NRM SOUTH
NATURAL RESOURCE MANAGEMENT

LANDSCAPE SCALE CONSERVATION PLANNING IN TASMANIA

THE SPATIAL IDENTIFICATION OF CONTEMPORARY REFUGIA

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Landscape Scale Conservation Planning in Tasmania

The Spatial Identification of Contemporary Refugia

Report prepared for NRM South by

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Summary

An investigation into the spatial identification of contemporary refugia in Tasmania is presented. The aims of the project were to identify the characteristics and location of areas of Tasmania which may be important for maintaining resilience, flexibility and adaptability for native vegetation and flora and fauna habitat in terms of climate change and related stresses.

The report defines contemporary refugia, gives criteria for their identification and recommends:

1. a program for the spatial identification of contemporary refugia be undertaken based on current knowledge and with the assistance of appropriate expert inputs.
2. an ongoing program of collaborative, multi-disciplinary research to deal with current unknowns should be established.

Whilst it is clear that some current refugia can be identified on maps now, there is a considerable body of research and development needed to cover the subject area comprehensively. It will require collaboration across land management agencies and research institutions.

Introduction

This report describes an investigation into the spatial identification of contemporary refugia in Tasmania. The project was established by NRM South to identify the characteristics and location of areas of Tasmania which may be important for maintaining resilience, flexibility and adaptability in terms of climate change and related stresses. The study aims to assist planning processes for reserve design and regional NRM planning. It is aimed mainly at the identification of refugia for elements of biodiversity. Biodiversity is usually considered at three levels: genes, species and ecosystems. The current project considers each of these but focuses mainly at the species and ecosystems levels, with vegetation and environmental attributes being the surrogates used to identify ecosystems. The use of such surrogates necessitates the incorporation of an assessment of the condition of the areas of the potential surrogate which are proposed as refugia. The protection of current and future refugia is considered an important adaptation strategy (e.g. Heller and Zavaleta 2009).

Definitions:

Refugia. In plain English a refuge (from the Latin *refugium*) is a place of shelter, protection or safety from danger, distress or calamity. In the current context, the term is usually used by biologists in conjunction with a perceived threat or danger, e.g. to identify refugia from fire, disease climate and glaciation).

Morton *et al*. (1995) provide a number of different ways in which the term is used in biology:

> Evolutionary refugia are regions in which certain types or suites of organisms are able to persist during a period in which most of the original geographic range

becomes uninhabitable because of climate change. Thus they are areas reflecting past environmental regimes and which may contain high numbers of endemic species.

The term may also be used by ecologists to mean a region where a species or a suite of species persist for short periods when large parts of their habitat become unusable because of changed conditions e.g. from fire, drought or flooding.

The term is also used to define areas in which threatened species occur.

Morton *et al*. point out that it is important to identify the type of refuge, because this will impact on the type of management which might be needed. In the context of their focus on arid and semi-arid lands, they identify the following categories of refugia. Some of these are relevant in the Tasmanian context:

- Islands: refuges from introduced predators, diseases and weeds and from changing land use found on adjacent mainland areas. In Tasmania islands such as Maria Is are important repositories of endemic species and refugia from diseases such as *Phytophthora cinnamomi*.
- Mound Springs: localised habitats with regional endemics of aquatic invertebrates. There are some mound springs in northern and northwestern Tasmania
- Caves: refugia in evolutionary time for species that were formerly forest dwelling. Cave environments in maritime environments such as at Hastings in Southern Tasmania harbour a much greater diversity and more troglomorphic species than is found in more intensely glaciated cave systems inland such as those at Mole Creek (R. Eberhard pers. comm.)
- Wetlands: provide habitat for migratory birds and for aquatic flora and fauna
- Gorges: microclimatic refugia for many plants and animals previously more widespread. Also may provide refugia from current threats such as wildfire.
- Mountain ranges: These provide sheltered environments and geographically isolated habitats. They also provide run-off water and nutrients and so may be resource-rich refugia for fauna.
- Ecological refugia: Some of the above categories may also be ecological refugia by providing habitat requirements such as water and nutrients and fire protection not otherwise available.
- Refuges from exotic animals: Includes islands but may also include human-induced areas protected by remoteness or other reasons.
- Refugia from land clearing: Areas where biodiversity survives because they are too dry, too rocky or too infertile to be cleared, or because they are protected by legislation or policy restrictions.

