Project Order, Variations and Research Progress

Project Title: Development of guidelines for sustainable offset population sizes in plants using reverse Population Viability Analysis

This document contains three sections. Click on the relevant section for more information.

GISERA, GPO Box 2583, Brisbane QLD 4001, Australia

1 Original Project Order

Project Order
Proforma 2016

1. Short Project Title

Guidelines for offset population sizes

Long Project Title	Development of guidelines for sustainable offset population sizes in plants using reverse Population Viability Analysis
GISERA Project Number	B5
Proposed Start Date	15 January 2017
Proposed End Date	30 June 2018
Project Leader	Dr Francisco Encinas-Viso, CSIRO

2. GISERA Region

☒ Queensland ☐ New South Wales ☐ Northern Territory

3. GISERA Research Program

☐ Water Research ☐ GHG Research ☐ Social & Economic Research
☒ Biodiversity Research ☐ Marine ☐ Agricultural Land Management Research

4. Research Leader, Title and Organisation

Dr Francisco Encinas-Viso Research Scientist CSIRO, NRCA Time commitment: 40%

5. Background

Proposals for development that would impact natural vegetation frequently include ecological work to offset the impact on or restore habitats or populations of rare species that are affected. The aim in all cases is to establish long-term sustainability by creating new habitats or populations that ultimately require no more human intervention than their pristine counterparts. For a population, sustainability is generally considered to be achieved if it is large and genetically diverse enough to maximise its survival across a 100-year timeframe. However, the number of individuals and level of genetic diversity necessary to achieve this state may differ from species to species, depending on life history traits and reproductive biology.

There are currently no science-based guidelines or adequate estimates for the size of plant populations needed to consistently maximise long-term population viability and local species persistence. Use of the 'precautionary principle' can inflate the required number of individual plants to ensure population viability. Its current widespread use, however, is not underpinned by previous rigorous study or evaluation of plant demography and genetics. This practice of over-planting: 1) is done without consideration of an individual plant species' biology and ecology, 2) risks investing considerable (and sometimes infeasible) effort far beyond the point of diminishing returns; and consequently 3) may produce less benefit per time and money invested than it could, e.g., by requiring a single but excessively large population to be created where four equally sustainable populations could be created with the same or reduced investment.

Population Viability Analysis (PVA) encompasses a range of modeling tools commonly used to predict future population size and extinction risk in vulnerable species. The same range of modeling tools can be applied to inform management decisions, such as population offsetting. Specifically, they can be used to predict population sizes beyond which additional investment will not lead to any significant increase in viability. A reverse application of PVAs using computer simulation models combined with our ecological and biological understanding of plants will be used to establish guidelines for operationally efficient and ecologically viable offset plantings that maximise population viability given certain restoration goals. This will help managers and government and state agencies to generate more effective and efficient regulations and targets for conservation.

This work will complement and extend previous work done to establish offsetting and restoration strategies for a single plant species *Rutidosis lanata* in a recently completed GISERA project. The development of the restoration guidelines to be undertaken by this project is a natural extension of previous work that will integrate knowledge and facilitate its general application to a much wider range of plant species that require restoration decisions.

The project will be undertaken at the National Research Collections Australia, CSIRO, led by Francisco Encinas-Viso, who has expertise in computer modeling, conservation genetics and plant ecology.

6. Project Description

This project will create generic but biologically-based guidelines for plant population restoration or offset practices using computer simulation models that consider ecology, demography and genetics. Plant species with different sets of life history traits have different ecological requirements for survival and reproduction. These considerations are important for accurately projecting population viability and the maintenance of genetic diversity. Our project will provide clear guidelines for several categories of plants defined by shared ecology or similar life-history traits (e.g. trees with episodic seed production, insect-pollinated shrubs with long lived seeds). For multiple groups of plants, we aim to provide guidelines for the size and number of populations needed to maximise population survival across 100 years. Plant categories will be defined to cover species of conservation and management interest in Queensland and especially in CSG areas, such as *Cadellia pentastylis*, *Calytrix gurulmudensis*, *Homopholis belsonii*, and *Philotheca sporadica* (these and twelve other species have already been identified as potentially affected by development in a recent stakeholder workshop). Results can be used to guide specific current and future restoration activities and more generally to inform future legislative requirements and frameworks.

