Submission

2016 National Research Infrastructure Roadmap Capability Issues Paper

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Question 1: Are there other capability areas that should be considered?

Question 2: Are these governance characteristics appropriate and are there other factors that should be considered for optimal governance for national research infrastructure.

Question 3: Should national research infrastructure investment assist with access to international facilities?

Question 4: What are the conditions or scenarios where access to international facilities should be prioritised over developing national facilities?

Question 5: Should research workforce skills be considered a research infrastructure issue?

Question 6: How can national research infrastructure assist in training and skills development?

Question 7: What responsibility should research institutions have in supporting the development of infrastructure ready researchers and technical specialists?

Question 8: What principles should be applied for access to national research infrastructure, and are there situations when these should not apply?

- There should be no restrictions on access to research infrastructure for bona-fide public good research;
- Contemporaneous co-use of infrastructure by multiple parties should not be unreasonably restricted by publication embargos unless it can be clearly shown new requests for use of infrastructure would disadvantage the initial user, particularly if for a degree requiring original research;
- Free access for commercial purposes should be restricted, but not prohibited. Consider charges for accessing infrastructure for commercial purposes;
- Parties contributing their own data to national research infrastructure should be able to freely access that data and be consulted when requests are made to access that data.

Question 9: What should the criteria and funding arrangements for defunding or decommissioning look like?

Question 10: What financing models should the Government consider to support investment in national research infrastructure?

Question 11: When should capabilities be expected to address standard and accreditation requirements?

Yes, and consider making standards and accreditation available to enterprises outside of the research infrastructure communities, who maintain measurement programs and sensor network that generate data that could be re-used for wider benefit.

Question 12: Are there international or global models that represent best practice for national research infrastructure that could be considered?

Question 13: In considering whole of life investment including decommissioning or defunding for national research infrastructure are there examples domestic or international that should be examined?

Question 14: Are there alternative financing options, including international models that the Government could consider to support investment in national research infrastructure?

NCRIS investment in national research infrastructure that leverages on considerable co-investment by institutions represents good value. TERN is a good example of this. Prior to the TERN investment there was little national integration of research infrastructure in environment and natural resource management. The co-investment was there but the national benefit was restricted because efforts largely focussed on local questions and independent measurement protocols. That existing co-investment is important because it signals a strong commitment by the institutions involved in local sites – this commitment is the fundamental foundation needed to ensure longevity of sites a factor critical for effective research infrastructure in environment and natural resource management where management actions can require long periods to become evident and threshold responses as the result of cumulative actions are unpredictable. Thus the TERN investment buys national co-ordination and standardisation among sites, which have already made strong commitment to providing the foundation for longevity. The case of how TERN investment has capitalised on existing co-investment is shown be example for the case of the Warra Long-Term Ecological Research Site in Tasmania. An attached summary of the research investment at Warra and what that investment has generated is described in the attached document.

Health and Medical Sciences

Question 15: Are the identified emerging directions and research infrastructure capabilities for Health and Medical Sciences right? Are there any missing or additional needed?

Question 16: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 17: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Health and Medical Sciences capability area?

Environment and Natural Resource Management

Question 18: Are the identified emerging directions and research infrastructure capabilities for Environment and Natural Resource Management right? Are there any missing or additional needed?

Better integration of bottom-up applications, e.g. sensor networks providing data to support local operational decisions, with top-down applications such as Earth system models and remotely-sensed products. Rapid expansion of sensor technologies and enterprise-level applications that use the data they generate provides a missing scale – high-resolution measurements at fine spatial scales across broad areas. Integrating high resolution measurements from networks of ground sensors with continental models fed by remotely-sensed satellite data could improve the quality of information in areas where variation occurs at small spatial scales, such as regions of steep bio-physical gradients.
Should consider a capability paralleling ALA for the capture and reuse of biological data from a variety of sources to enable the capturing and reuse of sensor measurements from a variety of sources.

Question 19: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 20: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Environment and Natural Resource Management capability area?

Advanced Physics, Chemistry, Mathematics and Materials

Question 21: Are the identified emerging directions and research infrastructure capabilities for Advanced Physics, Chemistry, Mathematics and Materials right? Are there any missing or additional needed?

