Monitoring the effectiveness of the biodiversity provisions of the Tasmanian *Forest Practices Code* 2022–23 summary report

Amelia Koch

Report to the Board of the Forest Practices Authority

Hobart, September 2023

FPA Scientific Report 36

Disclaimers

Front page photographs:

- Left: A masked owl caught to attach a transmitter (Photo: J. Wiersma)
- Top right: Masked owl eggs inside a hollow (Photo: D. James)
- Bottom right: A tracked masked owl leaving a hollow (Photo: J. Service).

Acknowledgements

Many thanks to the large number of people that have contributed to the project summaries covered in this report. The main collaborators are acknowledged in the relevant sections. The full project reports and papers should be referred to for greater detail, ethics approvals, scientific permits and for information on the funders who have supported the projects. We have only supplied information on funders here if no other report or publication is available.

Special thanks to the people who provided us with brief summaries of their work and have allowed us to include the results from their research undertaken independent of the Forest Practices Authority. Such research provides information that can be used to assess the effectiveness of the *Forest Practices Code* provisions.

Citation

This report should be cited as:

Koch, A 2023, *Monitoring the effectiveness of the provisions of the Tasmanian* Forest Practices Code: *2022–23 summary report,* September 2023, FPA Scientific Report 36, report to the Board of the Forest Practices Authority.

Table of Contents

Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ANU	Australian National University
ARC	Australian Research Council
BLL	Blood lead levels
CNBC	Central North burrowing crayfish (*Engaeus granulatus*)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DNA	Deoxyribonucleic acid
EPBC Act	*Environmental Protection and Biodiversity Conservation Act*
FGM	Faecal glucocorticoid metabolites
FPA	Forest Practices Authority
FPP	Forest Practices Plan
FWPA	Forests and Wood Products Australia
GPS	Global Positioning System
ICP-MS	inductively coupled plasma mass spectrometry
LiDAR	Light Detection and Ranging
NRE Tas	Department of Natural Resources and Environment Tasmania
NRM	Natural Resource Management
PTPZ land	Permanent Timber Production Zone land
RFF	Reliance Forest Fibre
RHAP	River Health Advisory Project
RHMP	River Health Monitoring Program
RWUS	Rural Water Use Strategy
SFM	Sustainable Forest Management
SPIBA	Swift Parrot Important Breeding Area
STSM	State and Transition Simulation Models
STT	Sustainable Timber Tasmania
TSA	Threatened Species Advisor
UTAS	University of Tasmania
XRF	X-ray fluorescence
WWW	Where? Where? Wedgie!

1. Executive summary

- The Tasmanian forest practices system follows an adaptive management framework which includes an emphasis on research, review and continual improvement.
- This report summarises projects by FPA staff and students, carried out during the 2022–23 financial year, as well a brief summary of projects done by other researchers (independent of the FPA), where the results contribute to our understanding of the effectiveness of the Tasmanian forest practices system.
- Two FPA-affiliated projects current in 2022–23 contribute to our understanding of the effectiveness of the *Forest Practices Code* provisions for biodiversity in general. One project is considering how the forest practices system should adapt to climate change, and one is examining if tree fern survival differs between partial harvest coupes subject to tree fern harvesting, and those without tree fern harvesting.
- There were 10 FPA-affiliated projects current in 2022–23 that contributed to our understanding of the effectiveness of *Forest Practices Code* provisions for threatened species. Species covered include wedge-tailed eagles, masked owls, swift parrots, Tasmanian devils and eastern quolls, giant freshwater crayfish, and Lake Fenton trapdoor spider. Many of these projects have been underway for several years. One of these projects has resulted in a change to management to eagle nests.
- Research not affiliated with the FPA continues to inform management and monitoring practices. Three major projects have potential implications for the design of production landscapes, and two have potential implications for stand level management. Three other projects are examining the biological impacts on forest health, and there are 5 baseline monitoring projects reported. There were also a number of projects examining threatened species issues.
- The results of research are used to improve management under the forest practices system. Over the last year range boundaries have been reviewed and a new approach to managing ‘derelict’ eagle nests has been developed.

2. Introduction

The Tasmanian forest practices system follows an adaptive management framework which includes an emphasis on research, review and continuing improvement. It is widely recognised that ongoing research and monitoring is important for the scientific credibility of the *Forest Practices Code'*s provisions applied in forest management plans (Commonwealth of Australia & State of Tasmania, 1997; Davies et al., 1999; Wilkinson, 1999). There is also a legislative requirement to monitor the effectiveness of *Forest Practices Code* provisions applied in forest practices plans. The Tasmanian *Forest Practices Act 1985* states that, 'the Board must…assess the implementation and **effectiveness** of a representative sample of forest practices plans'. In addition, Clause 7 of the procedures for the management of threatened species agreed with the Department of Natural Resources and Environment (FPA and DPIPWE, 2014) requires monitoring of the effectiveness of management actions for threatened species. With ongoing public scrutiny of forest practices in Tasmania, the scientific basis for particular *Forest Practices Code* provisions needs to be clear.

The overarching objective of Tasmania's forest practices system is 'to achieve sustainable management of Crown and private forests with due care for the environment and taking into account social, economic and environmental outcomes…'. A General principle for the management of biodiversity is 'Forest practices will be conducted in a manner that recognises and complements the contribution of the reserve system to the maintenance of biological diversity, ecological function and evolutionary processes through the maintenance of viable breeding populations and habitat for all species' (Forest Practices Authority, 2020). The Forest Practices Code and associated planning tools deliver a variety of actions that aim to meet the management objective for biodiversity in areas covered by the system. The processes, policies and strategies involved are outlined in (Munks et al., 2020). These have been developed from a mixture of expert judgement, practical experience and the outcomes of research and monitoring.

Information on the effectiveness of the biodiversity provisions of the *Forest Practices Code* was reviewed in 2012 (Koch et al., 2012). This review identified gaps and these were used as the basis for determining priorities for effectiveness monitoring of the *Forest Practices Code* (FPA, 2013). To identify priority monitoring projects, the management objectives and threats to values were linked with management actions. All threat/action pairs were assessed and ranked according to a range of attributes, such as the proportion of forestry operations or land area that may be affected, the effort to conduct effectiveness monitoring, the expected effectiveness of management, and degree of uncertainty about whether the management action is effective. This assessment was done both for the general *Forest Practices Code* provisions for biodiversity and the recommendations for threatened fauna delivered via the Threatened Species Adviser. See Box A and Box B for the highest priorities for Code provisions and threatened fauna provisions respectively (FPA, 2013). Priorities for threatened flora species were identified in 2018–19 as part of the development of management recommendations for the Threatened Plant Adviser, and a report is now available (Koch et al., 2022) (Box C).

Box A. The priorities identified for monitoring the effectiveness of the general biodiversity-related *Forest Practices Code* provisions (FPA, 2013), in bold if progressed in 2022–23.

1. Evaluate the degree to which the coupe dispersal guidelines limit the amount of harvesting within a subcatchment and thereby reduce impact on water flow
2. Determine the degree to which mature habitat availability is changing across the forest estate in Tasmania
3. Determine if hygiene measures help prevent spread of *Phytophthora cinnamomi*
4. **Determine whether significant habitat definitions for threatened species are adequate**
5. Determine whether wildlife habitat clumps help maintain forest birds, hollow users, fungi and bryophytes in forestry areas
6. Determine whether the mature habitat availability map can be used to assess availability of mature forest features (e.g. hollows and coarse woody debris)
7. Determine the degree of mature forest connectivity across the production forest estate
8. **Determine whether water quality is maintained in streams under current management**
9. Determine whether soil productivity is maintained over the long-term by current forestry practices.

Box B. The priorities identified for monitoring effectiveness of threatened fauna management provisions (FPA, 2013), with projects progressed in 2022–23 indicated in bold.

1. Assess effectiveness of giant freshwater crayfish management recommendations for managing changes in stream morphology and water quality
2. Assess effectiveness of Skemps and burgundy snails management recommendations for managing loss of habitat
3. Assess effectiveness of grey goshawk management recommendations for managing loss of foraging habitat
4. Assess effectiveness of keeled snail management strategy
5. **Assess effectiveness of eagle management recommendations for managing breeding failure due to disturbance**
6. Assess effectiveness of grey goshawk management recommendations for managing loss of nesting habitat
7. Assess effectiveness of swift parrot management recommendations for maintaining breeding habitat
8. **Assess effectiveness of masked owl management recommendations for maintaining potential nesting habitat**

Box C. Draft priorities identified for monitoring the effectiveness of threatened flora management provisions (Koch et al., 2022). In bold if research was done during 2022–23.

General

1. Effectiveness of *Phytophthora cinnamomi* management.
2. Effectiveness of surveys for identifying threatened plants.
3. The occurrence of threatened plants in plantations.
4. Effectiveness of the current management approach for three sites of potential significance for flora (rocky outcrops, swamps and inland *Eucalyptus amygdalina* forest).

Species specific

Rank	Species	Rank	Species
1	*Hibbertia calycina*	3	*Boronia hemichiton*
1	*Epacris moscaliana*	3	*Hibbertia rufa*
1	*Cyathea cunninghamii*	3	*Conospermum hookeri*
1	*Thynninorchis nothofagicola*	3	*Spyridium lawrencei*
		3	*Epacris virgata* Beaconsfield
2	*Blechnum spinulosum*	3	*Caladenia pallida*
2	*Euphrasia collina* subsp. *deflexifolia*	3	*Caladenia tonellii*
2	*Euphrasia collina* subsp. *gunnii*	3	*Epacris curtisiae*
2	*Euphrasia scabra*	3	*Epacris limbata*
2	*Euphrasia semipicta*	3	*Thelymitra jonesii*
2	*Isolepis habra*	3	*Pultenaea mollis*
2	*Pomaderris phylicifolia* subsp. *ericoides*	3	*Xanthorrhoea bracteata*
2	*Pomaderris phylicifolia* subsp. *phylicifolia*	3	*Epacris exserta*
2	*Sowerbaea juncea*	3	*Epacris apsleyensis*
2	*Thelymitra holmesii*	3	*Austrocynoglossum latifolium*
2	*Rhodanthe anthemoides*	3	*Bertya tasmanica* subsp. *tasmanica*
		3	*Eucalyptus perriniana*
		3	*Pomaderris pilifera* subsp. *talpicutica*
		3	*Prasophyllum crebriflorum*
		3	*Prasophyllum robustum*
		3	*Prasophyllum stellatum*
		3	*Pterostylis falcata*
		3	*Pterostylis grandiflora*
		3	*Cyathea* x *marcescens*
		3	*Hypolepis distans*

Work is done each year by FPA staff on a number of the priority effectiveness monitoring projects. The degree of effort depends on available funds, logistic considerations and staff/student availability. This report summarises findings from projects current during the 2022–23 financial year. It includes projects undertaken by FPA staff (mostly in collaboration with other research providers) and those done by other researchers (independent of the FPA) where the results contribute to our understanding of the effectiveness of actions taken for biodiversity values through the forest practices system.

3. Summary report on FPA research and effectiveness monitoring covered in 2022–23

This section provides short summaries of projects that have involved FPA staff.

3.1. General *Forest Practices Code* provisions for biodiversity

The following sub-sections provide a brief summary of the projects current in 2022–23 which contribute to our understanding of the effectiveness of actions and inform continual improvement of *Forest Practices Code* provisions.

3.1.1. Climate change

Tasmania is experiencing a changing climate. The FPA have undertaken a project to identify the ways in which production forests may be impacted, and potential ways the forest practices system could adapt in response.

Expert feedback was sought on the potential impacts of climate change on Tasmanian production forests, and ways that land managers could adapt in response. A report synthesising this information is available on the FPA website (Koch, 2022). The results of a stakeholder workshop exploring how the potential adaptation strategies might be actioned has also been drafted into a report (Koch, 2023). The information and potential adaptation actions outlined in these reports will be considered by the Board of the FPA.

3.1.2. Retention of *Dicksonia antarctica* under partial harvest

Dicksonia antarctica is a conspicuous and long -lived understorey species of the cool wet forests of south-eastern Australia. This species plays an important ecological role, via the provision of substrate for rainforest tree and shrub germination and as a support for the obligate and facultative epiphytic flora. Tree ferns are available for harvest in Tasmania under the Tree Fern Management Plan.

