Heritage, should refresh the koala research plan and share research findings to feed back into the strategy's delivery. General outcomes of the symposium should be agreed upon and made available to community members and land managers in a suitable form to permit them to act on the best available science.
>
> An immediate set of research priorities has been identified through this review. These include knowledge gaps relating to key koala populations:
>
> - better understanding of the impact of managed and wild fire on koala habitat

[1] The recommendation has been edited to focus on those elements that relate to koala research and the research plan.

- local population movements and viability in relation to connectivity, roads and dogs
- cumulative impacts on koala populations from pressures of native forest harvesting, fire and dogs
- effectiveness of offset and rehabilitation activities
- cumulative impacts on koala gene flow from fragmented habitat and populations
- results from the Koala Genome Consortium to better inform disease research including chlamydia and koala retrovirus (KoRV)
- climate change impacts and identification of climate refugia
- key socio-economic and institutional barriers to the effective implementation of koala conservation strategies
- effectiveness of management strategies to minimise impacts on koala populations including development consent for residential subdivision and mitigation activities for reducing mortality on roads.

## 2.2 The NSW Koala Strategy

Because of the key recommendation of the report by the NSW Chief Scientist and Engineer (2016), the NSW Koala Strategy was developed and released in May 2018 (NSW Office of Environment and Heritage 2018a). Building our knowledge is one of the four pillars of the strategy and built into that pillar is research, directed by a research plan.

Specifically, the NSW Koala Strategy states that:

> A research plan will be developed and further refined at a research symposium in 2018. The plan will identify priority gaps that need to be addressed. … The NSW Government is committing funding to support this research plan and to leverage further funding through linkage grants and partnerships.

The strategy also includes several specific research questions/projects that have research funds already attached to them. These include investigating:

1. How koalas are responding to regeneration harvesting[2] on the North Coast of New South Wales. This specific project is being run by the Natural Resources Commission and is not part of the research plan. Related research proposals may however be considered under this plan (see Section 4).
2. The effectiveness and challenges of undertaking the relocation/translocation of koalas. Translocation in this context refers to reintroducing koalas from existing NSW populations to improve genetic diversity and health of local populations.
3. The impacts of chlamydia on koala populations and identifying potential management options.
4. Trialling chlamydia vaccines to increase the number of healthy and disease-free koalas and significantly decrease the incidence of the disease.

[2] Regeneration harvesting as referred to in the NSW Koala Strategy is referred to as ‘intensive harvesting’ in the Coastal Integrated Forestry Operations Approval (IFOA) (see www.epa.nsw.gov.au/your-environment/native-forestry/integrated-forestry-operations-approvals/coastal-ifoa)

# 3. Developing the Koala Research Plan

Development of the NSW Koala Research Plan involved two steps that built upon the work completed during the preparation of the report by the NSW Chief Scientist and Engineer and the NSW Koala Strategy. These two steps are described below.

## 3.1 Expert elicitation of knowledge gaps

It is known that different stakeholders will have different views on contributing factors ranging across the significance of threats, knowledge gaps and ultimately research priorities. To address and account for the range of views, a logical, transparent and structured process was put in place that focused on expert elicitation and structured decision-making so as to **identify** and **prioritise** key knowledge gaps.

The NSW Government engaged researchers from the Centre for Environmental and Economic Research (CEER) at the University of Melbourne to design an elicitation process and facilitate an elicitation workshop. Participants in the workshop were chosen by the NSW Office of Environment and Heritage in consultation with the CEER group, based on their knowledge of koalas and koala conservation/management. Selection emphasised recruiting diverse participants from a range of professional backgrounds (i.e. years of experience, specialisation, regional knowledge and affiliations). There was a further emphasis on achieving demographic diversity, particularly in relation to age and gender. Finally, the number of participants was limited to ensure the expert elicitation process was feasible in a workshop setting. In total, 25 participants attended the two-day workshop, held on 24 and 25 July 2018.

The full report (Hemming et al. 2018) detailing the process and results of the expert elicitation is provided as an accompanying document to this research plan. A summary is provided below.

### 3.1.1 Summary of the expert elicitation of knowledge gaps

The aim of the expert elicitation workshop was to develop an understanding of the key knowledge gaps impeding the successful management of koala populations in the wild across New South Wales. This understanding led to the development of a series of research questions, targeted at addressing the uncertainty that, if resolved, will provide the most benefit to the viability of koalas in New South Wales.

In the elicitation process, the steps of structured decision-making were used to:

Specify the **management objective and associated performance measure***:* a long-term genetically diverse and viable koala population in New South Wales (NSW Office of Environment and Heritage 2018a), measured in the workshop as the number of breeding female koalas in the wild (per Koala Management Area – KMA) in 60 years (2079).

Identify the key threats to the persistence of koala populations in six different KMAs across New South Wales, then develop a series of **alternative management actions** that could be employed to reduce the impact of the key threats.

Use structured expert elicitation to predict the **consequences**, with uncertainty, of the alternative actions on the persistence of koala populations in six different KMAs across New South Wales. Predictions were made under two climate change scenarios.