Importance and necessity

This project is important because it will improve current population restoration and offsetting practices by providing biologically-based guidelines for establishing viable populations of different native species at lower cost and time investment. Its results will significantly increase operational efficiency and the likelihood of restoration success for the maximum number of species for a given amount of effort. The project will use computer simulation models to predict target population sizes for establishment of viable populations of different relevant plant groups based on their biology and ecology (e.g. insect-pollinated shrub with long-lived seeds, or wind-pollinated grass with no seed bank). In doing this, the project will deliver general guidelines for operationally efficient and viable population offsetting for multiple categories of plants commonly encountered in restoration projects.

In the future, the results can also be used to inform the development of legislative requirements and frameworks regarding revegetation targets. This will directly address community concerns about the evidence-based management of rare species, especially in the face of land use changes, and about the conservation of biodiversity in general. These issues have also been identified in discussion with industry and consultants (e.g. Origin Energy, ECOAUS) as important research, operational and compliance challenges for the industry.

7. Budget Summary

Expenditure	2016/17	2017/18	2018/19	Total
Labour	$52,468	$118,162	-	$171,262
Operating	$16,000	$12,000	-	$23,000
Subcontractors	-	-	-	-
Total Expenditure	**$68,468**	**$130,162**	**-**	**$198,630**

Expenditure per Task	2016/17	2017/18	2018/19	Total
Task 1	$29,907	-	-	$29,907
Task 2	$38,561	-	-	$38,561
Task 3	-	$60,895	-	$60,895
Task 4	-	$28,971	-	$28,971
Task 5	-	$30,531	-	$30,531
Task 6	-	$9,765	-	$9,765
Total Expenditure	**$68,468**	**$130,162**	**-**	**$198,630**

Source of Cash Contributions	2016/17	2017/18	2018/19	Total
GISERA Industry Partners (70%)	$47,928	$91,113	-	$139,041
- APLNG (35%)			-	
- QGC (35%)			-	
Total Cash Contributions	**$47,928**	**$91,113**	**-**	**$139,041**

In-Kind Contribution from Partners	2016/17	2017/18	2018/19	Total
CSIRO (30%)	$20,540	$39,049	-	$59,589
Total In-Kind Contribution from Partners	**$20,540**	**$39,049**	**-**	**$59,589**

	Total funding over all years	Percentage of Total Budget
GISERA Investment	$139,041	70%
CSIRO Investment	$59,589	30%
Total Other Investment		
TOTAL	**$198,630**	

Task	Milestone Number	Milestone Description	Funded by	Start Date	Delivery Date	Fiscal Year Completed	Payment $ (excluding CSIRO contribution)
Task 1	1.1	Pre-development of model (stakeholder workshop & research)	GISERA	January 2017	Feb 2017	2016/17	$20,934
Task 2	2.1	Development of model	GISERA	March 2017	June 2017	2016/17	$26,992
Task 3	3.1	Simulations: Sensitivity analysis and effects of environmental variation	GISERA	July 2017	Dec 2017	2017/18	$42,627
Task 4	4.1	Development of guidelines	GISERA	January 2018	March 2018	2017/18	$20,280
Task 5	5.1	Client workshop	GISERA	April 2018	May 2018	2017/18	$21,372
Task 6	6.1	Delivery of report	GISERA	June 2018	June 2018	2017/18	$6,836

8. Other Researchers (include organisations)

Researcher	Time Commitment (project as a whole)	Principal area of expertise	Years of experience	Organisation
Francisco Encinas-Viso	40%	Ecological and evolutionary modelling	**7**	CSIRO
Alexander Schmidt-Lebuhn	10%	Botany	14	CSIRO

9. Subcontractors

Subcontractors (clause 9.5(a)(i))	**Subcontractor**	**Role**
	Not applicable	

10. Project Objectives and Outputs

The main aim of the project will be to deliver guidelines for several broad categories of plant species that can be used to inform effective and efficient management operations and develop policies that will form a science-based legislative framework for practical population restoration and conservation strategies. Taking into account the biology of an individual species will enable more targeted and resource-efficient approaches to conservation management as an integrated part of industry development. The main benefit of this project will be improved practices for offset planting and habitat restoration for plant categories of conservation and management interest in Queensland, and especially in CSG areas.

Two specific objectives to achieve the main aim of this project are:

1. **Classification of plant groups and identification of key life-history traits for the species studied**: more accurate and pertinent estimations of population viability are only possible with good knowledge of the biology and ecology of the species studied. To be able to provide general guidelines we will classify the list of species considered into several categories based on their life-history traits. We will also identify which traits are most informative for modelling population viability. **Research**: We will identify key sets of life-history traits for the different plant groups by conducting a thorough literature review and by collecting expert knowledge from different stakeholders (i.e. consultants, government and researchers).
2. **Estimations of population viability for multiple plants categories using the simulation model**: population sizes and number of populations for biodiversity offsetting can be estimated using a simulation model that will consider the ecology, genetics and the different life-history traits identified in the previous objective. **Research**: using realistic model parameter values collected from available data and literature, the simulation analysis aims to: 1) conduct a

sensitivity analysis for the key life-history traits identified on each plant group 2) Explore the effects of environmental variation (e.g. stochastic temporal variation of vital rates).