The Tree Fern Management Plan 2022 states that tree ferns can be harvested from partially harvested coupes as long as certain principles are met. These principles include that tree ferns would otherwise have been destroyed by the harvesting activities, and tree ferns will regenerate adequately on the site. To date, tree ferns have largely been harvested from clearfall coupes where it is more obvious that the tree ferns would be destroyed. However, some forms of partial harvest have a considerable impact on tree fern survival. Therefore, a study was initiated to determine if tree fern survival differs between partial harvest coupes subject to tree fern harvesting, and those without tree fern harvesting. The initial field methods planned were not suitable so a new technique, using drone imagery, is currently being trialled.

This study is being done in collaboration with STT.

3.2. Threatened species management

The following summaries are for projects current in the 2022–23 financial year that looked at the effectiveness of provisions for threatened fauna and flora species. They contribute to priority area A4 (Box A), threatened fauna project areas B5 and B8 (Box B).

3.2.1. Wedge-tailed eagles

The Tasmanian wedge-tailed eagle (*Aquila audax fleayi*) is listed as endangered at both a state and federal level. It is currently recognised as an endemic sub-species although a genetics study raised questions about this taxonomic status (Burridge et al., 2013). Management of this species under the forest practices system focuses on the nest site. Given the large number of wedge-tailed eagle nests recorded in Tasmania, there is considerable interest from industry to ensure effective and efficient management. During 2022–23 FPA staff were involved, to varying degrees, in four projects which contribute to our understanding of the effectiveness of management actions for this species.

FPA annual nest monitoring

The FPA Eagle Research and Monitoring Program was initiated in 2007 with the aim of monitoring the rate of nest success and the timing of breeding season events. This work was revised during 2015 to limit surveys to establishing the timing of the breeding season.

During the 2022–2023 breeding season annual nest monitoring surveys were completed in October 2022. The total number of nests flown was 283, of which 69 were identified as active (with nests containing either a young chick, egg or adult in an assumed incubation pose). A second round of flights was done in November 2022. Of the 19 nests where a chick could be aged, the last bird from the sample was expected to fledge on the 3/2/23 if using a 12-week hatchling phase. Given the lack of evidence indicating a late breeding season, the Eagle Management Constraint Period ended on the 31 January 2023.

Strategic eagle nest management

In 2016 FPA initiated a project to develop a strategic approach to managing eagle nests in production forests. This study used expert assessments to try and develop a method for identifying unused or non-priority nests (Koch et al., 2023). It was concluded from this process that ‘derelict’ nests, being those highly unlikely to ever be used again for breeding, can be identified by experts based on the form of the nest. The results of this study have been used to modify eagle management, whereby nests confirmed by experts to be ‘derelict’ can by treated as ‘absent’ nests.

Testing the effectiveness of select actions to mitigate the impact of disturbance

FPA is collaborating with UTAS researcher Dr James Pay, to determine whether the 500m/1km line-of-sight recommendation is effective in mitigating the impact of disturbance to breeding eagles. This is being done by attaching transmitters to adult birds, monitoring their activity and how it changes in response to forestry activities occurring in a nearby coupe.

In 2021 transmitters were attached to seven 'industry' birds. Of these, two birds bred at the target nest allowing industry data to be collected. Six more transmitters were deployed in 2022, of which again only two bred in the target nest. Five potential sites have been set up for the 2023 season. The data from the birds and the harvest operation will be used to assess the types of activities, and distances from the nest at which breeding eagles are disturbed.

This project is being done in collaboration with UTAS and is funded through a FWPA grant received by the FPA in 2018 with funding support from, Forico, Timberlands, SFM, STT and Norske-skog.

Predicting habitat use

Modified abstract from Pay et al. (2022).

The resources an animal selects within the landscape relate to its behavioural state and, therefore, incorporating behaviour into habitat selection analyses can help inform management of threatened species. Pay et al. (2022) developed behaviour-specific spatial habitat-use models for Tasmanian wedge-tailed eagles. They used 231,478 GPS fixes from 22 recently fledged eagles to classify behaviour as perching, short-distance flight, or long-distance flight. They then developed spatial models predicting where these behavioural states occur. Recently fledged eagles selected for areas close to forest edges during perching and short distance flights, whereas for longer flights they selected more strongly for areas with steep topography (slopes > 15 degrees) and further from forest edges. Models using distance to forest edge and topographic slope effectively predicted where eagles engaged in long flights in each of six regions, whereas the performance varied by region for models describing perching and short flights.

3.2.2. Masked owls

The Tasmanian masked owl (*Tyto novaehollandiae castanops*) is an endemic subspecies that is listed as vulnerable under the *EPBC Act* and endangered under the Tasmanian *Threatened Species Protection Act 1995.* The Threatened Species Adviser recommends retention of mature forest habitat (as a surrogate for nesting habitat) in areas where the bird is likely to occur. In areas where an operation is to occur near a known masked owl nest or roost site, the FPA and NRE Tas might recommend a 100 m radius reserve be retained around such a site.

Tracking masked owls to understand their habitat use

UTAS student Jack Service submitted his Honours thesis on masked owls in May 2023 (Service, 2023). This study aimed to identify which habitats masked owls use for three different behaviours: active hours, roosting, and nesting. To do this Jack tracked six owls with GPS telemetry between September 2022 and January 2023, collecting a total of 680 location fixes. The GPS dataset was categorised into active hours fixes (collected during the night) and roosting fixes (collected after dawn and before dusk). Jack modelled habitat selection independently for each behaviour using resource selection functions. No consistent patterns in habitat selection across all individuals were found for either roosting or active hours, although one individual exhibited different habitat selection for each behaviour. Jack also examined habitat selection using confirmed masked owls nest locations obtained from a variety of sources (n = 16). Masked owls appeared to potentially select areas of lower solar radiation for nest sites. The lack of consistent trends in habitat selection may indicate that owls select nest and roost sites at a different scale than was considered by this study (e.g. the attributes of the tree hollow).

Jack installed cameras at the two nesting hollows found, one of which obtained data proving that two chicks were raised. He also installed acoustic records at the nest sites, and at 200 m and 400 m from these locations. The small sample size prevents conclusions from being drawn but they are important data that can be built on in the future.

Jack also visited the 18 potential roost sites used by the birds he tracked. Of these, only four were likely to be in hollows, with the remaining occurring in areas without an obvious hollow bearing tree, suggesting that roosting was occurring in the midstory species.

The project was done under the supervision of Dr James Pay, Dr Chris Burridge, Dr Amy Koch and Jason Wiersma. The project is funded through a FWPA grant received by the FPA in 2018 with funding support from, Forico, Timberlands, SFM, STT and Norske-skog.

Figure 1. (a) Masked owl nesting hollow (Photo: D James).

Implementation monitoring

In 2022 a study was done to determine if masked owl planning is being done correctly. A draft report has been prepared, but not finalised.

3.2.3. Swift parrot

The swift parrot (*Lathamus discolor*) is federally listed as critically endangered and state listed as endangered. This species relies on tree hollows for nesting, and forages primarily on the flowers of *Eucalyptus globulus* and *E. ovata*. Many threats affect this species, including habitat loss and predation by sugar gliders (*Petaurus breviceps*). Management recommendations for this species in areas covered by the forest practices system are delivered via the Threatened Species Adviser. Under this system all forest operations within the swift parrot breeding range are subject to habitat surveys and assessments. As swift parrots are so wide-ranging, conservation efforts are prioritised to areas with the highest likelihood to support swift parrot breeding, namely the core range and swift parrot important breeding areas (SPIBAs). In these areas all high and medium, and the majority (90%) of low density potential breeding habitat (nesting and foraging) is excluded from harvesting. Outside the core range and SPIBAs, a mix of these habitat retention measures is applied depending on regional context.

Implementation monitoring

FPA undertook a project looking at implementation of the swift parrot management recommendations. FPPs and associated information were examined for forty coupes, comprised of 27 on public land and 13 on private land, containing a mix of dry and wet forest types, and covering the potential range, core range and a number of SPIBAs. The use of planning tools, decisions reached and management recommendations identified were examined.

Overall a high level of planning was achieved. Where mistakes were made it appeared to be due to issues of individual Forest Practices Officers not being used to dealing with swift parrot management prescriptions. In response, four training days on swift parrot habitat management and ecology were run in early 2023. The results of this work will be written up into a report and be used to review current management.

3.2.4. Devils and quolls

Tasmania supports the most diverse guild of marsupial carnivores on the planet, consisting of Tasmanian devils (*Sarcophilus harrisii*), spotted-tailed quolls (*Dasyurus maculatus*) and eastern quolls (*Dasyurus viverrinus*). These carnivores occupy an important role in Tasmanian ecosystems, and all three are federally listed as threatened (devils and spotted-tailed quolls are also listed under state legislation). They are all managed under the forest practices system, and FPA have been involved in one project in the last financial year.

UTAS student Evie Jones submitted her PhD thesis in May 2023 titled “The response of marsupial carnivores to production forest landscapes and operations” (Jones, 2023). During her research Evie established a network of camera traps to analyse the abundance of Tasmanian devils and eastern quolls across three production forest landscapes (Jones et al., 2023). Devil and quoll abundance increased with the extent of timber plantations within production forest landscapes. Overall, devils were positively associated with higher tree density and eastern quolls with indicators of open habitat. Within plantations, devil abundance increased with the volume of windrows (linear piles of harvesting debris), as did eastern quoll abundance in pine plantations. Neither species showed a strong response to logging-related features in native forest such as time since harvest.

Evie used GPS collars to track devils in a eucalypt plantation to identify their habitat selection in three behavioural states. Devils did not show preferences for any of native forest, native grassland, and plantation. Within plantations, devils preferred a plantation age of 4–7 years and slightly avoided older plantations. Devils preferred roads and plantation edges in all behavioural states, and moved faster on roads and edges than away from them, indicating they use them for foraging and travel.

Evie also investigated devil exposure to lead in a eucalypt plantation, from scavenging on browsing marsupials culled using lead ammunition. To assess medium-term lead exposure to devils in the landscape she used a new method of hair analysis, portable X-ray fluorescence (XRF). She first validated the method by analysing hair samples from 39 road-killed devils across Tasmania using portable XRF and with the traditional method of inductively coupled plasma mass spectrometry (ICP-MS) (validation study). Portable XRF measures of hair lead levels were positively correlated with ICP-MS values. Lead concentrations were then measured in 61 hair samples collected from a eucalypt plantation landscape using portable XRF only (plantation study). Contrary to expectations, mean lead levels in the plantation study were not significantly different to those in the validation study.

To assess the short-term impact of browser culling events on lead exposure to devils, Evie analysed devil blood lead levels (BLLs) before and after a marsupial culling program, and compared lead isotope signatures in devil blood to those in the culling ammunition. BLLs were not significantly different before and after culling, but the results were uncertain due to low sample sizes. While 18% of devil blood lead had an isotope signature similar to the ammunition samples, the majority did not, possibly indicating other sources of lead in the landscape. BLLs in the study landscape were relatively low, similar to other published BLLs of wild devils.

Evie concluded from her research that devils and eastern quolls are highly adaptable to production forest landscapes. She suggests several management techniques that are likely to improve the value of production forests to carnivores, such as preserving coarse woody debris including windrows, and creating heterogeneous landscapes.

3.2.5. Giant freshwater crayfish implementation monitoring

The giant freshwater crayfish (*Astacopsis gouldi*) is listed as vulnerable under both state and federal legislation. In the recovery plan for this species, habitat disturbance by forestry is listed as a threatening process (Commonwealth of Australia, 2017). The Threatened Species Adviser recommends that the giant freshwater crayfish habitat suitability map and field surveys be used to assess habitat quality for this species, and that wider streamside reserves are implemented in areas of higher quality habitat (FPA, 2015).

A new project was undertaken examining a number of FPPs to review how well management recommendations for this species are being implemented. Data collection was completed in 2022. There have been delays finalising this project.

3.2.6. Lake Fenton trapdoor spider

The Lake Fenton trapdoor spider (*Plesiothele fentoni*) is currently listed as endangered under the Tasmanian *Threatened Species Protection Act 1995*. There are only a small number of records of this species on the Natural Values Atlas and the species was thought to have a highly restricted distribution. New observations in 2022 led to a confirmed extension of the range of this species. Under the Tasmanian forest practices system *P. fentoni* is currently managed on a case-by-case basis, with no agreed management prescriptions for the species delivered via the Threatened Species Adviser.

Given the lack of ecological information on this species, a study was initiated in 2022 to determine how the presence of trapdoor spiders is impacted by timber harvesting (both clearfall and selective harvesting) and regeneration burns.

The research plan for this project was revised after a trial of field methods. The current research plan is to survey for the presence of *P. fentoni* burrows in retained and harvested areas in a number of coupes that range in time since harvest. However, due to a lack of resources this project has been put on hold and will most likely require a university student to complete it.