Cryptic refugia: These are small areas which are locally suitable for the survival/persistence of species and vegetation and from which recovery might ensue after the threat has passed or become ameliorated. In fact some impacts from threats may be so locally severe that it is not possible to define refugia at a local scale and then recovery can only be by stepwise reintroduction from external areas into the devastated landscape. On the other hand, the causes of some disease outbreaks may be so prevalent that it is not possible to identify adequate refugia. An example is the pathogenic fungus *Chalara australis* responsible for a disease known as myrtle wilt and which ultimately results in the death of myrtle trees. In such cases it may be possible to identify places where background levels of disease occurrence are very low and thus of prime concern to be managed to maintain low levels of disturbance.

Resilience: Resilience is the ability 'to spring back' or return to the original form or position. In an ecological/biological context it refers to the ability of an entity such as a vegetation type or a species or other taxonomic unit to recover to its original state after some perturbation or disturbance.

Refugia for what?

Ultimately a refugium-based approach to conservation may be relevant for all forms of biodiversity. However there are particular elements of biodiversity which can be prioritised as being more risk-prone and therefore where the immediate identification and management of contemporary refugia may provide an appropriately precautionary approach. These elements occur across all components of biodiversity, *viz*. genetic, species and ecosystems.

Genetics: Refugia may be important for the conservation of areas where species show high genetic diversity, in areas of active speciation and places of introgressive hybridization and where hybrid swarm formation occurs. Refugia may also be important to maintain gene flow among populations of native species, and also to limit or prevent gene flow between native and introduced species.

Species: Some characteristics of species which are likely to suffer under climate change and which could be targeted by a refugia-based approach to conservation are outlined below, adapted from the Gran Canaria Declaration II on climate change and Plant Conservation (BGCI 2006):

- Taxa with nowhere to go e.g. those confined to mountain tops or low-lying island
- Species with restricted ranges
- Taxa with poor dispersal &/or long generation times
- Species susceptible to extreme conditions – fire-sensitive, floods droughts
- Species with extreme habitat/niche specialization e.g. narrow tolerance to climate-sensitive variables
- Taxa with narrowly co-evolved or synchronous relationships with other species
- Species with inflexible physiological responses to climate change
- Keystone species important in primary production or ecosystem processes and functions
- Species of direct value to humans.

Ecosystems: Ecosystems which may benefit from contemporary refugia may have some of the following characteristics:

- Highly depleted extent because of past land-use practices
- Rare, of restricted occurrence or having a narrow ecological amplitude
- Fire sensitive ecosystems
- Occupancy of habitats which are susceptible to depletion through climate change or other threats– e.g. drought or flood prone fire affected or subject to c coastal erosion
- Ecosystems susceptible to disease, weed and pest invasions

Determination of other contemporary refugia could include areas containing concentrations of endemic species, especially local endemic species, as well as areas of high beta diversity (i.e. containing diverse vegetation communities or ecosystems) and of high gamma diversity (high turnover of biophysical environments or domains).

Refugia from what?

There is an inherent assumption that refugia provide shelter from extant or potential threatening processes. The main threats identified as being relevant to the present discussion are:

1. **Climate change** which directly affects the physiology/nature of the vegetation and flora, and also fauna, both directly and secondarily through their interaction with the plant world.

2. Other threats (which may themselves be exacerbated by climate change)

- Fire
- Drought
- Floods
- Disease
- Weeds and invasive fauna:
- Geomorphology: Changes in karst, fluvial and coastal systems
- Land use change

Many of these threats are tenure-blind (i.e. they occur on both public and private land).. Whilst reservation can greatly assist conservation, a refugia-based approach is much more specifically targeting particular areas for management for biodiversity conservation. Thus refugia may be within or outside reserves. In many cases management may be more easily implemented within reserves, but there will be places where a reserve-based approach and/or management by benign neglect is inappropriate, and situations where proactive management is needed.

Past approaches to the identification of refugia in Tasmania.

In Tasmania, most of the approaches undertaken to date have focused on identifying contemporary refugia from existing threats, as identified above (RFA 1997), or have identified areas which are presumed refugia from past glacial events e.g. Kirkpatrick and Fowler (1998).

More recently Carter *et al*. (2010) have completed a program to assemble information to identify focal landscapes [1]on private land in Tasmania for the Protected Areas on Private Land Program (PAPL) based on defined natural values including some layers covering identified National Estate natural values developed by expert processes under the Tasmanian Regional Forest Agreement (RFA). These include layers on glacial refugia, and some of these can be viewed as contemporary refugia. Carter *et al*. have produced business rules which set out the policy context and the inputs considered in the development of these spatial layers (Table 1). These layers are stored in the DPIPWE's Conservation Information System.

These layers are primarily focused on private land, but the identification rules used to underpin the prioritisation process are statewide and tenure-free. They would form an excellent basis for further development a contemporary refugia layer, both for individual themes and for a composite layer.