There will be four main outputs of this project:

1. A simulation model that will allow systematic investigation of population parameters that affect viability of offset plant populations.
2. Identification of a key list of plant species of interest to the gas industry and their associated ecology and life-history traits.
3. General guidelines to maximise population viability and improve the operational efficiency of offset plantings for multiple plant groups.
4. Workshops for stakeholders to: 1) collect information about their needs and challenges (e.g. industry, government) for offset plantings, and 2) explain the model outputs, the guidelines for the different plant categories and applications for offset plantings, and provide information bearing on improving a legislative framework for the Gas Industry. Government representatives will be involved at all stages of the project through invitations to participate in the Technical Reference Group and workshops.

11. GISERA Objectives Addressed

By providing science-based guidelines for increasing operational efficiency and maximising population viability in offset plantings, the project addresses the GISERA objective of carrying out research and improving and extending knowledge of environmental impacts of unconventional gas projects for the benefit of the Gas Industry, the community and the broader public. The guidelines will also have the potential to inform future policy and regulations regarding offset targets and requirements, thus addressing the objective of informing government, regulators and policy-makers on key issues regarding policy and legislative framework for the Gas Industry.

12. Project Development

The present project developed out of discussions with industry and consultancy stakeholders during the last stages of GISERA Queensland project B4. During a GISERA knowledge transfer meeting on 27 May 2016, the presentation of the project results included a slide showing the use of Population Viability Analysis to predict extinction risk of a plant population for a given number of starting individuals and a given starting genetic diversity. Much of the subsequent discussion focused on the potential of this approach, with various participants expressing concern about the current lack of knowledge about minimum viable population sizes and the resulting understandably cautious but potentially inefficient and operationally unrealistic requirements. Of particular interest was the idea of “knowing when you have done enough”, so that resources could be used to manage an additional population or species instead of achieving an insignificant reduction in extinction risk by doubling the investment.

These conversations were continued, in particular with Graeme Bartrim (Origin Energy) and Brad Dreis (ECOAUS) over the following months, and the topic was discussed again during the client workshop concluding project B4. Queensland government representatives, consultants and industry partners have continued to express their interest in science-based guidelines for viable population sizes taking into account the biology of the managed species and consistently encouraged us to develop the present project. These guidelines could also inform or initiate discussions about creating new government regulations that have more science-based policies and are more cost-effective and efficient for biodiversity offsetting.

13. Project Plan

We will begin by conducting a workshop to obtain (a) stakeholder input on a list of species relevant to managers so that subsequent work will cover their ecological space, and (b) expert opinion on the key ecological processes and plant life-history traits that should be included in a model (Task 1). The project will then develop a spatially-explicit, individual-based simulation model that will consider the life-history, demography and genetics of the plants, as well as environmental variation (Task 2). The model will be able to simulate multiple plant populations and their connectivity as well as predict population viability (population size and growth), demography (i.e. population structure) and genetics (e.g. genetic diversity and inbreeding depression). As established in our specific objectives, before running the simulations, we will define multiple plant categories according to different sets of life-history traits and identify key life-history traits. Following the second specific objective, we will run a sensitivity analysis for each category under different environmental conditions (e.g. different levels of pollinator availability or pollen flow) (Task 3). The model will be parameterized with available data. We will then align plants currently being assessed for offsetting against these groups to provide management guidelines (Task 4). Finally, we will conduct a final workshop with the stakeholders to explain the results of our analysis and present the management guidelines (Task 5).

Gantt chart of the project divided into monthly increments:

Task	**2017**												**2018**					
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Task 1	■	■																
Task 2			■	■	■	■												
Task 3							■	■	■	■	■	■						
Task 4													■	■	■			
Task 5																■	■	
Task 6																		■

13.1 Project Schedule

ID	Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Pre-development of model (stakeholder workshop & research)	Francisco Encinas-Viso	16 Jan 2017	28 Feb 2017	
Task 2	Development of model	Francisco Encinas-Viso	1 March 2017	30 June 2017	Task 2
Task 3	Simulations: sensitivity analysis and effects of environmental variation	Francisco Encinas-Viso	1 July 2017	31 Dec 2017	Task 3
Task 4	Development of guidelines	Alexander Schmidt-Lebuhn	1 Jan 2018	30 March 2018	Task 4
Task 5	Client workshop	Alexander Schmidt-Lebuhn	1 April 2018	30 May 2018	Task 5
Task 6	Delivery of report	Francisco Encinas-Viso	1 June 2018	30 June 2018	Task 6

Task 1

TASK NAME: Pre-development of model

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: January-February 2017

BACKGROUND: Biological and ecological knowledge of the species studied is a basic requirement to do population viability analysis. Therefore, more accurate and relevant estimations of population persistence are only possible with good background knowledge and data of the species studied.