Use a sensitivity analysis to explore the uncertainty around the efficacy of the alternative management actions to prioritise where research could most effectively be applied to inform the conservation/management of koalas in New South Wales.

The workshop findings suggested that:

- Participants specified approximately 24 threats to koalas across New South Wales, with major threats including habitat loss and habitat fragmentation, disease, bushfires, cars and roads, and climate change (including drought and heatwaves).
- Many threats were shared across KMAs. For example, **habitat loss** (and **habitat connectivity loss/fragmentation***)* was consistently listed by respondents as the first-ranked threat across all KMAs. Likewise, the threat posed by **disease** was relatively consistent as a top three threat. As expected, the frequency at which key threats were mentioned by experts, and their ranking, did vary across KMAs. For example, **cars and roads** were considered a greater threat by more participants in KMA1 (North Coast) and KMA2 (Central Coast), while more participants viewed **bushfires and wildfires** as a number one threat in KMA3 (South Coast) and KMA5 (Southern Tablelands), and **climate change** was considered as a higher ranked threat in KMA5 and KMA6 (Western Slopes and Plains).
- Using structured elicitation, the consequences of 14 actions (targeted at the key threats) were predicted for the year 2079. The following actions were identified as being of most value for targeting for potential research questions, given uncertainty about climate change. The relevant KMA is noted in brackets, though the associated research questions could be relevant to any region with the associated key threat:
    - Habitat Restoration (KMA2 and KMA4 (Northern Tablelands))
    - Climate Change Refuges (KMA5)
    - Climate Change Water Supply (KMA6)
    - Habitat Logging Controls (KMA1)
    - Disease Insurance Population (KMA6)
    - Fire Asset Protection (KMA3 and 5).
- The remaining actions were, comparatively, unlikely to be implemented or unlikely to have a positive effect on koala abundance (or both).
- Eighteen key research questions were subsequently identified. Prioritisation of these research questions is dependent on the size of the research budget, and the estimated likelihood of the different climate change scenarios. However, it would appear research into habitat restoration should be prioritised, as the predicted gains for koalas are greatest, regardless of budget and uncertainty due to climate change. Examples of relevant research questions and topics include:
    - ‘Future proofing’ revegetation
    - What is adequate habitat?
    - Strengthening private land partnerships
    - What private land is most at risk and the most valuable to protect?

The full elicitation report can be found at: NSW Koala Research Plan: Expert elicitation of knowledge gaps

## 3.2 Koala Research Symposium

Following on from the elicitation workshop, a Koala Research Symposium was held on 16 November 2018. The aim of the symposium was to present the elicitation findings to a broad audience of people involved with koala research, management and care, and to get feedback on any significant gaps in the elicitation results. The symposium was intended to build upon, not replace, the results of the elicitation workshop. As such, no formal elicitation process was followed, rather the additional input was sourced through four facilitated Q&A sessions with a panel of four or five participants with expertise in the panel topic. Questions and discussion were generated among the panel and audience. The four session topics were:

1. habitat identification and management
2. climate change, extreme weather events and fire
3. disease
4. other research questions.

A total of 82 people attended the research symposium.

The research symposium proved particularly useful for the broad topic of disease. Actions related to disease did not generally score highly during the expert elicitation in terms of effectiveness or likelihood of implementation. The research symposium was able to further investigate the options for this topic.

# 4. Key knowledge gaps

Key knowledge gaps have come from four sources:

1. NSW Chief Scientist and Engineer's Report (NSW Chief Scientist and Engineer 2016)
2. NSW Koala Strategy (NSW Office of Environment and Heritage 2018a)
3. knowledge gap elicitation (Hemming et al. 2018)
4. the Koala Research Symposium.

A summary of the key knowledge gaps, presented by source and theme, is shown in Table 1.

These knowledge gaps should lead to research questions; examples of research questions derived from the knowledge gap elicitation are shown in Appendix A.

**Table 1 Key knowledge gaps**

| Broad theme (sub-theme) | Source of knowledge gap | | | |
|---|---|---|---|---|
| | Chief Scientist's Report | NSW Koala Strategy | Key knowledge gap elicitation | Research Symposium |
| **Climate change and extreme weather events (habitat)** | | • Changes in availability of preferred koala habitat including eucalypt leaf quality | | • Koala habitat suitability under different climate change scenarios and identifying and categorising ranked climate-risk refugia |
| **Climate change and extreme weather events (refugia)** | • Climate change impacts and identification of climate refugia | | • Climate change refuges | • Identifying key characteristics of refuges (e.g. leaf water, microclimates) |
| **Climate change and extreme weather events (water supply)** | | | • Climate change water supply | • Effects of artificial water supply at the population level<br>• Natural waterway protection/ restoration vs artificial water supply |
| **Disease (dynamics of emergence)** | | | | • Dynamics of emergence and re-emergence of disease in expanding or translocated populations |