Figure 2. FPA researcher using an endoscope to survey a burrow, and two images inside the burrow (Photo: A Gardner).

4. Other Tasmanian project outcomes that contribute to our understanding of the effectiveness of *Forest Practices Code* provisions for biodiversity in 2022–23

These studies have mostly been done independently of the FPA, but the results have either been published as a thesis or scientific publication or the authors have contacted the FPA. Only a brief summary of the results relevant to the forest practices system are presented here.

4.1. General *Forest Practices Code* provisions for biodiversity

4.1.1. Landscape design

Effective management of biodiversity in a production forest landscape requires consideration of stand and landscape impacts in the short and long term. While many management recommendations are applied at the coupe scale, Section A2.1 of the Forest Practices Code specifies that ‘the provision of reasonable protection to the environment includes landscape management …’ (Forest Practices Authority, 2020). Three studies are reported below that have potential implications for the design of forest landscapes to ensure biological and environmental objectives are met over the long term.

Land sparing vs land sharing: determining the optimal mix of forestry and reserves to produce timber at least cost to biodiversity

The Forest Conservation Group at the University of Tasmania are working with industry partners to establish a large-scale landscape ecology trial. This multi-disciplinary research project aims to find out how forestry management of different intensities affects multiple taxa (plants, beetles, birds, and mammals) at both site and landscape scales. This project is based on the premise that the best management for biodiversity at a site-scale is not necessarily the best at a landscape-scale because of trade-offs in meeting timber supply commitments between intensity of management at site-scale and the area available for reserves. That premise is called the sharing/sparing paradigm.

Forestry landscapes can be configured with various forms of management to produce the same overall amount of timber. At the one extreme, a ‘land sparing’ focused landscape has site-scale intensive management (e.g., short-rotation plantations) which allows for a larger area of unmanaged reserves at a landscape scale. The other extreme is a ‘land sharing’ landscape, with low-intensity production (e.g., long rotation aggregated retention in native forests) over a larger area to meet timber production requirements and less land dedicated to unmanaged reserves at a landscape scale. A range of intermediate strategies are possible, as is the current forestry situation in Tasmania.

The project objectives are:

- to quantify the impacts of different forestry systems and wildfire on plants, beetles, birds, and mammals locally over a disturbance and successional gradient.
- to identify the impacts of forestry on critical species-species and species-environment interactions to recommend monitoring indicators and improved management practices within existing forestry systems.
- to determine the best overall theoretical mix of forestry systems and reserves to balance biodiversity conservation and timber production at a landscape scale.
- to optimise the landscape configuration of land-use types for biodiversity and timber production in Tasmania, accounting for the risks associated with predicted increases in wildfire impacts, and practical constraints associated with land tenure.

The biodiversity data for this research will be collected during field-surveys in the wet eucalypt forests of western Tasmania from Tarraleah to Dover (Figure 3). The team have selected 11 different land-use classes each with 8 site replicates and 4 back-ups spanning a range of management intensities and times since disturbance. Site selection considered multiple environmental, spatial, and practical criteria for the sites to get an even distribution of variation in each class. Each site will be surveyed on a 250 m sampling transect.

The field-surveys and research will be conducted by 4 PhD students. Weiyi Wang will use 25 m radius point-counts to survey birds, Emanuela Cosma will use pitfall traps to survey beetles, Janneke Scheeres will use unbaited camera traps to survey mammals, and a 4th student will join the team in October 2023 to survey plants. Besides the biodiversity surveys, a number of environmental variables (e.g. canopy and understory coverage and structure) will be sampled. These data and the biodiversity data will be combined with landscape-context related variables calculated in GIS to assess the local impact of different forestry systems and wildfires. Furthermore, the biodiversity data will be integrated with information on timber yield to determine the best overall mix of forestry systems and reserves at a landscape scale. The results of this study could be used to help design production landscapes to ensure biodiversity and production objectives are both met.

The team had an interactive stakeholder meeting in July to present the study plans, with partners from the FPA, NRE, STT, Forico, RFF, SFM and ABARES. During the meeting, the importance of the landscape context when considering local impacts and the additional value of monitoring the spread of deer and wild pig populations in southern Tasmanian forest areas were also discussed.

This project is funded by an ARC Future Fellowship to Sue Baker, an ARC Discovery grant to Sue Baker, Menna Jones, Vanessa Adams and Andrew Balmford, and additional funds provided by STT and UTAS. In-kind support is provided by STT, RFF, SFM, Forico, FPA and NRE.

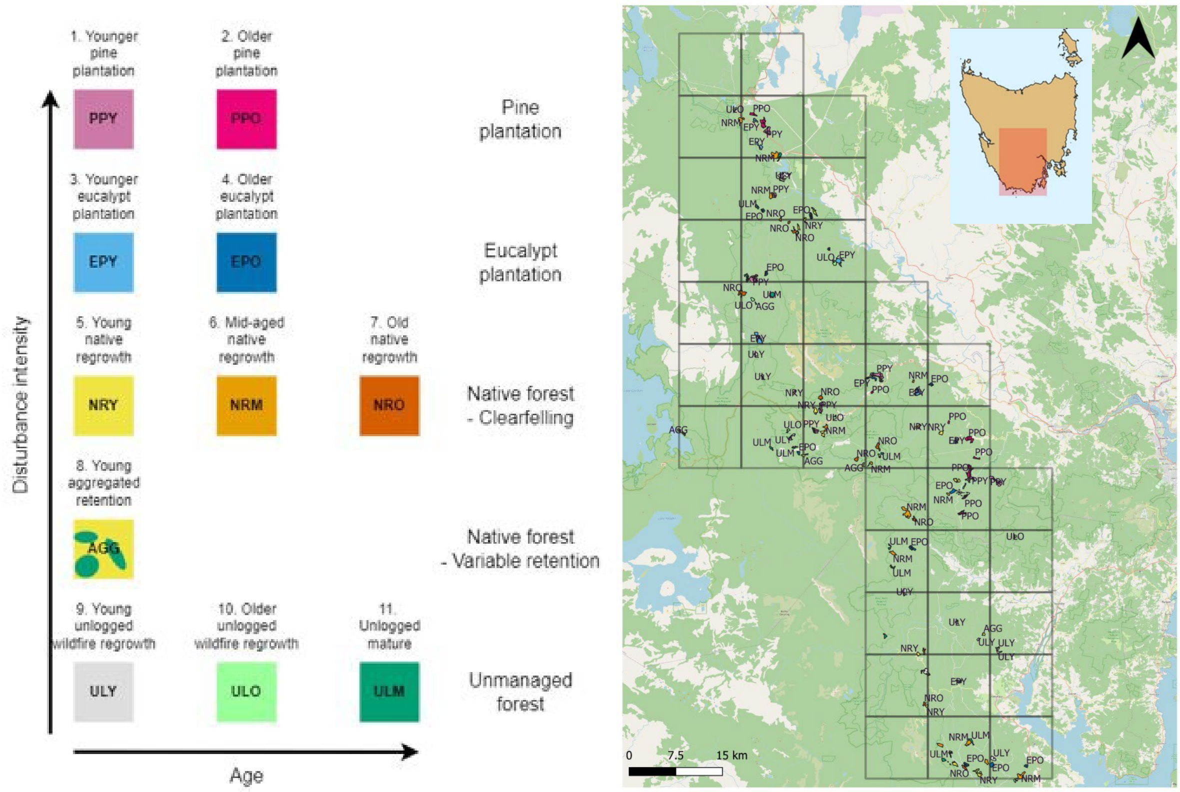

Figure 3. The left shows the 11 land-use classes included in the study over a disturbance and age (time since disturbance) gradient. The right image shows the study landscape with the 88 study sites spread across the area.

Modelling the future of Tasmania's wet forests

Forests are dynamic environments that change over time, with considerable changes expected in the future due to climate change and bushfires. James Furlaud and colleagues from CSIRO aim to build a landscape-level State and Transition Simulation Model (STSM) to make fine scale predictions about vegetation changes in the Southern Forests of Tasmanian

They are using existing model frameworks (AusEcoModels) as a starting point for expert elicitation. They held a two-day workshop in May 2023, inviting experts from across the Tasmanian Government, the forest industry, and UTAS to identify relevant states and transitions and estimate initial model parameters. Next steps are to further refine parameter estimates using an extensive existing dataset describing the effects of the 2019 fire, additional field data collection and targeted expert interviews. The fully parameterised models will then be used to simulate future scenarios under climate change and answer specific research questions about Tasmania's Southern Forests. The types of questions that may be answered include:

- What are the long-term effects of different proposed forest management regimes on future fire risk and on the extent and condition of different types of forest?

- Where is rainforest most at risk from increased landscape flammability?
- Where are asset protection interventions (such as thinning or irrigating) most effective in the long term?

These models will be incorporated into national models that can inform continental scale fire risk maps and predict future bushfire risk under climate change. They could also be used to help prioritise areas for retention within the production forest landscape.

Beetles, mature forest, fire, fragmentation, and extreme weather events

Understanding how species respond to disturbance is central to managing sustainable production forest landscapes. Given a global loss of species from increasing drought, wildfire, and extreme temperatures induced by climate change, predicting, and managing the impact of altered disturbance regimes on all biodiversity, whether listed as threatened or not, is of increasing concern.

The doctoral research of Lynne Forster examined the persistence of beetles in a managed wet eucalypt forests following disturbance by fire and fragmentation, and considered how beetles respond to climate (Forster, 2022).

<u>Fire recovery</u>

Lynne sampled forests at different ages of regrowth since the last major fire event and found rapid colonisation by early successional beetles, but a lag of 45 years before mature-forest beetles colonised regenerating forest. An estimated 137 years was required for assemblages to become 95% similar to those in 200-year-old forest. Current practices, which vary from 60-year rotations on highly productive sites to 120 years on sites with low productivity, are unlikely to be optimal for long-term retention of mature-forest species.

The results of this research are different to some previous research which relied more heavily on the use of 'indicator species'. Many of the mature-forest indicator beetle species in current use are derived from earlier studies of 3 families of beetles (ground beetles, slime-mould beetles and weevils) in forests up to 45 years after disturbance. The longer time interval examined by Forster (2022) found these 'indicator species' were present in 42–210-year-old forest with closed canopy and therefore should be classified as 'forest generalists associated with canopy closure'. Further work that includes other beetle families is required to establish reliable indicators of old-growth forest.

<u>Fragmentation of mature forest</u>

Forster (2022) examined the genetics of flightless log-dwelling beetles across the landscape and found three clusters: Western (next to the World Heritage Area), Middle and Eastern (near rural townships). These clusters correspond to the cumulative disturbance or loss of mature forest that may alter geneflow among patches. In the Western cluster of lowest disturbance, mature forest cover within 2 km landscapes was 28–43%; in the Middle cluster it was 22–29% and in the Eastern cluster with the highest disturbance, mature forest coverage was 5–16%. Genetic homogenisation of populations was evident when there was less than 20% mature-forest cover (Eastern). Genetic homogenisation reduces the genetic resilience of populations to survive unexpected disturbance or undergo adaptive evolution. Forster (2022) recommends that mature forest cover in degraded areas be maintained at a minimum of 20% within 8 km radii landscapes.

Modelling the occurrence of the 634 species showed that the proportion of mature forest within a 2 km radius was associated with the occurrences of beetles that are sensitive to disturbance. Recolonisation 25–50 years after clearfelling was inhibited as disturbance in the surrounding landscape increased. In mature forest patches beetles were more resilient to disturbance in the landscape. This research contributed to a larger body of research published by Wardlaw et al. (2018) which provide support for the landscape context planning system for managing biodiversity landscapes.

<u>Climate change – a mountain as a surrogate</u>

Assemblages of beetles were studied during extreme weather events at Mt Weld, which provided a gradient of temperatures which act as a surrogate for climate change. Changes to the distributions of species during record warm events revealed the strong effect of ecotones on beetle behaviour. An increased number of species was present during wet, cold years. During extreme heat the distributions of beetles below the treeline shifted downslope, presumably to track microclimates under canopy cover rather than cross exposed open habitat upslope. Above the ecotone population dynamics showed a different response, with previously rare species dominating during extreme heat versus extreme cold.

These insights are applicable to regenerating coupes where colonisation by beetles at habitat-edge ecotones may be hindered during extreme weather events. Colonisation to early regenerating patches may decline across edges with high contrast under prolonged extreme weather. Edge effects on mature patches may also increase, extending further under the canopy to cause a contraction of available mature habitat and a stronger negative effect in small patches compared with large.