TASK OBJECTIVE: To decide what sources of environmental variation (e.g. temporal variation) and plant life-history traits will be included in the model, and to decide for what groups of plants guidelines are required. For the former, a review of the relevant scientific literature will be conducted. For the former and the latter, a workshop will be conducted to bring together selected ecologists with relevant expertise and stakeholders (e.g. industry, consultants, regulators) who can nominate plant species. Collect any available data for the nominated species.

TASK OUTPUTS: Determination of what parameters will be included in the model, and for what groups of plants guidelines will be developed.

SPECIFIC DELIVERABLES: Workshop, list of critical ecological and genetic parameters for inclusion in the model, and list of plant groups capturing specific examples relevant to offset work in the Queensland CSG area.

Task 2

TASK NAME: Development of model

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: March-June 2017

BACKGROUND: The simulation model will be developed to be flexible enough to accommodate the different sets of life-history traits from the different plant groups. Debugging and testing the performance of the model will be essential to avoid erroneous predictions and improve the computational efficiency of the program.

TASK OBJECTIVE: Test performance of the simulation and explore the parameter space.

TASK OUTPUTS: Efficient and tested simulation model that will be used for subsequent simulation analyses.

SPECIFIC DELIVERABLES: A software tool implementing the population model needed to run simulation analyses.

Task 3

TASK NAME: Simulations – Sensitivity analysis and effects of environmental variation

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: June-December 2017

BACKGROUND: Sensitivity analysis helps us to identify what vital rates (e.g. adult fecundity, seedling survival) and population parameters (e.g. population size) are more important for population viability. Therefore, this analysis is important to evaluate different population offsetting options (e.g. population size, number of populations and connectivity), to maximize overall viability. The use of available data for some of the species will be extremely useful to get more accurate predictions. It is also important to evaluate the effects of environmental variation on population viability since uncertainty in vital rates and changes of populations is partly linked to stochastic changes in the environment and can have negative effects to population persistence.

TASK OBJECTIVE: Conduct a sensitivity analysis for each plant group to detect key vital rates that might be highly affected by changes in population size. Explore the effects of stochastic temporal variation to assess, for example, the consequences of potential catastrophes (e.g. droughts) on population viability.

TASK OUTPUTS: Projections of population growth and size (based on estimates of the mean and their associated uncertainty) for each plant group with and without environmental variation. Identification of key vital rates for population viability detected by the sensitivity analysis.

SPECIFIC DELIVERABLES: Identification of key vital rates and predictions of population sizes and growths under different ecological scenarios for each plant group.

Task 4

TASK NAME: Development of guidelines

TASK LEADER: Alexander Schmidt-Lebuhn

OVERALL TIMEFRAME: January-March 2018

BACKGROUND: Science-based guidelines are necessary for more efficient and cost-effective management decisions for offset planning. The information collected from the first workshop with stakeholders and the simulation analysis of the different plant groups will set general and basic guidelines for plant population offsetting management that will consider important aspects of plant ecology and genetics.

TASK OBJECTIVE: To use the results of simulation analyses (task 3) to develop guidelines on the approximate viable population size and the approximate number beyond which diminishing returns apply and there is little further benefit in terms of species persistence.

TASK OUTPUTS: A set of guidelines that can be used to inform specific management decisions and discussions on offset policy, by providing 'ballpark figures' for viable population sizes for a range of ecological groups that are commonly encountered by the gas industry.

SPECIFIC DELIVERABLES: Guidelines for offset plantings tailored to previously defined ecological groups of locally relevant rare plants, to be included into the final report (task 6).

Task 5

TASK NAME: Client workshop

TASK LEADER: Alexander Schmidt-Lebuhn

OVERALL TIMEFRAME: April – May 2018

BACKGROUND: A client workshop is ideal for communicating research results directly to end users, to answer their questions, and to obtain feedback. It will also allow us to bring together different groups of stakeholders such as consultants, industry, academics and regulators to inform both specific operations on the ground and future policy development.