| Broad theme (sub-theme) | Source of knowledge gap | | | |
|---|---|---|---|---|
| | Chief Scientist's Report | NSW Koala Strategy | Key knowledge gap elicitation | Research Symposium |
| **Disease (impacts)** | | • Causes and impacts of chlamydia and other diseases (including management options) [1] | | • Impacts of treatment and rehabilitation on populations |
| **Disease (insurance populations)** | | | • Disease insurance population | |
| **Disease (risk mapping)** | | | | • A disease risk map for koalas incorporating targeted management strategies |
| **Habitat (landscape)** | | • Future habitat availability | | • Landscape thresholds and cumulative impacts |
| **Habitat (logging)** | | • Habitat logging controls [2] | • Habitat logging controls [2] | • Focus on disturbance regimes |
| **Habitat (occupancy)** | | | | • What is driving koala occupancy across the landscape? Is unoccupied habitat necessarily bad habitat?<br>• What is good quality/ adequate habitat?<br>• The processes and mechanisms that underlie landscape change patterns and drive species loss |
| **Habitat (restoration)** | • Effectiveness of offset and rehabilitation activities | | • Habitat restoration | • Future proofing restoration activities |

| Broad theme (sub-theme) | Source of knowledge gap | | | |
|---|---|---|---|---|
| | Chief Scientist's Report | NSW Koala Strategy | Key knowledge gap elicitation | Research Symposium |
| **Other (cumulative threats)** | • Cumulative impacts on koala populations from pressures of native forest harvesting, fire and dogs | • Links between heatwave and other threats to koalas such as the onset of chlamydia | | • Ecological consequences of fuel reduction and their impact on koalas and the broader ecosystem, e.g. weed invasion, increased predator access, etc. |
| **Other (fire)** | • Better understanding of the impact of managed and wild fire on koala habitat | • Bushfire risk and the impact of bushfire management activities such as planned burns to address the risk | • Fire asset protection | • Understanding the resilience of populations in terms of their response to hazard reduction burning and wildfire events |
| **Other (genetics)** | • Cumulative impacts on koala gene flow from fragmented habitat and populations | | | • Factors driving genetic diversity throughout different parts of the koala's range<br>• Defining discrete koala populations |
| **Other (management effectiveness)** | • Effectiveness of management strategies to minimise impacts on koala populations including development consent for residential subdivision and mitigation activities for reducing mortality on roads | | | • Using disease as an indicator of population health and following that the effectiveness of management actions<br>• Using demographic modelling and sensitivity analysis to determine effectiveness of management actions |

| Broad theme (sub-theme) | Source of knowledge gap | | | |
|---|---|---|---|---|
| | Chief Scientist's Report | NSW Koala Strategy | Key knowledge gap elicitation | Research Symposium |
| **Other (population viability)** | • Local population movements and viability in relation to connectivity, roads and dogs | | | • Demographic modelling and sensitivity analysis |
| **Other (socio-economic)** | • Key socio-economic and institutional barriers to the effective implementation of koala conservation strategies | | | • The true cost of private land conservation<br>• Economic and social barriers to implementation of conservation measures<br>• Conserving koala habitat in the most efficient and economical way<br>• The dollar costs of vaccination vs the effectiveness |
| **Other (translocation)** | | • Impacts, challenges and potential benefits of relocation /translocation [3] | | • Assessing what is good koala habitat in areas with no evidence of use by koalas (such as for translocation) |

Notes:

1: Two research projects related to disease have been identified in the NSW Koala Strategy and have discrete funding attached to them: a) a research project to better understand the impacts of chlamydia on koala populations and to identify potential management options; b) trialling chlamydia vaccines to increase the number of healthy and disease-free koalas and significantly decrease the incidence of the disease.

2: The NSW Koala Strategy identifies how koalas are responding to regeneration harvesting on the North Coast of New South Wales as a research priority. This project is being run by the Natural Resources Commission and is not included as part of this research plan.

3: The NSW Koala Strategy identifies the effectiveness and challenges of undertaking the relocation/ translocation of koalas as a research priority with discrete funding attached to it.

# 5. Implementing the research plan

The process and timing of implementing the research plan is shown in Figure 2. Details of the steps in the process are presented in the sections following.