Question 22: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 23: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Advanced Physics, Chemistry, Mathematics and Materials capability area?

Understanding Cultures and Communities

Question 24: Are the identified emerging directions and research infrastructure capabilities for Understanding Cultures and Communities right? Are there any missing or additional needed?

Question 25: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 26: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Understanding Cultures and Communities capability area?

National Security

Question 27: Are the identified emerging directions and research infrastructure capabilities for National Security right? Are there any missing or additional needed?

Question 28: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 29: Is there anything else that needs to be included or considered in the 2016 Roadmap for the National Security capability area?

Underpinning Research Infrastructure

Question 30: Are the identified emerging directions and research infrastructure capabilities for Underpinning Research Infrastructure right? Are there any missing or additional needed?

Difficulty in industry users in gaining access to high capacity networks was recognised but not identified as a priority for resolving. Response to question 18 indicated a likely growth in enterprise-level data from sensor networks. Once the enterprises use this data for their needs it becomes an overhead to retain the data. The cumulative endeavours of individual enterprises in collecting “operational” data from individual sensor networks is likely to far exceed the data collected by national facilities such as TERN and its capture for re-use by the research community would reap considerable national benefit. In the cases of big data generated by, say, imagery and bioacoustics sensors the cost and time required for enterprises to transfer the data onto national computer infrastructure is a disincentive. Regional nodes to access high capacity networks could be considered. The decision on where to locate such nodes could be based on a national audit to identify regions of high concentration of enterprise-level sensor networks.

Question 31: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 32: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Underpinning Research Infrastructure capability area?

Data for Research and Discoverability

Question 33 Are the identified emerging directions and research infrastructure capabilities for Data for Research and Discoverability right? Are there any missing or additional needed?

Question 34: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 35: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Data for Research and Discoverability capability area?

Other comments

See attached document signalled in question 14.

Warra: research infrastructure investments and use before and after the creation of TERN

Much of the focus of national research infrastructure such as TERN is towards supporting continental and global knowledge needs. However, the infrastructure also supports the knowledge needs for dealing with more regional issues, particularly those associated with land management practices. Warra is used as an example of how research infrastructure is being used to support these more regional land management issues.

1. The first 15 years (1995-2010)

Warra was formally established as a long-term ecological research (LTER) site in 1995. The model was for a site, which was chosen because of its representativeness of a forest type important to the Tasmanian environment and economy[1], to provide an enabling framework for long term ecological research and monitoring that could capitalise on short-term funding cycles[2]. The establishment of Warra as an LTER site was also the catalyst for creating an informal network of Australian LTER sites, co-ordinated within the Bureau of Rural Sciences. This allowed Australia to participate in the International LTER Network[3].

The first 15 years of research at Warra was successful in developing a long-term research program that capitalised on short-term funding cycles. Six "Icon" (long-term) research trials, plus a Bureau of Meteorology automatic weather station were established during that period. These six Icon studies hosted projects funded by: eight Australian Research Council Linkage (or SPIRT) and Discovery grants; two large grants from Forest and Wood Products Australia; projects within five Co-operative Research Centres; and project-specific funding from the Commonwealth and State Governments under the Tasmanian Community Forest Agreement. Appendix 1 lists the six Icon studies and the research grants they attracted.

A crucial aspect for the early success of Warra was a strong institutional commitment of the Warra partner organisations: Forestry Tasmania, University of Tasmania, Forest Practices Authority, Department of Primary Industries, Parks, Water and Environment, CSIRO, Forest and Forest Industries Council (now defunct), Department of Agriculture and Water Resources. The partner institutions through representation on the Warra Policy Committee have guided the continual evolution of a research agenda that reflects the most pressing issues surrounding the management of Tasmania's tall, wet eucalypt forests (Table 1).

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[1] Neyland, M., Brown, M., Su, W. (2000) Assessing the representativeness of long-term ecological research sites: a case study at Warra, Tasmania. *Australian Forestry*, **63(3)**: 194-198.