<u>Synthesis</u>

Retention of mature forest increases the resilience of native forests to disturbance and is crucial for ensuring the recovery/maintenance of mature-forest species. Overwhelmingly the persistence of mature-forest beetles was dependent on the recovery of forest to provide structure and micro-climatic modification through canopy cover, old logs, habitat connectivity and a variety of habitat niches (see Figure 4). While mixed eucalypt forests are adapted to disturbance, they are sensitive to inappropriate fire return intervals which could trigger transitions from wet to dry eucalypt forest or to buttongrass moorland. Such a transition would result in the loss of fire-sensitive mature-forest species such as stag beetles and other saproxylic species that break down large, decaying logs to recycle nutrients in the soil. The best way to minimise the risk of such a transition is to maintain legacy mature forest and disturbance regimes within historic bounds.

Recognising that transition in vegetation-types is a key threatening process to the persistence of mature-forest beetles shifts the focus towards triggers that might alter the recovery of wet eucalypt forests or slowly alter species composition in the understory. Increased frequencies of wildfire in production forests at disturbance intervals of 80–100 years already approach fire-frequency thresholds for wet sclerophyll forest that may be crossed by a series of unexpected wildfires.

Regenerating forests face risks such as failure of seeds to regenerate or establish, hydraulic failure causing decline and death of established trees and increased fire frequencies. Any of these mechanisms have the potential to drive changes in understory species that initiate the transition to an alternative vegetation-type, with cascading effects on the assemblages of associated biodiversity.

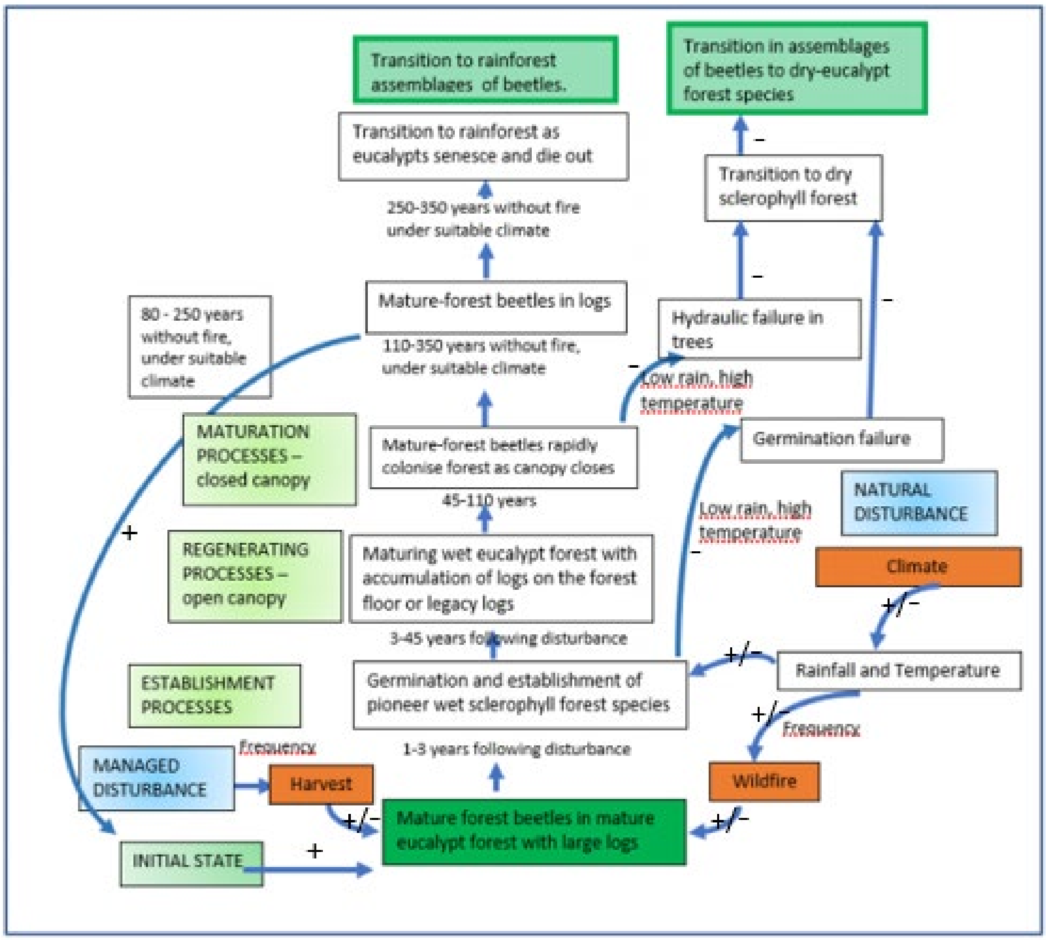

Figure 4. Example of a conceptual state-transition-model for mature-forest beetles associated with logs in wet eucalypt forest showing variables that would drive transition (orange boxes: harvest, fire and climate) between three alternative types of assemblages (dark green boxes). Values for red-underlined variables have not been estimated to account for climate interactions. Vegetation-fire transitions are based on Gilbert (1959), Jackson (1968) and Tabor and Hickey (2007).

4.1.2. Stand management

The forest practices system largely (but not exclusively) applies management at a stand scale. However, the distribution of forestry operations means that stand level management has considerable implications for landscape impacts or benefits. Two studies are reported here that have implications for how management at the stand scale could potentially be adjusted to improve management of landscape-scale biodiversity issues.

Helping Tasmania's* Eucalyptus obliqua *tall forests adapt to a warmer climate

Independent researcher Tim Wardlaw has been conducting research using the Warra Flux tower, looking at the vulnerability of tall eucalypt forests to a warming climate. Tasmania's *E. obliqua* tall forests are among the most productive and carbon dense natural forests in the world. They also show an unusually strong sensitivity to warming temperatures - productivity rapidly declines when air temperature exceeds a relatively low optimum. At the current rate of warming, the current generation of Tasmania's tall forests will be severely impacted, with reduced carbon capture (via photosynthesis) causing strong positive feedback to global warming. Effective adaptation will be needed to make future generations of the forest more resilient to a warmer climate and reverse this positive feedback. Such adaptation strategies may include consideration of the genotypes of the seed used to restock forests.

The forest's high sensitivity to supra-optimal temperatures is linked to the high latitudes occupied by those forests in Tasmania – gradients of rainfall and temperature have little effect on the sensitivity of these forests to supra-optimal temperatures. Because of the latitudinal response, management that accelerates adaptation of local genotypes to warmer temperatures is recommenced. Refinements to routine methods used for seed production and sowing in regenerating tall eucalypt forests after harvesting in Tasmania provides an opportunity to implement accelerated adaptation. Demonstrating the effectiveness of such an approach would provide a powerful message of the critical role forestry has in making Tasmania's *E. obliqua* tall forest more resilient to warmer climates.

Trialling new habitat retention silviculture on PTPZ land

Large mature trees provide important habitat for a range of species. Since mid-2020 STT have been trialling new initiatives aimed at increasing mature habitat features at the stand scale in areas that would traditionally have been clearfelled. Target habitat features include overmature and mature trees with hollows or senescence, as well as large diameter coarse woody debris. The prescription used is to 'retain habitat trees where operationally feasible' in nominated coupes.

The operational feasibility, safety, productivity, regeneration success and effectiveness for biodiversity of this type of dispersed retention in wet forests are being monitored, and this will help inform whether this type of habitat retention silviculture can be adopted more broadly. With regards to effectiveness monitoring, retained habitat trees are being mapped and monitored using a combination of aerial photography, LiDAR imagery and field assessment. Retained trees are assessed post-harvest to evaluate the habitat values being retained, such as senescence, visible hollows, growth stage and diameter class, and trees are re-assessed post-burn at set intervals (1–6 months, 18–24 months, 5-years post burn) to assess burn damage, increase in hazardous trees, windthrow and long-term survivability of the retained trees. Monitoring may also extend to assessing habitat use by key indicator taxa.

So far, data from nearly 1000 trees have been collected. This information, combined with the fine scaled spatial data, will help identify drivers of mortality to help inform whether there is an optimal retention strategy for dispersed retention silviculture in Tasmania’s wet eucalypt forests.

4.1.3. Managing biological impacts on forest health

Maintaining healthy forests is integral to achieving sustainable forest management. Forest health can be impacted by biotic or abiotic factors. Three studies are reported here that assess the impact of biological agents on forest health.

Weeds

Researchers from the University of the Sunshine Coast are doing a project in collaboration with STT to explore how minimising the impacts of weed competition and insect attack can help maintain and improve the productive capacity of the Australian forest industry.

Mammal browsing

STT is collaborating with UTAS researcher Jamie Grimsdale to explore innovative solutions to mammal browsing impacts in native forestry areas.

Invasive species and habitat degradation

Antje measured the diversity and abundance of native and invasive mammal species in undisturbed, plantation, and agricultural land (Chiu Werner, 2023). She focused on the mechanisms that could be influencing the population growth rates of nine native and two highly invasive mammal species and analysed these mechanisms at the community level. Specifically, she measured:

1) stress levels through faecal glucocorticoid metabolites (FGM);
2) diet composition and resource competition through a combination of environmental DNA and stable isotope analyses; and
3) viral load and risk of disease spill-over and spillback.

Antje found that land-use influences the structure and composition of the mammalian community.

- Land use was an important variable explaining the variation in FGM concentrations in all species. Animals inhabiting plantations generally present with lower FGM concentrations.
- There is regionalisation in the diet of smaller species (rodents, brushtail possums and eastern quolls) but not in the two larger predators (Tasmanian devil, spotted-tailed quoll) which consume widespread prey species. Land-use further defines what each species feeds on. Dramatic changes in the diets of native swamp rats may be a result of land-use and/or the densities of sympatric black rats. Black rats were most likely to be found in plantations, but when present in agricultural areas they were more abundant.
- The virome composition of Tasmanian mammal host species is surprisingly homogenous among land-uses, bioregions, status (native/invasive), and trophic levels (Chiu Werner, 2023).

4.1.4. Baseline monitoring

Baseline monitoring is a vital component of a comprehensive monitoring system, as it facilitates detection of broad trends in populations that may be occurring due to land management decisions, or other factors.

River health monitoring

Across spring 2022 and autumn 2023, NRE Tas undertook river health monitoring at more than 74 sites in Tasmania. This work was conducted under the River Health Monitoring Program (RHMP) and the River Health Advisory Project (see below for further details). The RHMP is a long-term, broad-scale program that focuses on freshwater ecosystem health and the effects of landscape-scale pressures and diffuse pollution on rivers in Tasmania (DPIPWE, 2018; Krasnicki et al., 2002). This program has been running since 1994 and supports State Government legislation (e.g. *Tasmanian Water Management Act 1999*) and State Policy (e.g. State Policy on Water Quality Management 1997) that governs the management of freshwater ecosystems in Tasmania.

The RHMP employs protocols which focus on benthic macroinvertebrate communities and habitat quality (Davies, 2000). Since autumn 2018, in line with the recommendations of a review of the RHMP (DPIPWE, 2018; Hardie et al., 2018), monitoring under the program has also assessed the cover and load of fine deposited sediment, and the cover and biomass of periphyton (i.e. benthic algae).

The results of the program can be used in many applications (see DPIPWE, 2018) and are particularly useful for land and water managers who are interested in the health status of rivers. The results of the RHMP were used in recent state-wide analysis of spatio-temporal patterns in river health and associated environmental factors (e.g. water and land use) (DPIPWE, 2020). While the RHMP does not target areas where forestry activities are present, several of the 53 long-term monitoring sites have forestry activities (plantation or production forestry) in their upstream sub-catchments. Therefore, the results of the surveillance-style monitoring under the RHMP are relevant to forestry managers.

Waterway health projects under the Rural Water Use Strategy

During 2022–2023 NRE Tas began implementing a work program associated with the Rural Water Use Strategy (RWUS). The RWUS is providing a platform for several projects that are focussing on strategic work that will inform the sustainable management of water resources in Tasmania into the future. Three activities under the RWUS relate to waterway health: (1) the River Health Advisory Project (RHAP), (2) the development of a new collaborative state-wide water quality monitoring program, and (3) the formation of the Water Managers and Data Custodians Working Group.

The RHAP has three components, namely:

- Reviewing waterway health data coordination and sharing in Tasmania
- Undertaking research to assess drivers of change in waterway health
- Preparing a Strategic Directions for Healthy Waterways Paper.