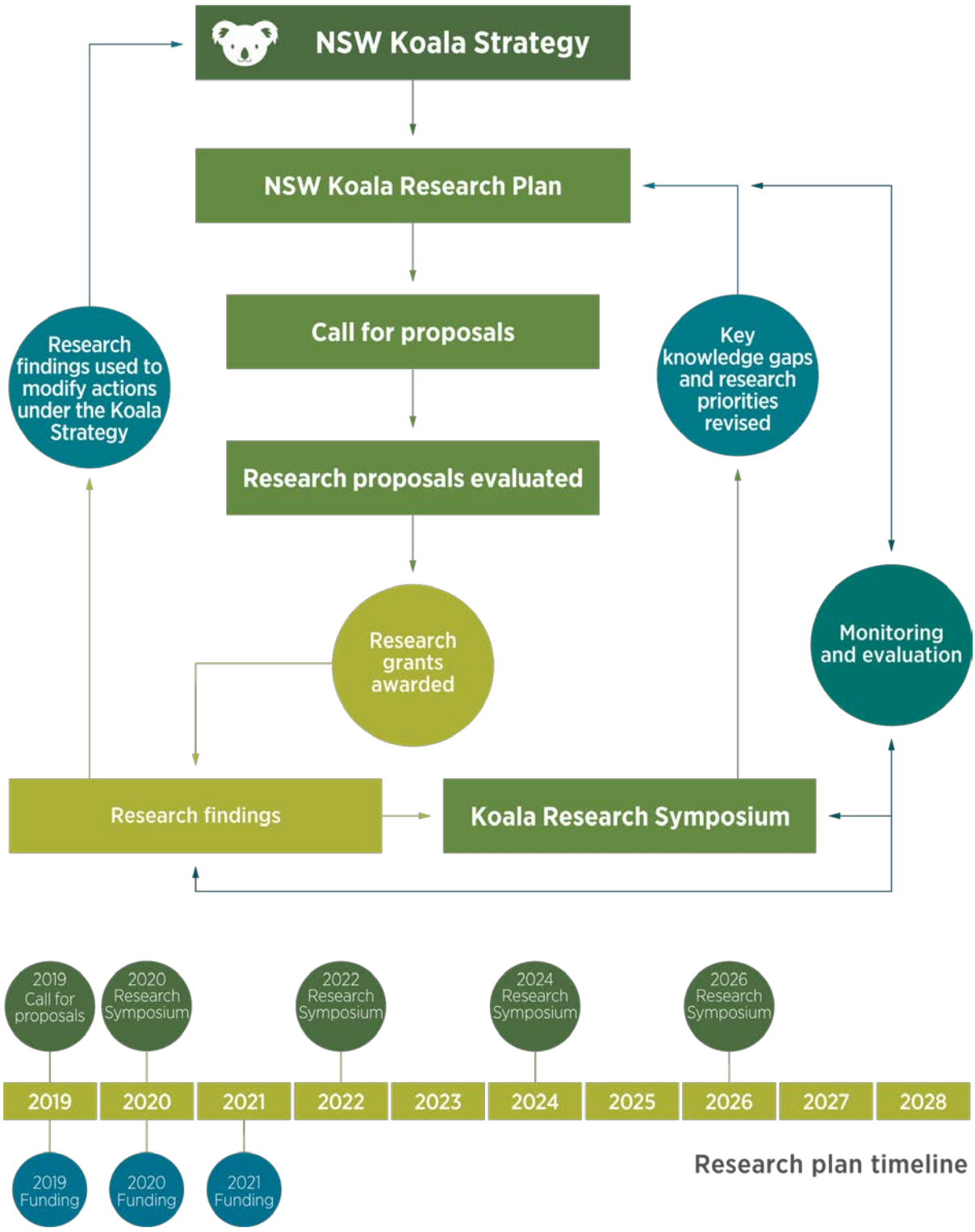


**Figure 2 The process and timeline for implementing the NSW Koala Research Plan**

## 5.1 Call for proposals

To provide consistency and transparency in decision-making and financial negotiations, the call for proposals will follow the NSW Office of Environment and Heritage Research Procurement Guidelines (2018–2021) (NSW Office of Environment and Heritage 2018b).

With the key research priorities identified in this plan, there will be an initial open call for proposals. The call will include the specific targeted research questions identified in the NSW Koala Strategy as well as a more general call for research proposals that align with the broader key knowledge gaps (Table 1).

Details of the application process, the funds available (and the funding priorities), the evaluation and reporting requirements, and the proposed grant contract will form part of the call for proposals.

During the life of the research plan there will be additional calls for proposals. The timing and nature of any additional calls for proposals will depend on: research funds allocated to successful proposals from previous calls; additional funds allocated to the research plan; and, updated key knowledge gaps (see Section 5.3).

## 5.2 Evaluation of proposals

All proposals received will be subject to a rigorous evaluation process that will consider the criteria outlined in Table 2.

**Table 2 Criteria to be used to evaluate research proposals**

| |
|---|
| **Appropriateness of proposed research approach** |
| a) Clear research objectives |
| b) Relevance of proposed research in addressing key knowledge gaps |
| c) Demonstrated understanding of how the research outcomes may address the effectiveness and/or likelihood of implementation of actions related to koala conservation |
| d) Clear scientific merit of research, including methods |
| **Understanding of issues and feasibility of project delivery** |
| a) Clear timeframes for project kick-off and deliverables |
| b) Likelihood of cost-effective delivery against stated objectives within timeframes |
| c) Identified risks and mitigations |
| d) Demonstrated capacity to work collaboratively and share data with other researchers as required |
| **Demonstrated capacity to produce high-quality research** |
| a) CVs and publication record demonstrating a track record of high-quality, peer-reviewed research in a relevant research area |
| b) Details of intended research products and dissemination (including peer-reviewed publications and presentation of results at the Koala Research Symposia (Section 5.3)) |
| **Cost estimate for deliverables** |
| a) Clear budget breakdown, including justification |
| b) Details of ‘in-kind’ or additional external funding |

It is expected that the successful research proposals will adhere to principles outlined in the NSW Office of Environment and Heritage Scientific Rigour Position Statement[3]. The principles include:

1. **Appropriate design,** including:
   a. establishing a clear objective
   b. selecting a scientifically sound and appropriate method
   c. ensuring the people involved have relevant skills and experience to undertake the work
   d. peer review of the design before implementation
2. **Meticulous implementation,** including:
   a. adhering to the adopted method, and documenting variations
   b. ensuring data are reproducible, secure, discoverable and accessible
3. **Objective analysis and reporting of results,** including:
   a. ensuring evidence supports results and conclusions
   b. peer review prior to publishing data, results and conclusions
   c. publishing results in appropriate media.