TASK OBJECTIVE: To organise and conduct a client workshop.

TASK OUTPUTS: Communication and discussion of results, engagement of stakeholders.

SPECIFIC DELIVERABLES: A client workshop, most likely taking place in Brisbane, to explain results and implications for offset planning to various groups of stakeholders, and to discuss their practical application.

Task 6

TASK NAME: Delivery of report

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: June 2018

BACKGROUND: Project report is a key deliverable, and it will communicate the results.

TASK OBJECTIVE: Communication of results through a written report.

TASK OUTPUTS: Final report.

SPECIFIC DELIVERABLES: Final report.

14. Communications Plan

Communication of the results of the project will be managed in accordance with GISERA's communication strategy. Specifically,

- presentations will be delivered at GISERA meetings as appropriate, such as knowledge transfer sessions;
- regular progress reports will be communicated to GISERA;
- the model will be published in a scientific article;
- a factsheet on the results will developed;
- towards the end of the project a client workshop will be conducted to communicate the results and their implications for management and policy to various stakeholders including community groups, industry, consultants and the state government; and
- a final project report will be prepared for GISERA.

Options for promoting and raising awareness of the research findings and their application have been discussed with GISERA communications manager Tsuey Cham. Possibilities include a short video or animation, press releases or articles

The project will establish a Technical Reference Group (TRG) aimed at seeking peer-to-peer technical advice on contextual matters and to discuss research needs as well as outputs as the project progresses. The TRG will include the project leader and a group of different stakeholders as appropriate.

15. Intellectual Property and Confidentiality

<table>
<tr><td rowspan="3">Background IP (clause 11.1, 11.2)</td><td>Party</td><td>Description of Background IP</td><td>Restrictions on use (if any)</td><td>Value</td></tr>
<tr><td></td><td></td><td></td><td>$</td></tr>
<tr><td></td><td></td><td></td><td>$</td></tr>
<tr><td>Ownership of Non-Derivative IP (clause 12.3)</td><td colspan="4">CSIRO</td></tr>
<tr><td>Confidentiality of Project Results (clause 15.6)</td><td colspan="4">Project Results are not confidential.</td></tr>
<tr><td>Additional Commercialisation requirements (clause 13.1)</td><td colspan="4">NA</td></tr>
<tr><td>Distribution of Commercialisation Income (clause 13.4)</td><td colspan="4">NA</td></tr>
<tr><td rowspan="4">Commercialisation Interest (clause 1.1)</td><td colspan="2">Party</td><td colspan="2">Commercialisation Interest</td></tr>
<tr><td colspan="2">APLNG</td><td colspan="2">NA</td></tr>
<tr><td colspan="2">QGC</td><td colspan="2">NA</td></tr>
<tr><td colspan="2">CSIRO</td><td colspan="2">NA</td></tr>
</table>

2 Variations to Project Order

Changes to research Project Orders are approved by the GISERA Director, acting with authority provided by the GISERA National Research Management Committee, in accordance with the National GISERA Alliance Agreement.

The table below details variations to research Project Order.

Register of changes to Research Project Order

Date	Issue	Action	Authorisation

3 Progress against project milestones

Progress against milestones are approved by the GISERA Director, acting with authority provided by the GISERA National Research Management Committee, in accordance with the National GISERA Alliance Agreement.

Progress against project milestones/tasks is indicated by two methods: Traffic Light Reports and descriptive Project Schedule Reports.

1. Traffic light reports in the Project Schedule Table below show progress using a simple colour code:
   - Green:
     - Milestone fully met according to schedule.
     - Project is expected to continue to deliver according to plan.
     - Milestone payment is approved.
   - Amber:
     - Milestone largely met according to schedule.
     - Project has experienced delays or difficulties that will be overcome by next milestone, enabling project to return to delivery according to plan by next milestone.
     - Milestone payment approved for one amber light.
     - Milestone payment withheld for second of two successive amber lights; project review initiated and undertaken by GISERA Director.
   - Red:
     - Milestone not met according to schedule.
     - Problems in meeting milestone are likely to impact subsequent project delivery, such that revisions to project timing, scope or budget must be considered.
     - Milestone payment is withheld.
     - Project review initiated and undertaken by GISERA Research Advisory Committee.

2. Progress Schedule Reports outline task objectives and outputs and describe, in the ‘progress report’ section, the means and extent to which progress towards tasks has been made.