[2] Brown, M. and Elliott, H., Hickey, J. (2001) An overview of the Warra Long-Term Ecological Research Site. *Tasforests*, **13(1)**: 1-8.

[3] Bradley, J., Howell, C., Brown, M., Norman, P. (2000) Australia's Long Term Ecological Research Forest Sites. Pages 8-13 in P. Sprott (Ed) *The International Long Term Ecological Research Network 2000. Perspectives from Participating Networks.* The US Long Term Ecological Research Network Office, Albuquerque New Mexico.

Having established long-term studies to address specific questions, the drivers for ongoing maintenance and timely re-measurement of those studies may change. Forest certification has provided such a driver in the case of forests managed for timber production. Certification creates the need for an adaptive management framework: forest managers need to demonstrate the operational use of research-informed management practices that are applied widely across the landscape is providing the intended outcomes predicted from intensive, site-based research. This creates the need for programs of effectiveness monitoring that are financially sustainable and have the necessary sensitivity to detect change, or lack-thereof, to an agreed level of confidence.

Table 1. A summary of the research drivers, research results and outcomes of research for four of the initial "Icon" (long-term) studies established at Warra.

Silvicultural Systems Trial (1998) Driver: Tasmania Regional Forest Agreement (1997) noted as a priority for research on examining the commercial viability of alternative techniques (to clearfelling) for harvesting and regenerating wet eucalypt forests. Results: Aggregated retention shown to be a viable alternative (Neyland, Hickey and Read, 2010, *Australian Forestry*, **75(3)**: 147-162) Outcome: Supplementary Tasmanian Regional Forest Agreement (2005) - Clause 30 – gave effect to the intent of the Commonwealth and Tasmanian governments for non-clearfell harvesting techniques be used of 80% of harvesting operations in areas of oldgrowth by 2010. The translation of research findings into operational practices to enable this has been documented: Forestry Tasmania (2009). *A New Silviculture for Tasmania's Public Forests: a review of the variable retention program.* Forestry Tasmania, Hobart. 107 pp.	***Log Decay Study (1999) and CWD research*** Driver: Uncertainty about consequence of shorter rotations in production forests on species dependent on large logs from mature trees coupled with need to model future availability of CWD habitat in production areas, particularly in the context of harvesting residues for biomass energy (Raison *et al*., 2002, *Review of the science relevant to the sustainable use of native and plantation forest-harvesting residues for energy production in Tasmania*. Report for John Holland by CSIRO). Results: Large logs from mature trees provide a distinctive habitat that supports a saproxylic community different from smaller logs from younger trees. CWD decay rates established and used to develop CWD dynamics model. Model predicts second and subsequent rotations (as long as 200 years) of clearfell harvesting will have greatly reduced volumes of CWD in large logs from mature trees. Aggregate retention harvesting identified as best mitigation measure. Outcome: CWD prescriptions for managing CWD habitat on public native forest (timber production) written and adopted.
Warra Hydrology (1998) Driver: Comprehensive review of the soil and water provisions in the Forest Practices Code in 1999 identified knowledge gaps relating to the effectiveness of the current Class 4 stream prescriptions. Results: Autotrophic but not heterotrophic processes recovered quickly after clearfell harvesting: sustained depression in CWD inputs after clearfelling. Outcome: Revised management prescriptions for class 4 streams were developed and endorsed by the Forest Practices Advisory Council and the board of the FPA and the new guidelines were implemented	***Experimental Forest Landscape (2007)*** Driver: 2009 review of the biodiversity provisions of the forest practices system identified the need for more guidance for planning at multiple spatial and temporal scales, particularly in relation to mature forest habitat. Results: Populations of plants and birds in retained mature forest are quite resilient to amount of disturbance in surrounding 1-km landscape. However, populations of a significant subset of mature-forest affiliated species of birds and plants in regenerating forest declined with increasing disturbance in surrounding 1-km landscape. Outcome: Landscape Context Planning System

through an administrative instruction to Forest Practices Officers in 2003.	introduced by Forestry Tasmania. Target of 90% of harvested coupes have at least 20% forest in the surrounding 1 km landscape set-aside in long-term retention.