Proposals will be evaluated against the criteria by a panel brought together for this purpose. The panel may call on technical experts to provide comment on the methods in individual proposals. A shortlist of research proposals recommended for funding will be prepared by the panel and will be endorsed by the Koala Strategy Board.

## 5.3 Future Koala Research Symposia

A Koala Research Symposium will be held every two years (Figure 2) and will be an opportunity to include a broad range of stakeholders in reviewing the progress of research initiated under the research plan, as well as reviewing the plan and having input into any change of research priorities. It is expected that as research initiated under the Koala Research Plan is completed, research priorities identified in the plan will change. The Koala Research Symposia will be an opportunity to reflect on the key knowledge gaps and research priorities, leading to a revision of the research plan.

The broad objectives of the Koala Research Symposia will be to:

- resent and review progress with research initiated under the Koala Research Plan (this will include presentations from research groups funded under the research plan)
- present and review overall progress in implementing the Koala Research Plan, including links back to the NSW Koala Strategy (Section 5.5)
- review and revise the key knowledge gaps identified in the Koala Research Plan.

Information from the Koala Research Symposium, along with information obtained through monitoring and evaluation of the research plan (Section 5.4), will be used to revise/update the Koala Research Plan. This will then direct priorities for future calls for proposals.

[3] The NSW Office of Environment and Heritage (OEH) Scientific Rigour Position Statement is available at: www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Research/Our-science-and-research/oeh-scientific-rigour-position-statement-2013.pdf

## 5.4 Monitoring and evaluation

### 5.4.1 Monitoring progress of individual research projects

Every research project under the Koala Research Plan will have a set of objectives and deliverables identified at the project's inception, agreed upon and included in the grant contract. Progress towards meeting these objectives and producing these deliverables will be reported on every six months.

### 5.4.2 Evaluating benefits and success of the Koala Research Plan

A detailed evaluation plan will be prepared for the Koala Research Plan. The evaluation plan will consider:

- aims and objectives of the Koala Research Plan
- research projects funded under the plan as well as their objectives and deliverables
- allocation of funding and value for money
- dissemination of the research results
- availability/sharing of data generated by the funded research
- the realised benefits of the research in the form of resultant changes in management decisions linked to project outcomes.

The results of the evaluation will be presented at the Koala Research Symposia.

## 5.5 Linking research to actions

Vital to the success of the Koala Research Plan will be the linking of the research findings to actions that will improve the conservation of koalas (Figure 1). The links may be made through several pathways, including:

- new or revised actions in the NSW Koala Strategy
- changes in policy relating to koalas and their threats
- changes in implementation of on-ground actions relating to koalas and their threats (e.g. through the SoS Iconic Koala Project[4]).

The Koala Research Plan has been prepared on the premise that research supported under the plan should address key knowledge gaps: those gaps that, when addressed, have the best chance of increasing the effectiveness of actions or the likelihood that actions will be implemented. This premise has been considered in the elicitation process (Hemming et al. 2018) and will be included in the assessment criteria for research proposals (Section 5.2). Research supported under the Koala Research Plan must lead to clear changes in how we manage koalas and their threats. Ultimately, the management/policy changes must lead to net increases in long-term koala viability attributes.

[4] More details about the SOS Iconic Koala Project can be found at: www.environment.nsw.gov.au/research-and-publications/publications-search/saving-our-species-iconic-koala-project-2017-to-2021

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# Appendix A – Research questions identified during the expert elicitation workshop

**Table A.1 The list of research questions developed by participants in the expert elicitation workshop for the eight priority research actions, noting that prioritisation depends on the budget available**

'Other values' includes where participants specified objectives relevant to research other than koalas, 'Research' specifies the research questions or details, and 'Interacting' lists interacting threats/drivers that participants felt were relevant. The other KMAs that the research might be relevant to are noted.