The drivers of change research includes targeted case studies in four catchments (Mountain River, Ringarooma River, Pipers River, River Leven) and state-wide water quality monitoring that focuses on diffuse pollution. Field sampling for case studies is planned for autumn 2023 to autumn 2024, while the water quality monitoring will be conducted from July 2023 to July 2025.

In addition to short-term water quality monitoring that is supporting the drivers of change research, a new long-term, state-wide water quality monitoring program is being designed. This program is taking a collaborative approach (i.e. it will employ a shared resourcing model) and will incorporate a range of existing water quality monitoring and logistical support from various water management agencies in Tasmania. This program will monitor the effects of diffuse pollution on Tasmania's rivers over the long term.

The Water Managers and Data Custodians Working Group aims to improve collaboration across agencies and is bringing together the six primary water management agencies in Tasmania (NRE Tas, TasWater, Environment Protection Authority, Hydro Tasmania, Tasmanian Irrigation and Inland Fisheries Service) to discuss waterway health monitoring and data sharing.

NRE Tas will release an update of progress on these projects in a Rural Water Use Strategy Progress Report in September 2023.

CallTrackers - monitoring Tasmania's bats, Australasian bitterns, and other calling animals

The CallTrackers project (naturetrackers.com.au/projects/calltrackers) is designed to monitor for state-level population changes in calling species. It involves annual deployment of wildlife acoustic recorders across the same survey squares as *Where? Where? Wedgie!* (see 4.2.1), with the option of some extras in known core habitat of particular species of interest. Following a successful pilot project for CallTrackers in 2021, a state-wide version was launched in September 2022, with a view to repeating this same effort during September–April annually. Volunteers choose a square that has not yet been surveyed, and a survey date when a recorder is free. On the date, they collect a recorder from the nearest state library and set it up for 8 days in the survey square. Afterwards, they load up the resulting recordings and receive feedback on species identified through automatic call recognisers. Bookings, upload, feedback and data storage are all managed by the British Trust for Ornithology's Acoustic Pipeline software. During the 2022–23 season 27 different locations were covered. As more recorders are acquired, the project will focus on additional engagement to increase survey effort. Automatic species identification is at a very basic level at this stage, but work to improve this is ongoing with calls gathered from identified species, starting with Tasmania's 8 resident bat species and the Australasian bittern. Two of Tasmania's bats, the Tasmanian long-eared bat (*Nyctophilus sherrini*) and the Eastern falsistrelle (*Falsistrellus tasmaniensis*) are internationally listed as Vulnerable, while the Australasian bittern is internationally and federally listed as Endangered. As recognisers are increasingly developed, volunteers will receive increasingly accurate feedback both immediately and retrospectively on species identified in their recordings. Species location records will also be stored on the Natural Values Atlas.

Bird monitoring

In 2022 BirdLife Tasmania published the fifth State of Tasmania's Birds report which focused on describing the current status of the 12 Tasmanian endemic species (Newman et al., 2022). The report draws on survey information collected in Birdata, BirdLife Australia's national bird monitoring project. The data are used to provide estimates of extent of occurrence, area of occupancy, number of mature individuals, generation time and conservation status for each of the 12 species. This was the first attempt to estimate these parameters for endemic species in any Australian state. The methodology closely followed those used in the Action Plan for Australian Birds 2020 (Garnett & Baker, 2021), ensuring consistency with national efforts.

The conclusions drawn by the authors of the report are that 3 of the 12 endemics should be considered Threatened. The forty-spotted pardalote (*Pardalotus quadragintus*) has Endangered status and is listed under both State and Federal legislation. The authors assessed both the strong-billed honeyeater (*Melithreptus validirostris*) and the dusky robin (*Melanodryas vittate*) as Vulnerable, due to regional decreases of more than 50% over a 10-year period. The causes of the decreases are not understood.

The results of this work may trigger a revision of the conservation status of these species under state and federal legislations (Newman et al,. 2022).

Monitoring priority wildlife in the TWWHA: Central Plateau

An array of camera traps was established on the Central Plateau to assess the distribution and activity of priority wildlife and the effect of the 2016 and 2019 bushfires on mammal community activity. Bushfire effects on mammal communities were assessed 1.5 years post-fire in highland vegetation and 4.5 years post-fire in forest and highland vegetation. Overall, the mammal community composition was similar between long unburnt areas and areas burnt by recent bushfires. Some species were more active in burnt areas (eastern quoll, Bennett's wallaby, European rabbit and fallow deer) whereas others were less active (spotted-tailed quoll, Tasmanian devil and common wombats). There were fire effects on daily activity, with Bennett's wallabies, brushtail possums, Tasmanian devils and common wombats more active during the day in unburnt vegetation than in recently burnt vegetation (NRE, 2022).

4.2. Threatened species provisions

4.2.1. Wedge-tailed eagles

Where? Where? Wedgie! State-wide population monitoring of Tasmanian wedge-tailed eagle, and more

Where? Where? Wedgie! (WWW) was launched in 2018 to monitor state-wide population trends in Tasmanian wedge-tailed eagles and other raptors. Volunteers survey annually for presence/absence of all Tasmanian raptor species as well as 'white cockatoos' (sulphur-crested cockatoos, and little and long-billed corellas). The dedicated website and app coordinate effort in regularly spaced survey squares across Tasmania, and provide training in the survey method and raptor identification. Additional training and promotion are achieved through media, school visits, online lessons, and community talks. Findings from the 2018 pilot guided methodological refinements to improve geographic coverage and indicated that participation inspires conservation action. The refined method has been carried out every May since 2019 by at least 100 teams each year (110 teams in 2022).

If participation rates remain steady, the WWW data will be more than sufficient to detect state-level population trends over the 10+ years typically required by standard threatened status assessments. However, early warning of any serious decline is clearly preferable, and stakeholders value regular feedback. Power analyses show that, with annual two-day surveys of 100 squares, the program could confidently detect a wedge-tailed eagle population change from one year to the next if it was dramatic (over 30%). The subtler the change, the more years it would take to detect; however, the more squares and days surveyed, the more swiftly such changes will be detected. In particular, the project would require significantly more years and higher participation rates to detect any local population changes. Overall, state-level population trends will most swiftly be detected with confidence for the most frequently observed species: wedge-tailed eagles, sea eagles (*Haliaeetus leucogaster*), brown falcons (*Falco berigora*) and sulphur-crested cockatoos (*Cacatua galerita*).

So far, 80–90 squares are surveyed for at least two days annually. Coverage across Tasmania is quite good, but promotion to inspire more survey effort in the western half, on private land and on the Bass Strait islands would be preferable to ensure optimally representative results. Recognising the limitations of the data to date, the 2019–2022 survey data for the wedge-tailed eagle provide no indication of a substantial change or trend in population size (Figure 5).

A successful application for ARC Linkage funding by the University of Tasmania includes support for a PhD candidate to review alternative analytical methods in obtaining the most accurate estimates of population trends from WWW data, refine the survey method, and translate WWW data into absolute population size estimates with the aid of data from GPS-tagged birds.

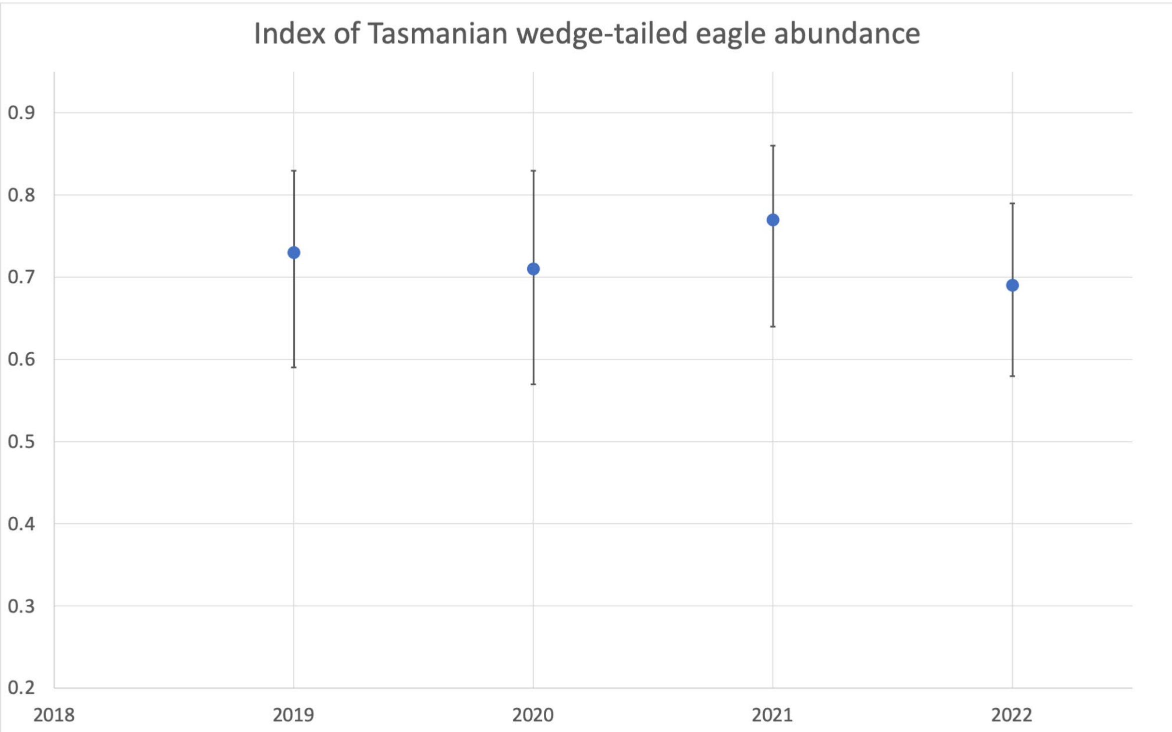

Figure 5. Annual index of abundance of Tasmanian wedge-tailed eagles derived from Where? Where? Wedgie! surveys carried out 2019–2022. Note that population size has not been calculated through this process; the abundance is purely relative, providing an indication of how population size is changing over the years. The analytical method is described by White (2020).

Examination of the ecotoxin threat to Tasmanian wedge-tailed eagles

ANU and UTAS researchers (Dejan Stojanovic, Adam Cisterne and James Pay) are investigating ecotoxin exposure in the Tasmanian wedge-tailed eagle. They are sampling soil, pellets and other material from under wedge-tailed eagle nests to examine the diversity and concentrations of heavy metals and rodenticides accumulating under eagle nests, and if this differs from background environmental levels. Their research aims to estimate the prevalence and source of ecotoxin exposure in the Tasmanian wedge-tailed eagle population, and the magnitude of potential demographic impacts of ecotoxins.

This research is funded through the Wedge-tailed Eagle Research Fund, managed by NRM South.

4.2.2. Masked owls

Modified abstract from Gros et al. (2023).

The Tasmanian masked owl is endangered, primarily due to on-going habitat loss, though significant knowledge gaps in its ecology and spatial distribution have hindered conservation actions. Over the past 30 years, survey techniques for masked owls have largely relied on the detection of calls in response to call playback. Both passive point count and active call playback surveys suffer from high false absence rates for the masked owl, a species described as rarely vocal even when present. Gros et al. (2023) trialled passive audio monitoring with autonomous recording units to develop an efficient standardised survey technique for this species. They used these recorders to establish the species' presence and examine its detectability within a ~400 hectare study area in north-western Tasmania. They developed an automated recognition algorithm for the species screech call to analyse >5,500 hours of recordings over 144 nights from five recorders between June and November 2021. They quantified detection rates at the site-level and over the study area, as well as the frequency and timing of calling each night and over the study period. Across all sites the nightly detection rate of the Tasmanian masked owl was 38.9%. Nightly detection rates varied between sites (range: 0 – 43.4%) as did the timing and frequency of calling. Their study demonstrates the efficacy of acoustic monitoring to establish the presence-absence of the Tasmanian masked owl, and to assess habitat use at an ecologically relevant spatial scale. Their study provides a platform to markedly increase our understanding of the Tasmanian masked owl's distribution and spatial ecology, allowing a more evidence-based approach to conservation planning and decision-making.

4.2.3. Swift parrots and sugar gliders

Long-term ecological data confirm and refine conservation assessment of critically endangered swift parrots

Modified abstract from Owens et al. (2022).

Owens et al. (2022) used detailed and long-term data to evaluate the accuracy of the 2015 conservation assessment for swift parrots. They did this by updating a range of life history parameter estimates, and then repeating the Population Viability Assessment (PVA) as per the 2015 assessment. This process confirmed the earlier finding that swift parrot nests were more likely to survive in places with high mature forest cover. They identify that high forest landscape integrity and abundant hollow-bearing trees best predict nest daily survival rates. Based on the updated PVA, they predict a 92.3% population decrease over three generations (11 years). This supported the predictions of the original conservation assessment. The main benefit of the additional data was improved confidence in projections (the magnitude and direction of the population decline were similar between the original and updated PVAs).