The critical elements for effectiveness monitoring are dealing with scale issues – both temporal and spatial. Forest processes, such as succession after harvesting (or wildfire), occur over multi-decadal time-scales (or even century time-scales). Broad-scale effectiveness monitoring across such time-scales to detect biological effects need to concentrate efforts at particular time periods when the effects become apparent. In the case of the effectiveness of aggregated retention as an alternative to clearfelling, the biological effect that is being sought is the more rapid return of the harvest areas towards the pre-harvest state in areas harvested using aggregated retention compared with areas harvested by clearfelling. Regular monitoring of those treatments in the Silvicultural Systems Trial, say at decadal intervals, to detect when such divergence begins to develop usefully informs when monitoring of operationally harvested areas in the wider landscape would be worthwhile.

2. The initial TERN period (2010-2016)

The establishment of TERN infrastructure at Warra coincided with a period of dramatic re-shaping of the policy settings and use of Tasmania's public forests. Warra was a microcosm of this re-shaping: a major proportion of the public production forest areas within Warra, including virtually all of the areas housing TERN-funded infrastructure, was added to the Tasmanian Wilderness World Heritage Area in 2013. Despite this, the original Warra partner organisations, including the Tasmanian government, have remained committed to the site.

The TERN infrastructure investment was pivotal in maintaining partner commitment to Warra. The TERN investment coincided with a transition in the research agenda for Warra from one of understanding the impacts of forest management on the components of the forest (particularly biodiversity) to understanding the processes that support the forest components. The TERN investment also coincided with the transition away from traditional aerial photo-interpretation and forest inventory approaches for wood-flow planning and sustained yield calculations to using LiDAR coupled with algorithms that model forest attributes. Together, these changes have provided the opportunity to re-purpose Warra so the infrastructure provides data that is relevant to the needs of a broader range of end users. Despite the short time TERN infrastructure has been operating at Warra, there has been significant engagement with an expanded range of end-users to use that infrastructure / data. The following section provides seven examples of how TERN infrastructure and data at Warra is being used.

1. ***Future sustainable yields from southern wet eucalypt forests***
   The tall *Eucalyptus* forests of southern Tasmania make a major contribution to the sustained yield supply of saw and veneer logs from public native forests to Tasmanian processors. Analysis of data from Warra OzFlux tower in southern Tasmania has discovered that the productivity of these tall *E. obliqua* forest is particularly sensitive

to warmer summertime temperatures when compared with flux measurements made in tall *Eucalyptus* forests further north (OzFlux sites at Wallaby Creek and Tumbarumba). Furthermore, the tall *Eucalyptus* forests in southern Tasmania overlap a region likely to experience among the future greatest summertime temperature increases in the State based on modelling by Climate Futures of Tasmania.
A project being done by Forestry Tasmania is examining the possible consequence of temperature-driven reductions in productivity of the southern tall *Eucalyptus* forests on the future sustained yield of saw and veneer logs. One outcome from that project will be to identify adaptation options to mitigate adverse impacts on the future sustained yield of saw and veneer logs from public native forests.

2. ***Certification of carbon emission intensity of the Gordon Power Scheme***
   The Gordon Power Scheme has the largest generating capacity of Tasmania's hydro-electric schemes. That scheme also has the greatest uncertainty around its carbon emission intensity – a central attribute of international renewable energy certification schemes. The reason for the high level of uncertainty surrounds quantifying the net changes to the carbon balance resulting from the flooding of a large forested river valley to create Lake Gordon. Hydro Tasmania have had to rely on data from comparable hydro schemes in Canadian boreal forests to inform its calculations of changes to carbon balance.
   The Warra OzFlux and Supersite (55 km southwest of Lake Gordon) is situated in tall *Eucalyptus* forest comparable to the forest submerged by the flooding of the Gordon River. It is planned that measurements of the carbon density and fluxes of the forest at the Warra Flux and Supersite Core 1-ha plot will be used to recalculate the carbon emission intensity as part of a planned campaign by Hydro Tasmania using local measurements.