| Research theme | Details |
|---|---|
| **Habitat restoration (developed for KMAs 4 and 2, but relevant across KMAs)** | |
| Future proofing revegetation | **Other values:** Cost<br>**Research:** Where should revegetation activities be targeted?<br>What are the most viable species to plant under climate uncertainty (changing species, soils) and where?<br>How long would revegetation take to become useful habitat to koalas, and is this altered under different climate change scenarios?<br>Consider research around leaf chemistry, and inoculated trees.<br>**Interacting:** Climate change, soil chemistry, genetics of revegetation species |
| What is adequate habitat? | **Other values:** Cost, development<br>**Research:** Research to understand the optimum and importantly the minimum habitat requirements for koalas, to guide investment and restoration in optimal habitats<br>**Interacting:** Climate change, development, disease, population dynamics |
| Strengthening private land partnerships | **Other values:** Social values, cost<br>**Research:** Social survey to understand drivers and barriers for protection of koala habitat on private land. What barriers are preventing scientists and private land managers working together to map and study koala populations? Who signs up to policies to protect koala habitats on their land, and why? What are the social implications / stigma of signing up to such schemes? What incentives are required? What are the costs to the landowner? |
| What private land is most at risk and the most valuable for us to protect? | **Other values:** Social values, cost<br>**Research:** Can we predict the best land parcels to target if we focus our efforts on working with landowners on protection of koala habitat? Can we predict the probability of land clearing?<br>**Interacting:** Development, climate change, population dynamics |
| **Drought/climate change refuge (developed for KMA5, but also most relevant to KMAs 4 and 6)** | |
| Exploring the potential of occupied and unoccupied refuge areas on private and public land (i.e. riparian, alpine areas) | **Other values:** Cost, agricultural values<br>**Research:** Exploring the efficacy of 'potential' refuges under different 'extreme event' scenarios (i.e. drought/hot day duration). Requires assessment of potential refuges in relation to: projected carrying capacity (available water and extent of palatable food supply), historical koala occupation, migration or translocation potential, risk of dieback, and likelihood of success on private land. Management scenarios to explore include with/without restoration around water sources, and/or incentive schemes for private landholders<br>**Interacting:** Disease |

| Research theme | Details |
|---|---|
| **Climate change water supply (developed for KMA6, but also relevant to KMAs 4 and 5)** | |
| At what density of water points does supplementing water in the landscape increase resilience of koala populations? | **Other values:** Cost<br>**Research:** Does supplementing water in the landscape increase resilience in individuals? Do individual effects translate to population effects?<br>**Interacting:** Extreme heat and drought, disease |
| Can we deliver water in more natural ways, such as restoring creek lines, etc., retaining and maintaining natural water bodies in the landscape? | **Other values:** Cost<br>**Research:** How can water be delivered and maintained at a useful/large enough scale to be effective? Perhaps a longer-term more natural approach could be supplemented with 'blinky' drinkers (or similar) in the short term<br>**Interacting:** Climate change, extreme heat and drought, disease, habitat quality and connectivity |
| What is the feasibility of filling man made water points? | **Other values:** Cost, farming community, other native species<br>**Research:** Explore the willingness of farmers to supply water to wildlife, and the role of incentives. Are there multiple viability delivery methods, i.e. alternatives to blinky drinkers?<br>**Interacting:** Climate change, extreme heat and drought, disease, habitat quality and connectivity, private land |
| Does the need for koalas to regularly come to specific watering points in the landscape modify population dynamics, e.g. alter home ranges of koalas? | **Research:** Monitoring of populations where watering already applies<br>**Interacting:** Climate change, extreme heat and drought, disease, habitat quality and connectivity |
| Do watering points influence the spread of disease and/or introduce pathogens from other species? | **Research:** Unintended consequences unknown, potential for disease transmission by changes to density around waterpoints and transmission through waterpoints<br>**Interacting:** Climate change, disease, habitat quality, habitat connectivity |
| **Fire asset protection (developed for KMAs 3 and 5)** | |
| What fire regime(s) possibly benefit koalas? | **Other values:** Cost, social acceptability<br>**Research:** To understand the role fire plays in koala habitat creation and provision of suitable habitat for koalas. Can we modify marginal habitats for koalas using fire?<br>**Interacting:** Habitat quality, climate change, disease |
| What is good quality feeding habitat for koalas? | **Research:** Understanding the chemical composition of leaves that best suit koalas. What is adequate vs good quality koala habitat?<br>**Requires:** Definition and identification of koala habitat<br>**Interacting:** Climate change (drought) |
| Impacts of fire on koala habitat and food resources | **Research:** Understand the ability of koalas to persist during 'crunch points' in low and high populations (immediately after fire). Involves understanding the nutritional requirements for food sources after fire, the ability to feed on epicormic regrowth, the reconfiguration of habitat after fire, and the ability of koalas to recover.<br>**Interacting:** Dog control, distance from roads |
| What does a successful inter-agency koala asset protection plan look like? | **Other values:** Landholder acceptance, cost (management and agricultural outputs), risk to life/property.<br>**Research:** Developing a spatial inter-agency koala asset protection plan and investigating the risk of failure (for koalas) over time and space under high severity wildfire scenarios (i.e. effectiveness of plan, and prioritisation of life/property objectives)<br>**Requires:** Understanding of koala asset areas in relation to fire history (i.e. refugia)<br>**Interacting:** Distance from populated areas |