Field and acoustic monitoring of swift parrots on PTPZ land

In spring 2022 STT's stewardship team, with the help of consultant ornithologists, conducted another round of swift parrot monitoring on Permanent Timber Production Zone (PTPZ) land for the 2022–23 breeding season. The four main monitoring objectives were to:

1. Identify and better understand where and how swift parrots are using breeding habitat on PTPZ land throughout the breeding season
2. Identify additional areas of high-quality habitat (not yet reserved or retained) that are important for breeding (being used this season or have good potential for use)
3. Examine whether habitat retention strategies implemented for the swift parrot on PTPZ land are effective — i.e. is habitat retained in harvested areas being utilised by swift parrots?
4. Investigate the use of acoustic recorders as a remote tool to help measure swift parrot breeding activity and success.

In the 2022–23 season swift parrots were dispersed across eastern Tasmania, with aggregations observed in the Eastern Tiers foraging on flowering *Eucalyptus ovata*, and aggregations on the Tasman Peninsula and Bruny Island foraging on the flowering *E. globulus*, and smaller numbers in the Wielangta and Levendale area. The survey approach this season involved nearly 200 rapid strategic field surveys to cover the broad area of PTPZ land across the eastern seaboard, coupled with fine-scaled longer-duration surveys in coupes to investigate habitat use during the breeding season.

In both the 2021–22 and 2022–23 seasons, acoustic recorders were used to complement the field survey program. Over 5000 hours of acoustic data in 2021–22 and 2,800 hours in 2022–23 have been collected. Within the Lonnavale Forests on PTPZ land in 2021–22, 18 sites were monitored for 18 hours per day with acoustic recorders, collectively surveying over 41 days between 2 November 2021 and 2 January 2022. In the 2022–23 season they used a deployment design to help understand the detection space of acoustic recorders, focusing on coupes in the Eastern Tiers with potential habitat.

There does not currently exist an available call recogniser that can automatically process the data, so the 2021–22 data were manually processed. Sites in the Lonnavale forests and coupes with potential habitat were prioritised. A strategic and adaptive approach was taken, which involved manually listening to samples of recordings of at least 5-minutes at 15 to 30-minute intervals. Listening predominantly focussed on the morning recordings to maximise swift parrot detectability, but it also included some afternoon recordings. In total, 502 aural samples averaging 7 min/sample, from 14 of the 18 monitoring sites were analysed, and listening time totalled over 58 hours of recordings. To minimise the risk of false negatives at sites where no swift parrots were detected, listening effort was increased in terms of sample duration (up to 30 minutes or longer), number of samples, number of sampled days, and sampling afternoon recordings, to ensure sufficient listening effort of the site and greater confidence in the result. In addition, any similar calls that could not be unquestionably assigned to swift parrots were subjected to a follow-up listen by a second person. Such questionable calls were noted from 204 aural samples, and of these 28 were identified as a positive swift parrot detection.

Across the sampled data from the Lonnavale forests, swift parrots were recorded from 21 of the 41 sampled days, giving an occupancy rate of 51.2%. Of the 502 samples, there were just 47 positive detections, giving an average detection rate of 9.4%. When comparing field and acoustic monitoring of the same sites, the acoustic presence-absence results were largely consistent with the field observations. Overall, the combination of survey methods has provided improved certainty of swift parrot use of an area. Field surveys provided good visual context on habitat availability and quality and particularly flowering and how swift parrots were using the area during the monitoring period. From the continuous monitoring afforded by acoustic recorders of sites it was noted that early breeding season detections do not necessarily indicate that birds remain at that location throughout the breeding season. They were also able to distinguish whether the observed presence was a passing visit or persistent use of that locality. Acoustic monitoring did provide additional positive detections that were not found during the STT field surveys, showing their added value to species detections. Hence, the two survey methods complemented each other, providing greater clarity of swift parrot habitat use than either method would have done on its own.

To progress the use of acoustic technology for threatened species monitoring, UTAS, STT and FPA are developing a project proposal that aims to develop computing sensor hardware embedded with machine learning automated call identification software. Here, species call detection of the target taxa (swift parrots, masked owl, wedge-tailed eagle and sugar glider) would be performed on remotely deployed optimised devices that are compatible with real-time sensing Internet of Things technology. This is where audio analysis is conducted on the device, with summaries of detections transmitted using low-power technologies such as the wireless Long Range Wide Area Network (LoRaWAN). Currently, funding is being sought to support this research.

Sugar glider control and habitat protection for swift parrot conservation

Since 2020 NRM South have been managing a project aiming to improve breeding success for swift parrots by focusing on methods of reducing predation pressure from sugar gliders, as well as protecting and improving key habitat areas on private land through conservation covenants.

Sugar glider management in Tasmania has proven difficult with a lack of understanding of their ecology leading to low trap success. The NRM South project included 4 field trials to determine an efficient and cost-effective way of controlling sugar gliders in swift parrot habitat. This included investigating the factors that impact sugar glider use of nest boxes, the efficacy of Mawbey traps versus nest box traps, the use of 4G cameras as a nest box monitoring tool and the impact of short-term vs longer-term trapping programs. One of the primary conclusions of early trials was that boxes and traps needed to be in place for a minimum of 3 months before they were regularly used by sugar gliders. Therefore, the final trial took place over 8 months, with active trapping in 7 of those months. This proved to be a successful strategy with 29 sugar gliders being removed from 2 sites. However, there were big differences between the 2 sites in trapping rates. More gliders were removed from the dry forest compared to the wet forest site. It is unclear whether this difference reflects actual glider densities or other factors such as how vegetation type may influence glider behaviour.

To meet the second objective of the project, 2 conservation covenants in the Huon Valley and Glamorgan-Spring Bay Council areas were approved over the last financial year (2021 – 2022). A further 2 are awaiting final approval, both in the Glamorgan-Spring Bay Council area. The 4 covenants will cumulatively protect 377 ha of natural values and 145 ha of high value foraging habitat on private property. Participating landholders will receive support to improve the condition of this protected habitat.

Delivery partners for this project include ANU, NRE Tas, The Tasmanian Land Conservancy, Conservation Landholders Tasmania, STT and Tree Wizard Environmental Arboriculture. The project is funded by the Australian Government as part of the project ‘Protecting the breeding population of swift parrots’. FPA sits on the steering committee for this project.

Detection and density estimation of sugar gliders

Modified abstract from Owens et al. (2023).

Owens et al. (2023) evaluate how optimising detections can affect the survey outcomes for the sugar glider *Petaurus notatus*, a key predator of threatened swift parrots. A literature meta-analysis found little innovation in baiting approaches for sugar gliders over four decades. Honey-based baits prevailed, despite emerging evidence of opportunistic carnivory by the species. They then conducted a field study comparing sugar glider detection probabilities using honey and fish-based baits in a spatially explicit capture-recapture study. Fish bait increased detections 33-fold, and density estimation (0.12 ha^{-1}) was only possible using the fish-baited data – detections were too sparse using honey-bait to facilitate analysis. Other factors that influence detectability include trap height and habitat connectivity, which were top moderators in their meta-analysis, but these may be secondary to the bait or lure used. By using (i) species-specific bait that accounts for the biology of the target species, and (ii) analytical tools to account for imperfect detection and heterogeneous movement of animals, they achieved good enough detection probabilities to undertake detailed analysis of the spatial ecology of sugar gliders. Compared to honey-based baits (the prevailing approach of other studies on this species), the high detection probability attained with fish-based baits provides an improvement on conventional practices.

Sugar glider occupancy and habitat associations in SE Tasmania

Research suggests sugar glider predation is a key cause of nest failure for the critically endangered swift parrot. To date, programs aimed at controlling sugar gliders have struggled due to a lack of understanding of sugar glider ecology in Tasmania. Sustainable Timber Tasmania and NRM South have collaborated on a project to further understanding the ecology of gliders in Tasmania.

This project aimed to investigate any associations between habitat variables and sugar glider occupancy in the core breeding range of swift parrots, with the hope that it will assist in future management efforts. In total, habitat assessments and sugar glider surveys were conducted at 156 sites in southeast Tasmania, on land managed by STT. From this fieldwork, sugar glider occupancy of sites will be modelled alongside habitat characteristics such as structure, forest connectivity and vegetation type to develop a better understanding of the factors that influence sugar glider distribution in Tasmania.

4.2.4. Eastern quolls

Cunningham et al. (2023) provide an updated analysis of eastern quoll population trends in Tasmania using a time series of annual spotlight counts (1985–2019) collected across most of the species' range. Eastern quolls were widespread and abundant in Tasmania until the early 2000s. In addition to a previously documented severe decline in the early 2000s in the east and northeast, they present new evidence of an earlier decline in the north (mid-1990s) and a more recent decline in the south (similar to 2009). Declines have continued unabated during the last decade, resulting in a 67% decline since the late 1990s in the area with high quoll abundance. Although the major decline in the early 2000s coincided with unfavourable weather, the continuing and more recent declines suggest other undetermined causes are also involved. It can no longer be assumed that the presence of eastern quolls in Tasmania ensures the species' long-term survival, highlighting the urgent need to conserve the remaining populations in Tasmania.

4.2.5. Eastern barred bandicoots

The eastern barred bandicoot (*Perameles gunnii*) is extinct in the wild on mainland Australia but remains relatively common in many areas of Tasmania. However anecdotal evidence and records databases (Atlas of Living Australia, Natural Values Atlas and spotlighting records from DPIPWE since 1975) suggest the eastern barred bandicoot (hereafter bandicoot) may be declining, particularly through the Midlands region. Management recommendations for this species are delivered via the Threatened Species Adviser.

UTAS PhD candidate, Joanna Lyall, is trying to understand more about the habitat requirements of this species. At this stage the reasons for the decline are unclear, but loss of habitat, intensification of agriculture and an increase in cat numbers are believed to be contributing factors. Jo has completed 2 three-month rounds of camera trapping across northern Tasmania and another 3 rounds of camera trapping on revegetation sites to investigate bandicoot use of these sites and whether replanting habitat encourages the bandicoots to re-establish. The huge number of images will be processed, and eastern barred bandicoot presence will be related to the presence of a range of animals, and to site attributes such as vegetation density, vegetation type, canopy, shrub and ground cover, height and density. A first round of GPS/VHF tracking of eastern barred bandicoots has been completed with 9 bandicoots tracked for 2 nights to determine where they are nesting and foraging. Already evident is the impact on population density of the limited availability of natural habitat. The next round of tracking may give an indication of the risks this species faces from harvesting operations on agricultural land.

4.2.6. Threatened burrowing crayfish

Claws on the Line - monitoring Tasmania's burrowing crayfish

Five species of burrowing crayfish are managed under Tasmania's forest practices system. In November 2019, the Bookend Trust launched a program to map and monitor Tasmania's burrowing crayfish populations, Claws on the Line. This is part of the NatureTrackers program. Additional aims of this program are to improve public understanding of the science and to unite threatened burrowing crayfish recovery efforts. The initial focus is on the Endangered Central North burrowing crayfish (*Engaeus granulatus*, or CNBC), which is endemic to a small region surrounding Devonport and Latrobe, throughout which it is very thinly scattered. The species' area of occupancy is estimated at less than 100 ha, and shrinking. The project invites participants to share location records of burrows and other crayfish signs via the app iNaturalist (on which precise locations can be hidden), as part of the iNaturalist project Claws on the Line. Questionnaires and other public engagement efforts provide additional avenues for reporting locations of crayfish burrows and body parts (details on naturetrackers.com.au/projects/claws-on-the-line). If regular monitoring can be achieved, and supported by species identifications at burrow sites, this will ultimately provide accurate, up-to-date information on the species' area of occupancy, and enable detection of any significant changes.

At the time of writing, contributions so far comprise 240 observations from 50 people on iNaturalist's Claws on the Line project, along with 20 more provided via the questionnaire. Burrow records of 'Australian burrowing crayfish', are shared with the Natural Values Atlas, and their locations are gradually being visited for identification by the expert team, although there are also plans to develop lower-effort identification methods. Confirmed observations from these sources and the Natural Values Atlas were used by University of Tasmania undergraduate Wade Bone to create an initial, biologically plausible species distribution model for the CNBC. High quality habitat was predicted along many waterways and drainage catchments and related to soil clay content and stream density variables. Ground-truthing for the model resulted in discovery of previously undocumented colonies. Additional field surveys and higher resolution raster data will allow refinement of model predictions.