3. ***Calibration of the Phoenix Fire Model for fuel accumulation rates in wet eucalypt forests***
   The current bushfire behaviour model used by Tasmanian fire management agencies is calibrated for tall eucalypt forests using data from Victoria. Climate modelling predicts greatly increased fire risk in Tasmania, particularly in the southeast. This region coincides with the tall *Eucalyptus* forests on the mountain ranges fringing Hobart. The combination of more frequent severe fire weather events and the high fuel loads generated in the tall *Eucalyptus* forests represents a potent future threat to the main population centre of Tasmania. For this reason, it is critical that the model used to predict fire behaviour is accurate as possible. Accordingly, the Tasmanian fire management agencies have funded a PhD study that will provide new data to better reflect fuel characteristics of the tall *Eucalyptus* forests of southern Tasmania. This study is being done using exiting vegetation data from AusPlots Forests plots; the Core plot of the Warra Supersite; and the Warra Wildfire Chronosequence Plots, together with additional measurements of standing fuels and fuel deposition rates in those plot networks.

4. ***Third party certification of Tasmanian and Victorian public production forests***
   A high priority for the Tasmanian and Victorian forest industries is for their public

production forest managers - Forestry Tasmania and VicForests, respectively - to achieve third-party certification against Forest Stewardship Council standards. This will maximise opportunities to sell their wood and timber into a wider range markets. A critical aspect of forest management that needs strengthening to achieve third-party certification is verifying that management to sustain biodiversity values, particularly those of high conservation value, is achieving the intended outcomes. To do this will require developing more cost-effective ways of monitoring biodiversity across large landscapes over time.

An ARC Linkage project, leveraging from TERN infrastructure and data at Warra is funding several projects to progress three prospective monitoring technologies: LiDAR for monitoring forest structural and floristic attributes; bioacoustics for monitoring birds and DNA metagenomics for monitoring beetles.

The AusCover high resolution, full-waveform LiDAR imagery obtained at the Warra Supersite is being used by a PhD student to develop ways of extracting information that describes structural and floristic attributes of the forest and of individual trees. Two honours projects are being done concurrently with this study to acquire measurements and metrics that can be used to ground-truth the high resolution LiDAR imagery and to infer mature forest attributes. Knowledge gained from these studies will help guide the development of algorithms that can be applied to operationally-acquired LiDAR imagery that currently exists, or is being acquired, across the Tasmanian and Victorian public production forest areas.

Bioacoustics data and annual bird census records acquired from the Warra Supersite are being used by a PhD student to progress prospective analytical approaches to accurately extract useful information from bioacoustics data.

The extensive collection of beetles and associated contextual information from nearly two decades of surveys at Warra are being used by a PhD student to develop analytical approaches to extract useful information from DNA metabarcodes to describe beetle communities.

5. ***Modelling the performance of* Eucalyptus *plantations***

Soils data from the National Soil and Landscape Grid was used in an analysis of the actual versus predicted productivity of *Eucalyptus* plantations in Tasmania's Permanent Timber Production Zone. This analysis is part of inter-rotational decision-making that Forestry Tasmania is doing. Gridded data (soils, climate, topography) was used to develop models to predict plantation productivity (measured using LiDAR imagery that FT has for its entire forest area). Separate models were developed for the two main plantation species - *E. globulus* and *E. nitens*. A comparison of actual versus predicted productivity for the two species identified areas where changes in species would result in greater productivity next rotation as well as areas with large deviations between expected and actual productivity. Future analysis will bring together historical data from forest health surveillance and operational practices to help discriminate sites with intractable problems that are better returned to native forests from those where specific events resulted in greater or lesser productivity. A better understanding of the practices or events that were associated with significant changes in productivity can be used to strengthen our management systems in subsequent rotations. Other plantation owners in southern Australia are

looking towards the analysis done by Forestry Tasmania with the view to use the same approach to make similar inter-rotational decisions for their estates.

6. ***Effectiveness monitoring of birds using bioacoustics***

   The design of a bioacoustics monitoring program that can be deployed operationally across public production forest landscapes will be fundamental to meeting the objectives of monitoring to evaluate how well management is achieving its intended outcomes. Forestry Tasmania, as part of its process of attempting to achieve Forest Stewardship Council (FSC) certification, is doing a project to design and deploy an operational bioacoustics monitoring program for evaluation.