| Research theme | Details |
|---|---|
| Is current protection adequate to ensure persistence of the isolated single population of koalas in KMA3? | **Other values:** Cost, political acceptability<br>**Research:** Perform a risk assessment for the one isolated population of koalas known in this management area, which are already protected under Flora reserve status. Fire is actively excluded, and rapid response is likely but also critical to their persistence. Is this level of protection going to ensure persistence of koalas in this area?<br>**Interacting:** Climate change, disease, population dynamics, habitat quality |
| **Habitat logging control (developed for KMA1, but relevant to other KMAs with logging as a key threat, e.g. KMA3)** | |
| Exploring the impact of logging strategies on koala populations over time on private and public land | **Other values:** Cost<br>**Research:** Explore costs and benefits (risk) at a landscape scale of the different logging scenarios: high impact logging, various types of 'sustainable' logging, and no logging (Public land)<br>**Interacting:** Private Native Forestry under current policies |
| Understanding the risk to koalas of changes in the palatability of species of logging regrowth | **Other values:** Koalas (survival, health)<br>**Research:** Understanding changes in the palatability of species for koalas in logging regrowth<br>**Interacting:** Climate change scenarios, microbiome |
| **Disease insurance population (developed for KMA6)** | |
| For disease, how do we reduce spread and prevalence in a drier climate? | **Other values:** Cost<br>**Research:** Is reduced fecundity controlling disease in KM6, and how is this likely to vary under a drier climate?<br>**Interacting:** Climate change, disease, wildfire, habitat quality, habitat connectivity |

**Table A.2 The list of research questions developed by participants in the expert elicitation workshop for the lower priority management actions**

'Other values' includes where participants specified objectives relevant to research other than koalas, 'Research' specifies the research questions or details, and 'Interacting' lists interacting threats/drivers that participants felt were relevant.

| Research theme | Details |
|---|---|
| **Road infrastructure (developed for KMAs 1 and 2)** | |
| Exploring consequences of alternative strategies for road development | **Other values:** Development impacts, cost<br>**Research:** Compare and explore efficacy of re-routing, overpasses, enclaves, etc., compared to business as usual management |
| Understanding best targeted dog attack management strategies | **Other values**: Cost<br>**Research**: Compare and explore efficacy of education and free training campaigns, compared to policing/fines for non-compliance<br>**Interacting**: Road density and time since fire |
| How can new technologies help to stop collisions with koalas? | **Other values:** Development impacts, cost, social acceptability<br>**Research:** Trial new technologies, e.g. GPS alert system, virtual fencing, others yet to be trialled |
| What should be included in a baseline monitoring program aimed at detecting changes in road mortality for koalas? | **Other values**: Koalas, development, cost<br>**Research**: Research aimed at understanding the most accurate and cost-effective methods to monitor the effectiveness of road strategies and to develop a database to record this information. Investigate the likelihood that such a monitoring program would have sufficient power to detect changes |

| Research theme | Details |
|---|---|
| **Habitat legislation (developed for KMA2, but relevant to KMAs with significant urban koala populations, e.g. KMA1)** | |
| Are there opportunities in sleeper development areas? | **Other values:** Cost, social, development impacts<br>**Research**: Research to understand percentage of habitat in sleeper development areas (i.e. land over which a development application has been approved, but which has not yet started). What options are available to buy back/retain critical habitat in these areas, and if a buy back / planning legislation change was enacted where would the best opportunities result, and would this result in a rapid increase in clearing?<br>**Interacting:** Climate change, disease, critical habitats |
| What is the likelihood of removal or decline in quality of revegetation sites? | **Other values:** Development impacts, cost<br>**Research:** Revegetation efforts are taking place to protect and restore koala habitats; however, there is uncertainty about how long the management of these areas will last, and what safeguards are in place to prevent future development of these areas. Such information could be useful to strengthen legislation, or to avoid revegetation in areas where it cannot be sustained and protected in perpetuity<br>**Interacting:** Development pressure, funding |
| **Habitat logging control (developed for KMA3, but relevant to other KMAs with logging as a key threat, e.g. KMA1)** | |
| What is the likelihood, and impact, of various logging scenarios on koalas? | **Other values:** Cost, logging industry impacts, political and social acceptability<br>**Research**: If koalas do occur in other parts of KMA3 (or do in the future) what is the likelihood, and impact, of various logging scenarios on koalas? To understand how logging practices, past and present, affect koalas<br>**Interacting:** Climate change, disease, habitat quality, habitat connectivity |
| Is restoring logged areas a viable option for koala habitat restoration? | **Other values:** Cost, social acceptability<br>**Research:** To understand how restoration of logged areas, past and present, affects koalas. Can we increase koala habitat through restoring logged forests? Where should we and how do we effectively restore koala habitat? This might include: what species to use/plant, can we use fire as a tool to create habitat?, ensuring adequate connectivity<br>What is the viability of repopulating alternative habitat? For this we need to know what constitutes adequate (or even better 'good') koala habitat (previous research themes). Can repopulation be achieved through improved connectivity, rather than translocations? Past experience indicates translocations are challenging<br>**Interacting:** Disease, translocation |
| What are the barriers to expansion of the existing koala population? | **Research:** To understand the ranges in koala tolerance of varying quality habitats. Why do koalas occur here and not in other seemingly suitable habitat? What are the drivers that caused contraction of koala distribution to a single area in KMA3?<br>Are koalas currently occupying marginal habitat?<br>**Interacting:** Disease |