Project Schedule Table

ID	Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Pre-development of model (stakeholder workshop & research)	Francisco Encinas-Viso	Jan-17	Feb-17	
Task 2	Development of model	Francisco Encinas-Viso	Mar-17	Jun-17	Task 2
Task 3	Simulations: sensitivity analysis and effects of environmental variation	Francisco Encinas-Viso	Jul-17	Dec-17	Task 3
Task 4	Development of guidelines	Alexander Schmidt-Lebuhn	Jan-18	Mar-18	Task 4
Task 5	Client workshop	Alexander Schmidt-Lebuhn	Apr-18	May-18	Task 5
Task 6	Delivery of report	Francisco Encinas-Viso	Jun-18	Jun-18	Task 6

Project Schedule Report

Task 1

TASK NAME: **Pre-development of model**

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: January-February 2017

BACKGROUND: Biological and ecological knowledge of the species studied is a basic requirement to do population viability analysis. Therefore, more accurate and relevant estimations of population persistence are only possible with good background knowledge and data of the species studied.

TASK OBJECTIVE: To decide what sources of environmental variation (e.g. temporal variation) and plant life-history traits will be included in the model, and to decide for what groups of plants guidelines are required. For the former, a review of the relevant scientific literature will be conducted. For the former and the latter, a workshop will be conducted to bring together selected ecologists with relevant expertise and stakeholders (e.g. industry, consultants, regulators) who can nominate plant species. Collect any available data for the nominated species.

TASK OUTPUTS: Determination of what parameters will be included in the model, and for what groups of plants guidelines will be developed.

SPECIFIC DELIVERABLES: Workshop, list of critical ecological and genetic parameters for inclusion in the model, and list of plant groups capturing specific examples relevant to offset work in the Queensland CSG area.

PROGRESS REPORT:

The workshop was held at the Spring Hill CSIRO venue in Brisbane on 24 February 2017. The workshop gave the opportunity to meet the different stakeholders of the project (scientists, government, consultants and industry) to discuss several aspects of the offsetting work at the Queensland CSG areas and the different factors related to plant population viability.

The workshop started with three introductory talks, including one from the invited speaker (Prof. Margaret Mayfield, UQ) about factors affecting long-term plant population viability. Finally, two activity groups were done to: 1) create a list of species relevant for the offsetting work, 2) gather biological and ecological information from those species and 3) create groups of the nominated species based on their biology. We ended with a group discussion about factors (including specific parameters related to life-history traits) to consider for the modelling work and the exploration of different environmental conditions.

Tasks performed:

- Selection of plant species to include in the modelling work.
- Gathering biological/ecological information from the nominated species.
- Creation of species groups based on their life-history traits and ecology.
- Discussion of ecological factors to consider for the modelling work.

Task 2

TASK NAME: Development of model

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: March-June 2017

BACKGROUND: The simulation model will be developed to be flexible enough to accommodate the different sets of life-history traits from the different plant groups. Debugging and testing the performance of the model will be essential to avoid erroneous predictions and improve the computational efficiency of the program.

TASK OBJECTIVE: Test performance of the simulation and explore the parameter space.

TASK OUTPUTS: Efficient and tested simulation model that will be used for subsequent simulation analyses.

SPECIFIC DELIVERABLES: A software tool implementing the population model needed to run simulation analyses.

PROGRESS REPORT:

The main model (spatially and genetically explicit) has been developed and tested for performance. We have also included fire as an environmental factor to study the effect of catastrophes (and bonanzas) and environmental variation on population viability. This is an important factor that should be studied in Task 3. Furthermore, we have implemented in the model the estimation of two valuable outputs to predict population viability (Log stochastic population growth and quasi-extinction threshold risk curves).

Tasks performed:

- Development of model to incorporate all the life-history traits identified in the workshop from the main plant groups (Acacia, eucalypts, grasses and insect-pollinated herbs).
- Debugging and testing computational performance of the model.
- Implementation of fire in the simulation model as an environmental factor and estimation of Log stochastic population growth and quasi-extinction threshold risk curves.
- Exploration of parameter space for a single plant group (insect-pollinated herbs).

Task 3

TASK NAME: Simulations – Sensitivity analysis and effects of environmental variation

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: June-December 2017

BACKGROUND: Sensitivity analysis helps us to identify what vital rates (e.g. adult fecundity, seedling survival) and population parameters (e.g. population size) are more important for population viability. Therefore, this analysis is important to evaluate different population offsetting options (e.g. population size, number of populations and connectivity), to maximize overall viability. The use of available data for some of the species will be extremely useful to get more accurate predictions. It is also important to evaluate the effects of environmental variation on population viability since uncertainty in vital rates and changes of populations is partly linked to stochastic changes in the environment and can have negative effects to population persistence.