   Previous research done at Warra, particularly landscape-scale studies done in the Southern Forests Experimental Forests Landscape anchored on Warra, will inform the design of an operational program. What that research tells us, and what the FSC standard requires, is that monitoring needs to be referenced against natural baselines where there are minimal effects of production forest management. The bioacoustics monitoring and annual bird census done at the Warra Supersite makes this an ideal candidate for a baseline natural forest site.

7. ***Effectiveness monitoring of Forest Practices Code prescriptions for headwater streams***

   The Forest Practices Code provides guidelines on how forestry operations need to be done to protect aquatic values. Harvesting operations in headwater streams are of particular concern because variation in code provisions for headwater streams have a large impact on forestry activities. Evidence that code provisions are protecting aquatic values will help in ensuring a good balance is struck between economic and environmental values.

   The Warra Weirs Hydrology study has monitored aquatic values in three pristine headwater streams since it was established in 1998. Funding received from TERN to operate the Warra Supersite has assisted the ongoing collection of data from the Warra Weirs Hydrology study in recent years. A planned harvest operation in the catchment of two of the three headwater streams in the study site will allow any effects of the harvesting operation on aquatic values to be evaluated in a Before-After-Control-Impact designed experiment.

Appendix 1: List of initial (pre-TERN) "Icon" (long-term) studies at Warra and the major project grants they have attracted

Silvicultural Systems Trial (1998) and variable retention research more broadly

- Forest and Wood Products Research and Development Corporation (Wood and Paper Industry Strategy): Evaluation of Montreal Process Indicator 4.1.c (Management of the risks to soil physical properties)
- Australian Research Council – Linkage Grant (LP0211170): "*Social Acceptability of Forest Management Systems*"
- Tasmanian Community Forest Agreement – accelerate the completion of biodiversity assessments in the SST.
- CRC for Forestry – PhD studies on (i) vegetation responses to a range of alternatives to clearfelling of tall, wet eucalypt forests; (ii) response of small mammals to VR and CBS harvesting
- Australian Research Council – Linkage Grant (LP100100050): "*Managing variable retention harvesting to maintain forest biodiversity—effects of forest influence and successional stage on recolonisation*".

Warra Weirs Hydrology (1998) and hydrology research more broadly

- Australian Research Council – Linkage Grant (LP0210383): "*How does Forestry Impact Headwater Streams?*"
- CRC for Forestry – PhD Scholarship, support for landscape characterisation for Warra broad-scale stream monitoring

Log decay study (1999) and Coarse Woody Debris research more broadly

- Australian Research Council – Strategic Partnerships with Industry – Research and Training (C19906735): "*Ecologically sustainable forest management: fungal and invertebrate biodiversity*" – post-doctoral and PhD study.
- CRC for Sustainable Production Forestry – two PhD studies comparing invertebrate and fungal communities in living trees of regrowth and mature *E. obliqua*.
- CRC for Forestry – PhD study examining the autecology of selected saproxylic beetle species.
- Australian Research Council – Linkage Grant (LP0989609): "*Managing for persistence of the saproxylic biota in production forest landscapes*"

Mt Weld Altitudinal Transects (1999)

- DIVERSITAS - International Biological Observation Year

Wildfire Chronosequence Plots (2006)

- Bushfire CRC – establishment of WCP plots

- Australian Research Council – Discovery Grant (DP120101735): "*Methane uptake of forest soils*"
- Bushfire and Natural Hazards CRC – fuel / litter accumulation rates in tall, wet eucalypt forests as a function of time since last fire.

Experimental Forest Landscape (2007) and landscape-scale research more broadly

- Australian Research Council – Linkage Grant (LP0561751): "*Social acceptability of forest management options: Landscape-level visualisation and evaluation*"
- Forest and Wood Products Australia (PNC142-0809): "*Persistesence of mature forest biodiversity elements in a production forest landscape managed under a Regional Forest Agreement*"
- Australian Research Council – Linkage Grant (LP140100075): "*A new integrated approach for ecologically sustainable forest management*"