| Research theme | Details |
|---|---|
| **Disease (relevant to all KMAs)** | |
| Disease risk assessment | **Other values**: Social values, cost<br>**Research:** Develop a disease risk map for koalas: Understand the spatial prevalence and dynamics of diseases (including sarcoptic mange, kidney stones, cryptococcus, chlamydia, etc.) under different koala populations (i.e. high vs low density, isolated vs continuous, etc.)<br>**Interacting:** Climate change scenarios and changes to food availability (extent and palatability), and varying (urban and rural) threats |
| Disease management: Develop management strategies for populations in different risk zones (see above) | **Other values:** Cost<br>**Research:** Management strategies could include: vaccinate, treat, vary other threats, etc. Uncertainties and research questions include:<br>• What is the effect of diseases on reproduction rate, and do they create a more sustainable reproduction rate given declines in habitat?<br>• Is there a threshold (in koala numbers) for when treatment is considered an effective and required management intervention? For example, is there a minimum percentage of koalas requiring vaccination to be effective?<br>• What is the spread of disease between other mammals and livestock?<br>• Is there the potential for mutation of disease following ineffective vaccinations? Are there other perverse outcomes?<br>• Why is disease a problem for some populations and not others?<br>• What are other novel methods for controlling disease?<br>• How long do treatments last? |
| Are there diseases which are natural to koala populations? | **Research:** Undertake historic/forensic research to understand the time at which diseases entered koala populations – are some diseases just naturally present? |
| Who is being treated? And is it effective? | **Research:** Research to collate a centralised database of koala treatment which can be used to document treatment success of koalas |
| Do treatments help the broader koala population? | **Other values:** Cost<br>**Research:** Methods to effectively monitor population size (and disease status?) of koalas. What are effective, quick, cheap, ethical, techniques that will enable us to survey the population? Can we draw on new technologies? |
| Examining the chlamydia re-infection rate of koalas | **Research**: Study koalas after vaccination and release, in relation to the microbiome of these individuals |
| Improve the microbiome of individuals | **Research:** Exploring ways to improve the microbiome of individuals in the field, vs before release, where vaccination is possible |
| **Other** | |
| What other methods do we have to monitor koalas? | **Other values:** Cost<br>**Research:** Explore other methods of monitoring than tracking faecal counts (i.e. thermal imaging, autonomous drones, etc.)<br>**Interacting:** Fire, disease |
| How sensitive is investment in koala protection to climate change? | **Other values:** Cost, policy adherence<br>**Research**: Climate change will have effects on a range of species, and on humans. How sensitive are current policies to these competing threats and how can we best safeguard koalas under policy and resource uncertainty?<br>**Interacting:** Climate change, human displacement, changes to livelihood |

| Research theme | Details |
|---|---|
| What are the existing population dynamics and habitat occupancy of KMA3's single isolated population? | **Research:** To understand fundamental population dynamics and habitat occupancy of single isolated populations, in order to manage them under climate change<br>Investigate the nature and drivers of koala population size and dynamics:<br>• isolated population (one) of low density, geographic barriers<br>• risk of stochastic events, i.e. fire, disease, especially under increased climate change<br>• inbreeding effects<br>**Interacting**: Disease, fire, genetic diversity |
| Determining the impacts of interactions between climate, disease, habitat suitability and koala dynamics to target management responses (e.g. through long-term longitudinal studies) | **Research:** What were the historical population changes, drivers (e.g. disease, dry climate) of peaks and declines across the landscape? How can we explain the current ageing population?<br>Long-term longitudinal study of the interactions between climate, disease, habitat suitability and koala dynamics to target management responses on private and public land<br>Nature and drivers of koala population size and dynamics:<br>• habitat loss<br>• population flux, 'boom and bust' cycle, boom may be related to rainfall, disease may be related to bust<br>• spatial 'patchy' distribution<br>• suspect overall decline<br>• large size and variability of region<br>• private land management dominates<br>• ageing population<br>**Interacting:** Climate change, disease, wildfire, habitat quality, habitat connectivity, private land |
| The impact of emerging agricultural industries on coastal remnant populations | **Research:** Document and explore scenarios of clearing koala habitat as a result of emerging industries (e.g. blueberry farming)<br>**Interacting:** Climate change, disease |
| The impact of dieback in disturbed (lantana dominated) areas | **Research:** Understand the role of dieback on persistence of koala populations, in areas dominated by lantana<br>**Interacting**: Climate change scenarios |
| Risk of sea level rise to koalas in coastal areas | **Research:** Understanding the risk of sea level rise (via salinisation, flooding) on persistence of koala populations in coastal areas, with a focus on swamp mahogany habitat |
| Exploring the social, ecological and economic implications of 'walking away' | **Other values**: Cost, social acceptance<br>**Research**: Explore and cost alternative strategies for koala protection under development and management budget scenarios, including a 'walk away' strategy<br>**Interacting**: Habitat loss/urban development |