To further support data collection and overall public engagement, an annual event was launched in spring 2020, when the species becomes more active and apparent. This involves visits to schools and the community within the CNBC's range and an art competition for primary school students, in collaboration with governmental and non-governmental organisations, corporates and interested individuals.

4.3. Other miscellaneous projects relating to Tasmanian forests

A range of other Tasmanian projects relate to forest ecology and management, but not to the effectiveness of the biodiversity provisions of the forest practices system. A subset of these projects is listed below.

Climate change, carbon and drought

- STT are collaborating with other partners to undertake a project modelling the carbon dynamics from native forestry in Australia, with Tasmania being one of the areas considered.
- Tonet et al. (2023) explored the role of xylem failure in *Eucalyptus viminalis* leaf death.
- Hartill et al. (2023) tested whether key hydraulic traits linked to drought stress, including the vulnerability of leaves to embolism (P50 leaf) and the minimum diffusive conductance of shoots (gmin) were associated with climatic characteristics

of fourteen Tasmanian eucalypt species from sites that vary in precipitation and temperature. They found evidence suggesting trait variation is influenced by both cold and dry conditions, highlighting the need to consider both aspects when exploring adaptive trait-climate relationships.

- Using a common-garden trial of 2-year-old trees, Prober et al. (2022) compared patterns of genetic-based population (co)variation in leaf economic and hydraulic traits, climate-trait associations, and genomic differentiation of 2 widespread tree species (*Eucalyptus pauciflora* and *E. ovata*).
- Jones et al. (2023) examined multiple lines of evidence (chloroplast and nuclear DNA markers, seedling morphology, and survival in common garden experiments) from a group of closely related endemic eucalypts (the alpine white gums) to argue that after the last glaciation (i) the Central Highlands of Tasmania were colonized by multiple glacial refugia with hybridisation among species and previously separated populations, and (ii) natural selection has filtered the admixed populations, resulting in local adaptation to the harsh sub-alpine environment. They conclude that the evolutionary response of these trees to past climate change highlights the importance of maintaining species interactions under future climate change.
- Dr Peter Harrison (UTAS) and colleagues have modelled the future climatic range of *Eucalyptus morrisbyi*. Dr Harrison and Rebecca Jones have designed, implemented and monitored translocations into these future climates. So far, survival has been excellent, with 3,099 of the 3,258 seedlings surviving by June 2023 (95%).
- Silva et al. (2022) studied a cohort of trees from multiple populations of *Eucalyptus pauciflora* grown in a common-garden field trial established at the hot and dry end of the species distribution in Tasmania. Under the environmental conditions of their trial they found that early-stage selection on the studied leaf traits may be mediated by their effects on growth performance, which in turn has a positive direct influence on later-age survival.

Fire

- Marsden-Smedley et al. (2022) presents equations for fuel load and fuel hazard rating models based on the time since last fire for dry eucalypt forests in eastern Tasmania.
- Bowman et al. (2023) concluded that forest-sedgeland boundaries in western Tasmania are resilient to fire because of keystone resprouter species, and geographically stable in historical time frames.
- Bowman et al. (2022) concluded that Fuel Moisture Index based on Hygrochron iButton data provides an economic and effective method to retrospectively measure landscape patterns in fuel moisture in wet and dry Tasmanian forests.

- To help understand the potential of forests to adapt to wildfire, Hernandez et al. (2022) explored the genetic architecture of fire-related structural, damage and recovery traits in *E. globulus.*
- Aguas et al. (2022) examined the microsite characteristics associated with the occurrence of post-fire *E. globulus* regeneration from seeds, outside the species native range. The study was conducted in four salvage-logged plantations of *E. globulus.* An abundant cohort of wildlings emerged after fire, in areas characterised by a high incidence of fire-related variables. A second low density cohort emerged after logging, in microsites where disturbance from logging was evident.
- Heaton et al. (2022) used scat counts to infer native and introduced vertebrate herbivore activity after fire in six temperate vegetation communities (grassland to rainforest).
- Kirkpatrick and Jenkinson (2002) found that in *E. viminalis* grassy woodland, fires in quick succession resulted in lower litter cover and higher exotic species richness than a single fire. The authors concluded that mechanical removal of young invading *Allocasuarina* may be successful in preventing its thickening and that burning at a five-year interval is likely to best maintain understorey conservation values.

Species

- Fielding et al. (2022) found that scavenging by ravens and feral cats increases in the absence of native mammalian carnivores.
- Scoleri et al. (2023) examined the spatial variation of the predation impact that the introduction of devils was having on brushtail possums on Maria Island.
- Lewis et al. (2023) examined how the diet of Tasmanian devils changed with land use. Populations in disturbed areas had restricted diets, suggesting individuals fed on similar food items even within regenerated native forest. Populations in undisturbed rainforest had comparatively broad diets.
- A study by Standaloft and Kirkpatrick (2022) used a long-term data set to identify factors that distinguish the distributions of the eastern bettong (*Bettongia gaimardi*) and the long-nosed potoroo (*Potorous tridactylus*). They concluded that the importance of infertile sites to *B. gaimardi* may have been overstated in the literature, with moderate to high fertility being more characteristic of its range.
- Driessen et al. (2022) provide a comprehensive conservation assessment of the 2 subspecies of wombat found in Tasmania, providing information on distribution and habitat, population trends and incidence of roadkill.
- Butler et al. (2022) examined the genetic diversity, population differentiation and linkage disequilibrium across the native range of *Eucalyptus globulus*. There was

some evidence to suggest the impact of a genetic bottleneck occurred at some point for the species in southeastern Tasmania.

- A study by Pfeilsticker et al. (2023) found genetic evidence of hybridisation contributing to the expansion of *E. risdonii* into the range of *E. amygdalina.* The results of their research suggest that the *E. risdonii* phenotype has been resurrected in isolated hybrid patches established from pollen dispersal, providing the first steps in its invasion of suitable habitat by long-distance pollen dispersal.
- In plants where seed dispersal is limited compared with pollen dispersal, hybridization may enhance gene exchange and species dispersal. A study by Pfeilsticker et al. (2023) found evidence that backcrossing of hybrids may have resurrected the *E. risdonii* phenotype in isolated hybrid patches established from pollen dispersal.

Mischellaneous

- STT are working on a number of projects to acquire remotely sensed data to monitor values in the production forest estate, including fire surveillance, fauna monitoring, mammal browsing and fuel moisture.
- Abdu et al. (2022) assessed existing arrangements of firewood collection and identified potential strategies that will aid in controlling the problem.
- Nguyen et al. (2022) examined the spatiotemporal predictors associated will road-kill risk for wildlife. They concluded that forested areas with no road barrier fence along curved sections of road posed the highest risk to animals.
- A PhD student, Isobella Grover, is looking at natural capital accounting in forestry, specifically mountain biking in state forests.
- Diengdoh et al. (2023) assessed the functional connectivity between protected areas in Australia for 59 butterfly species under present and future conditions. Functional connectivity is predicted to decrease in the future.

5. Reviewing current practices in light of new information

In 2022–23 a number of changes were made to biodiversity management as a result of new information and research.

5.1. Threatened fauna range boundaries

A review of the threatened fauna range boundaries commenced in 2022–23. The range boundary review focused on differences between the Natural Values Atlas and Biodiversity Values Database range boundaries, refinement of range boundary definitions, and revising out of date range boundaries to take account of new records, and produced recommendations for changes to improve these planning tools. Changes to range boundaries suggested through this review process have commenced and will be ongoing throughout 2023–24. Previously approved new range boundaries were added to the BVD for giant freshwater crayfish and Clarence galaxias.

New survey data were added to the Natural Values Atlas, suggesting range extensions may be required for the following species. Reviewing these range boundaries will be a focus for the period 2023–24.

- Salt lake slater – new records in northeast Tas.
- Schayers grasshopper – new records in northeast Tas from Rushy Lagoon to Musselroe. This may prompt consideration of a change in habitat description and extension of range. More surveys to be conducted around northwest known site at Woolnorth. This may further extend the range.
- Ammonite snail – new records at Tinderbox, major range extension.

5.2. Threatened species advisor

In 2022–23 the following changes were made to the FPA planning tools, following formal endorsement by FPA and NRE Tas through the Agreed Procedures:

- Giant freshwater crayfish: Threatened species advisor (TSA) recommendations adjusted to account for new range boundary.
- Clarence galaxias: TSA recommendations adjusted to account for new range boundary.
- Tasmanian devil: Updated wording for TSA Rec 2 for plantations to better achieve habitat management, based on feedback on implementation issues from industry.
- Tasman Peninsula Dusky Antechinus: New TSA recommendations made available, based on recommendations from an expert panel convened to discuss the matter.
- *Cryptandra exilis* (slender pearl flower) added to TSA due to listing in December 2022.

5.3. Eagles – new management option

The 2 species of eagle found in Tasmania (wedge-tailed eagles and white-bellied sea eagles) are both listed as threatened and are managed under the forest practices system. The management recommendations for eagles delivered through the Threatened Species Adviser focus on nest sites. Two key components of the management approach are:

1. Maintenance of a 10 ha nest reserve around known nests
2. Restriction of activities between 500 m and 1 km line-of-sight of active nests during the Eagle Management Constraint Period (July to January inclusive in most years, and February in late years).

Eagle breeding pairs tend to maintain a number of nests within their territory, which serve important ecological functions. Nests are typically extremely stable structures that persist long after active maintenance has ceased. However, nests that are not maintained will gradually disintegrate over time. Degraded or disintegrating nests probably serve little or no ecological role for eagles, although the areas in which they occur (nest reserves) may be used for breeding opportunities in the future.

To try and ensure that eagle management is efficient as well as effective, FPA conducted a study (see 3.2.1) to determine whether experts can use photographs to reliably identify nests that are very rarely visited by eagles, are not currently used for breeding and are not expected to be used into the future (i.e. 'non-priority nests'). The conclusion of this project was that visual assessments done outside of the eagle management constraint period can be used by experts to identify non-priority nests.

FPA had discussions with the Eagle Reference Group and the Threatened Species Section (TSS) of NRE Tas, and proposed these non-priority nests be referred to as 'derelict' nests and be treated as 'absent' nests. This means the nest reserve is maintained but the 500 m / 1 km line-of-sight constraints do not apply. Both parties were supportive of this change.

In response FPA updated Fauna Technical Note 1 and sought feedback from the Eagle Reference Group and the TSS. This draft technical note was circulated for comment to TSS and a select group of FPOs that are involved with eagle matters. This new management approach has now been fully endorsed and will be delivered via FPA planning tools.

6. Discussion and 2022–23 priorities for biodiversity monitoring

Research in 2022–23 continues to improve our understanding of the effectiveness of the *Forest Practices Code* provisions for biodiversity.

As usual a wide range of projects were undertaken. While numerous studies focusing on threatened species are still being done, there was an increase in the number of reported projects that relate to broader Forest Practices Code requirements. A number of these projects have implications for landscape management, such as the importance of maintaining mature forest, the optimal intensity of forestry to best achieve both ecological and wood production targets, and research with implications for forestry under a changing climate. This research highlights the importance of managing forestry at landscape scales as well as stand scales.

While considerable relevant research is being done across a range of areas, the climate change review highlights considerable knowledge gaps. More research is required to inform management under a changing climate, particularly in relation to landscape design and forest resilience, the role of genetics in maintaining healthy forests, and the efficacy of current management practices under changing conditions.

The forest practices system continues to adapt to emerging information, most notably with changes occurring to eagle nest management in response to an expert elicitation project that concluded it is possible to identify 'derelict' nests.

The diversity of research being done in Tasmania reflects the complex nature of forest management and the numerous factors that need to be considered. The number of researchers in Tasmania contributing to our understanding is one of the strengths of the Tasmanian forestry sector.

7. References

Abdu, N, Tinch, E, Levitt, C, Volker, P & MacDonald, DH 2022, 'Illegal firewood collection in Tasmania: Approaching the problem with the Institutional Analysis and Development (IAD) framework', *Land Use Policy* 118:2, 106130.

Aguas, A, Matias, H, Rodrigues, A, Bailey, T, Silva, J & Rego, F 2022, 'Microsite drivers of natural seed regeneration of *Eucalyptus globulus* Labill. in burnt plantations', *Forests* 13:6, 889.

Bowman, DMJS, Ondei, S, Lucieer, A, Foyster, S & Prior, LD 2023, 'Forest-sedgeland boundaries are historically stable and resilient to wildfire at Blakes Opening in the Tasmanian Wilderness World Heritage Area, Australia', *Landscape Ecology* 38:1, 205–222.