TASK OBJECTIVE: Conduct a sensitivity analysis for each plant group to detect key vital rates that might be highly affected by changes in population size. Explore the effects of stochastic temporal variation to assess, for example, the consequences of potential catastrophes (e.g. droughts) on population viability.

TASK OUTPUTS: Projections of population growth and size (based on estimates of the mean and their associated uncertainty) for each plant group with and without environmental variation. Identification of key vital rates for population viability detected by the sensitivity analysis.

SPECIFIC DELIVERABLES: Identification of key vital rates and predictions of population sizes and growths under different ecological scenarios for each plant group.

PROGRESS REPORT:

We conducted sensitivity analyses for each plant group (i.e. Acacia, Eucalypts, herbs and grasses) to: 1) Detect key vital rates for each plant group and 2) Quantify regions of high population viability and quasi-extinction thresholds under environmental stochasticity. A thorough literature review to parameterize the models was done based on the species list obtained from the workshop.

High levels of environmental stochasticity as expected, affected all plant groups. However, Acacias were particularly resilient to disturbances due to their large fecundity (i.e. large production of viable seeds) and seed longevity (i.e. seed bank). We detected two key vital rates of Acacias: fertility and seed mortality rates. In simulated scenarios where Acacia seed longevity and fertility rates are drastically reduced, long-term population growth can rapidly drop to critical extinction threshold levels if facing large environmental disturbances. On the contrary, the eucalypt group was the most affected when high environmental disturbances critically increased the mortality of young age classes (e.g. seedlings).

The sensitivity analysis of insect-pollinated herbs with self-incompatibility mating systems showed that adult reproductive survival was critical for long-term population viability. Regions of high population viability, obtained by estimating adult population size, stochastic log growth rate and quasi-extinction thresholds, can be attained with small increases of adult reproductive survival and fecundity rate. Simulations of the grass group did not differ much from insect-pollinated herbs results, however grasses were more resilient and could rapidly regrow after environmental catastrophes (e.g. fire), while insect-pollinated herbs were more sensitive to disturbances particularly when starting with small population sizes (i.e. less than 100 individuals).

Initial population sizes and structure have certainly a major effect on long-term population growth and viability for any plan group. On one hand, initial population sizes were more critical for plant groups with self-incompatibility mating systems such as insect-pollinated herbs and some grass species. Low mate availability drove very quickly populations to extinction in insect-pollinated herbs when adult survival rates were low. On the other hand, the initial population structure (population age structure), as expected, can have an enormous impact on long-term population growth. Populations of long-lived species with slow growth, such as eucalypts, can go rapidly to minimum viable population sizes (less than 15 generations) when the initial population structure consisted mainly on a single age class group (particularly seedlings and juveniles). Population viability only improved when it was considered an initial age population structure consisted mainly of adult reproductive individuals. It is therefore, extremely important to consider this factor when planning population offsetting of long-lived woody species.

The analyses have produced viable population sizes and demographic projections under different environmental conditions that will be used to develop the guidelines to improve management decisions and current population offsetting policies.

Task 4

TASK NAME: Development of guidelines

TASK LEADER: Alexander Schmidt-Lebuhn

OVERALL TIMEFRAME: January-March 2018

BACKGROUND: Science-based guidelines are necessary for more efficient and cost-effective management decisions for offset planning. The information collected from the first workshop with stakeholders and the simulation analysis of the different plant groups will set general and basic guidelines for plant population offsetting management that will consider important aspects of plant ecology and genetics.

TASK OBJECTIVE: To use the results of simulation analyses (task 3) to develop guidelines on the approximate viable population size and the approximate number beyond which diminishing returns apply and there is little further benefit in terms of species persistence.

TASK OUTPUTS: A set of guidelines that can be used to inform specific management decisions and discussions on offset policy, by providing 'ballpark figures' for viable population sizes for a range of ecological groups that are commonly encountered by the gas industry.

SPECIFIC DELIVERABLES: Guidelines for offset plantings tailored to previously define ecological groups of locally relevant rare plant s, to be included into the final report (task 6).

PROGRESS REPORT:

We have written science-based guidelines for each of the plant groups based on a literature review, engaging with stakeholders and the simulation modelling analysis, which specifically: 1) identified key vital rates for each plant group (Acacia, eucalypts, insect-pollinated herbs and grasses) for long-term population growth with a sensitivity analysis and 2) estimated offset sizes that maximise population viability under different scenarios (including environmental disturbances, such as fire). The guidelines aims to improve current population offsetting practices by making it cost-effective as well as increase the success of plant population offsetting. The groups of plant species considered here are representative of the Brigalow where the CSG development has been taking place. Therefore these guidelines, although as general as possible, might need to be improved when considering species from other types of habitats (for example, temperate areas).