Bowman, DMJS, Furlaud, JM, Porter, M & Williamson, GJ 2022, 'The fuel moisture index based on understorey Hygrochron iButton humidity and temperature measurements reliably predicts fine fuel moisture content in Tasmanian *Eucalyptus* forests', *Fire* 5:5, 130.

Butler, JB, Freeman, JS, Potts, BM, Vaillancourt, RE, Kahrood, HV, Ades, PK, Rigault, P & Tibbits, JFG 2022, 'Patterns of genomic diversity and linkage disequilibrium across the disjunct range of the Australian forest tree *Eucalyptus globulus*, *Tree Genetics and Genomes* 18:28, https://doi.org/10.1007/s11295-022-01558-7.

Chiu Werner, A 2023*, A mechanistic exploration of the effects of human land-use on the balance between native and invasive mammal species*, PhD Thesis, University of Tasmania.

Commonwealth of Australia & State of Tasmania 1997, *Tasmanian Regional Forest Agreement between the Commonwealth of Australia and the State of Tasmania*.

Cunningham, CX, Aandahl, Z, Jones, ME, Hamer, R & Johnson, CN 2023, 'Regional patterns of continuing decline of the eastern quoll', *Australian Mammalogy* 45:2, 151–159.

Davies, PE, Hart, R, Mitchell, C, Laffan, MD, Wright, D & Smethurst, P 1999, *Forest Practices Code: Review of Soil and Water Provisions*, Final Report to the Forest Practices Advisory Council and Forest Practices Board, Hobart, Tasmania.

Davies, PE 2000, 'Development of a national river bioassessment system (AUSRIVAS) in Australia', *Assessing the Biological Quality of Freshwaters: RIVPACS and Other Techniques*, Wright, JF, Sutcliffe, DW, & Furse, MT (eds.). Freshwater Biological Association: Ambelside, UK, 113–124.

Diengdoh, VL, Ondei, S, Amin, RJ, Hunt, M & Brook, BW 2023, 'Landscape functional connectivity for butterflies under different scenarios of land-use, land-cover, and climate change in Australia', *Biological Conservation* 277, 109825.

DPIPWE 2018, 'Review of the Tasmanian river health monitoring program (1994–2016): Program evaluation and redirection', *Water Assessment Aquatic Ecology Report Series*, Report No. WA 18/01, Water and Marine Resources Division, Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania.

DPIPWE 2020, 'Temporal and spatial patterns in river condition across Tasmania, and the influence of environmental factors', *Water Assessment Aquatic Ecology Report Series,* Water and Marine Resources Division, Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania.

Driessen, MM, Dewar, E, Carver, S, Lawrence, C & Gales, R 2022, 'Conservation status of common wombats in Tasmania II: population distribution and trends, and the incidence and significance of roadkill', *Pacific Conservation Biology* 28:2, 115–123.

Fielding, MW, Cunningham, CX, Buettel, JC, Stojanovic, D, Yates, LA, Jones, ME & Brook, BW 2022, 'Dominant carnivore loss benefits native avian and invasive mammalian scavengers', *Proceedings of the Royal Society B* 289, 20220521.

Forest Practices Authority 2020, *Forest Practices Code* 5th ed, Hobart, Tasmania, Forest Practices Authority.

Forster, L 2022 *Fire, fragmentation, and extreme weather events: Surprise impacts of disturbance on the persistence and vulnerability of beetles in dynamic landscapes lead to early warning signals of altered recovery and demonstrate the need to manage for multiple scenarios in an era of climate change,* University of Tasmania, PhD thesis.

FPA 2013, *Developing a framework for the conservation of habitat of RFA priority species – developing a biodiversity effectiveness monitoring program for the Forest Practices System: identifying priority projects*, FPA Scientific Report 17, Hobart, Forest Practices Authority.

Gros, C, McNamara, KK, Bell, P & Webb, MH 2023, 'Detection of the endangered Tasmanian masked owl *Tyto novaehollandiae castanops* using passive acoustic monitoring', *Corella* 47, 56–64.

Hardie, SA, Bobbi, CJ & Uytendaal, AR 2018, 'Evaluation and redirection of a long-term, broad-scale river health monitoring program in Tasmania, Australia', *Proceedings of the 9th Australian Stream Management Conference* (eds Vietz, GJ & Rutherfurd, ID), pp 317–324, River Basin Management Society, Hobart, Tasmania, Australia.

Hartill, GE, Blackman, CJ, Halliwell, B, Jones, RC, Holland, BR & Brodribb, TJ 2023, 'Cold temperature and aridity shape the evolution of drought tolerance traits in Tasmanian species of *Eucalyptus' Tree Physiology,* DOI: 10.1093/treephys/tpad065.

Heaton, DJ, McHenry, MT & Kirkpatrick, JB 2022, 'The fire and fodder reversal phenomenon: vertebrate herbivore activity in burned and unburned Tasmanian ecosystems', *Fire* 5, https://doi.org/10.3390/fire5040111.

Hernandez, MA, Butler, JB, Ammitzboll, H, Freeman, JS, O'Reilly-Wapstra, J, Vaillancourt, RE & Potts, BM 2022, 'Genetic variation in fire recovery and other fire-related traits in a global eucalypt species', *Tree genetics and geomes* 18:42.

Jones, E 2023, '*The response of marsupial carnivores to production forest landscapes and operations'*, University of Tasmania, PhD thesis.

Jones, EM, Koch, A, Mann, D, Hamede, RK & Jones, ME 2023, 'What drives the abundance of marsupial carnivores in production forest landscapes?' *Forest Ecology and Management* 529:1, 120745.

Jones, RC, Harrison, PA, Hudson, CJ, Hirst, CA, Matthews, AT, Rouger, R, Wise, SL, O'Reilly-Wapstra, JM, Wiltshire, RJE, Jordan, GJ, Vaillancourt, RE & Potts, BM 2023, 'Evolutionary processes shaping postglacial gene pools of high-altitude forests: evidence from the endemic eucalypts of Tasmania', *Forests* 14:6, https://doi.org/10.3390/f14061072.

Koch, A 2022, *Summary of scientific expert feedback on the potential impact of climate change on Tasmania's production forests and potential adaptation strategies: Background report,* August 2022, FPA Scientific Report 32, report to the Board of the Forest Practices Authority.

Koch, A 2023, *Adapting the forest practices system to climate change – results from a practitioner workshop*, March 2023, FPA Scientific Report 35, report to the Board of the Forest Practices Authority.

Koch, AJ, Wiersma, JM, Mooney NJ, Bown, B 2023, *Assessing the potential for using nest characteristics to prioritise Tasmanian wedge-tailed eagle nest management in production forests,* Forest Practices Authority Scientific Report 26, Hobart, Tasmania.

Koch, AJ, Chuter, A & Munks, SA 2012, A review of forestry impacts on biodiversity and the effectiveness of "off-reserve" management actions in areas covered by the Tasmanian Forest practices system, Hobart, Forest Practices Authority report to the Independent Verification Group.

Koch, A, Gardner, A, Kay, K, Chuter, A & Wapstra M 2022, *Prioritising effectiveness monitoring for the forest practices system: threatened flora*, FPA Scientific Report 33, report to the Board of the Forest Practices Authority.

Kirkpatrick, JB & Jenkinson, I 2022, '*Eucalyptus* grassy woodland in the process of invasion by *Allocasuarina verticillata'*, *Fire* 5:31, https://doi.org/10.3390/fire5020031.

Krasnicki, T, Pinto, R & Read, M 2002, 'Australia-wide assessment of river health: Tasmanian bioassessment report (TAS final report)', *Monitoring river heath initiative Technical Report No. 5*. Commonwealth of Australia and Department of Primary Industries, Water and Environment, Canberra, ACT and New Town, Tasmania.

Lewis, AC, Hughes, C & Rogers, TL 2023, 'Living in human-modified landscapes narrows the dietary niche of a specialised mammalian scavenger', *Scientific Reports* 13, 3582.

Marsden-Smedley, JB, Anderson, WR & Pyrke, AF 2022, 'Fuel in Tasmanian dry eucalypt forests: prediction of fuel load and fuel hazard rating from fuel age', *Fire* 5:4, 103.

Munks, SA, Chuter, AE & Koch, AJ 2020, ' Off-reserve' management in practice: contributing to conservation of biodiversity over 30 years of Tasmania's forest practices system', *Forest Ecology and Management* 465, doi: 10.1016/j.foreco.2020.117941.

Newman, M, Baker, GB, Ehmke, G & Jones, W 2022, 'State of Tasmania's birds: Tasmanian endemics', *State of Tasmanian Birds' Report* 5, BirdLife Tasmania.

Nguyen, HKD, Buettel, JC, Fielding, MW & Brook, BW 2022, 'Predicting spatial and seasonal patterns of wildlife-vehicle collisions in high-risk areas', *Wildlife Research* 49, 428–437.

NRE 2022, *Monitoring priority wildlife in the TWWHA: Central Plateau,* Research and Monitoring Synopsis, Natural Values Science Services Branch, Department of Natural Resources and Environment Tasmania.

Owens, G, Heinsohn, R, Crates, R & Stojanovic, D 2022, 'Long-term ecological data confirm and refine conservation assessment of critically endangered swift parrots', *Animal Conservation,* https://doi.org/10.1111/acv.12834.

Owens, G, Gracanin, A, Potts, J, Young, C, Heinsohn, R, Gibbons, P & Stojanovic, D 2023, 'Detection and density estimation for a cryptic species', *Authorea,* https://doi.org/10.22541/au.169029171.10503220/v1.

Pay, JM, Patterson, TA, Proft, KM, Cameron, EZ, Hawkins, CE, Koch, AJ, Wiersma, JM & Katzner, TE 2022, 'Considering behavioral state when predicting habitat use: Behavior-specific spatial models for the endangered Tasmanian wedge-tailed eagle', *Biological Conservation* 274, 109743.

Pfeilsticker, TR, Jones, RC, Steane, DA, Vaillancourt, RE & Potts, BM 2022, 'Molecular insights into the dynamics of species invasion by hybridisation in Tasmanian eucalypts', *Molecular Ecology* 32, 2913–2929.

Prober, SM, Potts, BM, Harrison, PA, Wiehl, G, Bailey, TG, Silva, JCE, Price, MR, Speijers, J, Steane, DA & Vaillancourt, RE 2022, 'Leaf economic and hydraulic traits signal disparate climate adaptation patterns in two co-occurring woodland eucalypts', *Plants* 11:14, 1846.

Scoleri, VP, Ingram, J, Johnson, CN & Jones, ME 2023, 'Top predator restricts the niche breadth of prey: effects of assisted colonization of Tasmanian devils on a widespread omnivorous prey', *Proceedings of the Royal Society B-Biological Sciences* 290, 20222113.

Service, JH 2023, *Behaviour-specific habitat selection of the Tasmanian masked owl (*Tyto novaehollandiae castanops*),* Honours thesis, University of Tasmania.

Silva, JCE, Potts, BM, Wiehl, G & Prober, SM 2022, 'Linking leaf economic and hydraulic traits with early-age growth performance and survival of *Eucalyptus pauciflora'*, *Frontiers in Plant Science* 13, 973087.

Standaloft, I & Kirkpatrick JB 2022, 'Identifying important environmental variables in the niche partitioning of two keystone ecosystem engineers (*Bettongia gaimardi* and *Potorous tridactylus*) in Tasmania', *Wildlife Research* 50:7, 507–516.

Tonet, V, Carins-Murphy, M, Deans, R & Brodribb, TJ 2023, 'Deadly acceleration in dehydration of *Eucalyptus viminalis* leaves coincides with high-order vein cavitation', *Plant Physiology* 191, 1648–1661.

Wardlaw, T, Grove, S, Hingston, A, Balmer, J, Forster, L, Musk, R & Read, S 2018, 'Responses of flora and fauna in wet eucalypt production forest to the intensity of disturbance in the surrounding landscape', *Forest Ecology and Management* 409, 694–706.

White, E 2020, *Where? Where? Wedgie! Citizen science for endangered eagle populations,* Data4Good https://data4good.com.au/where-where-wedgie-citizen-science-for-endangered-eagle-populations/.

Wilkinson, GR 1999, 'Codes of forest practice as regulatory tools for sustainable forest management', in *Practicising forestry today, Proceedings of the 18th Biennial conference of the Institute of foresters of Australia*, edited by Wllia, EX & Amwrhuear, PJ, Hobart Tasmania.