We suggest that more accurate estimates of population viability considered already in the population viability analysis literature (e.g. log stochastic growth and quasi-extinction probabilities) can be used as measures of 'effectiveness' or 'success' rates for plant population offsets (i.e. restoration offsets), as those implemented in the calculation of biodiversity losses and gains.

Finally, our analysis makes specific recommendations for each plant group in terms of offset ratios that can be used to inform practitioners and policy makers to: 1) incorporate scientific knowledge into the current policy framework and 2) improve current plant population offsetting practices.

Our main recommendation based on our modelling analysis is that mitigation and control of disturbances (e.g. fire, weeds) on offset sites can be more effective maximising population viability than restoring offset sites using inflated multipliers (e.g. 10:1). This is particularly important for long-lived woody species such as eucalypts and cycads.

Task 5

TASK NAME: Client workshop

TASK LEADER: Alexander Schmidt-Lebuhn

OVERALL TIMEFRAME: April – May 2018

BACKGROUND: A client workshop is ideal for communicating research results directly to end users, to answer their questions, and to obtain feedback. It will also allow us to bring together different groups of stakeholders such as consultants, industry, academics and regulators to inform both specific operations on the ground and future policy development.

TASK OBJECTIVE: To organise and conduct a client workshop.

TASK OUTPUTS: Communication and discussion of results, engagement of stakeholders.

SPECIFIC DELIVERABLES: A client workshop, most likely taking place in Brisbane, to explain results and implications for offset planning to various groups of stakeholders, and to discuss their practical application.

PROGRESS REPORT:

The workshop was held at Saxons training facilities in Brisbane CBD on 28 May 2018. The workshop was extremely useful to discuss the results of the modelling work with the different stakeholders of the project (scientists, government, consultants and industry) and their implications for: 1) the offsetting work at the Queensland CSG areas and 2) to improve current plant population offsetting policies at Federal and Queensland Government.

The workshop started with two introductory talks, one from Alexander Schmidt-Lebuhn (CSIRO) introducing the project and main objectives, and one from the invited speaker (Dr Laura Simmons (Queensland's Herbarium) (replacing Prof Shapcott) about a meta-analysis of translocation and offset data across Australia, which contains data about offset success rates. The talk of Dr Simmons was very interesting and well received by the participants as it provided important insights about problems related to the failure of offsetting work in plants. After these introductory talks, Francisco Encinas-Viso (CSIRO) presented the main results of the modelling work with specific recommendations for each plant group studied and general recommendations to improve the effectiveness of plant population offsetting. General implications for management and policy were also discussed at the end of the talk.

Finally, one activity group was done to discuss the results of the modelling work within each group. We ended with a group discussion summarising the most important results and implications for plant population offsetting work. Some of the main points that were raised as important for future work and the guidelines were: 1) Incentivising more long-term monitoring of offset results, 2) Identifying the main mortality factors (e.g. fire, drought, pathogens) for each plant species and 3) Getting more information about life-history traits, genetics and demographic data of the targeted species. The implementation of research project offsets, as done in the offsetting guidelines of Western Australia, was discussed as an excellent alternative for cases where uncertainty (e.g. lack of information) about population viability and biology of the species is high. Considering classifying plants by their life history or life form to improve current offsetting policies and their related multipliers in Queensland was discussed as something relevant to discuss for the new offsetting policy framework.

Tasks performed:

- Present modelling results and recommendations for each plant group studied.
- Discussion of policy and management implications for each plant group.
- Take note of main recommendations and feedback from stakeholders to incorporate in the guidelines.

Task 6

TASK NAME: Delivery of report

TASK LEADER: Francisco Encinas-Viso

OVERALL TIMEFRAME: June 2018

BACKGROUND: Project report is a key deliverable, and it will communicate the results.

TASK OBJECTIVE: Communication of results through a written report.

TASK OUTPUTS: Final report.

SPECIFIC DELIVERABLES: Final report.

PROGRESS REPORT

The final report of the project has been completed. This report communicates all the results and recommendations for each plant group studied as well as general recommendations for plant population offsetting. The guidelines aims to improve current population offsetting practices by making it cost-effective as well as increase the effectiveness of plant population offsetting. The groups of plant species considered here are representative of the Brigalow where the CSG development has been taking place. Future directions for this work include increasing the amount of biological information for plant species where there is limited information (e.g. Ooline) as well as information about offset success and demographic data for the plant groups studied in the project.