Phase 2 of the work by Carter *et al*. includes the development of spatial layers related to contemporary refugia considered important to contemporary conservation planning, and the development of the business rules will be informed by this report, as will the current work in DPIPWE on climate change adaptation planning.

[1] areas within the landscape that contain a disproportionate share of conservation values and are a focus for conservation planning and investment (Males (2008)

Table 1: Natural values considered in the construction of focal landscapes for the PAPL program.

Natural Value	Inputs	References
Biogeographic distinctiveness	Centres of endemism for flora and fauna Flora species, vegetation community and fauna species richness Primitive and Relictual flora and fauna Flora and fauna limits of range	See RFA (1997) and Carter *et al.* (2010) for primary reference sources
Biomes that are a priority for reservation in Tasmania	Identified biomes (broad vegetation classes amalgamated from TASVEG) with <10% of their Tasmanian or Bioregional extent represented in the Tasmanian Reserve System	Current TASVEG layer Harris and Kitchener (2005)
Important habitat for birds	Important Bird Areas developed by Birds Australia Important Bird Sites from CFEV	Birds Australia (2009) DPIWs (2008)
The conservation and reservation status of vegetation communities	Vegetation communities listed as threatened under NCA and EPBCA Vegetation communities nominated as threatened under the EPBCA Vegetation communities that are unreserved Vegetation communities that are a priority for reservation in a bioregion using reservation indicators with or without added expert interpretation.	NCA 2002 EPBC 1999
Contemporary fire and disease refugia	Existing maps of dry rainforest, sinkholes, pencil pine, Huon pine, King Billy pine, *Callitris*, *Phytophthora* management zones, *Cyathea* locations, relic rainforest, *Nothofagus gunnii*	RFA (1997)
Glacial refugia	CRA forest vegetation communities map. Refugial sites for flora in Tasmania	PLUC (1996) Kirkpatrick and Fowler (1998) RFA (1997)
The conservation of freshwater and associated riparian ecosystems	CFEV layers for water bodies, wetlands, saltmarshes, estuaries, karst. Riparian zone: CFEV and LIST rivers; native vegetation.	DPIW (2008)

Natural Value	Inputs	References
Native vegetation extent within bioregions with less than 10% of their area in the National Reserve System	TASVEG IBRA bioregions Tasmanian Reserve Estate	Carter *et al*. (2010)
Priority species distribution and density using Natural Values Atlas data (interim data).	**Tally for priority flora species within a 500m grid square** **Tally for priority fauna species within a 2500m grid square**	**Carter *et al*. (2010)**

Towards the identification of contemporary refugia for Tasmania

Many of the themes or layers identified in the PAPL program are directly relevant to the spatial identification of contemporary refugia in Tasmania. However there are some other themes and aspects which also need to be included to provide a more comprehensive coverage, and some of the base data layers used in the PAPL program need to be updated or further developed.

New or updated data layers needed to provide a more comprehensive coverage of refugia in Tasmania

There are four types of data layers required to inform a comprehensive treatment of contemporary refugia. The first are those themes which directly identify contemporary refugia for specified values and for which existing GIS layers are current. Secondly there are those which are already in existence but need to be updated. Thirdly there are some layers which currently do not exist. Finally there are a number of layers which could assist further identification of appropriate refugia or which can be used to derive modelled outcomes for refugia.

1. Existing current layers

2. Coverages needing to be updated

The existing National Estate/RFA data used in the compilation of the PAPL program were compiled in 1996-7 with limited resources. Molecular techniques and other recent work have lead to significant advances in these areas. Each of them should be reviewed by an appropriate panel of experts to determine whether they remain relevant or need to be updated.

Other layers which definitely need to be updated include:

- Rural tree decline layers (or eucalyptus dieback). This was mapped at the statewide scale in 1992 as part of the State of Environment Report.
- *Phytophthora* layer

3. Important coverages not currently included in the Conservation Information System are:

- Areas important as potential genetic refugia
- Key habitats for threatened species. This is currently being prepared by TSU and PAPL staff
- Refugia from weeds
- Freshwater habitats, including key habitats identified in CFEV

- Key areas of remnant vegetation

4. Layers which could assist in the identification of current refugia

- Identification of areas of high connectivity
- Identification of areas of high environmental, climactic and biological diversity (currently in preparation)

A comprehensive set of expert workshops would greatly assist the production of the refugia layers. However such an approach is beyond the scope to the current project. Instead it is proposed to seek the input of a number of key personnel who can provide a first pass overview of relevant material and expertise for later validation by others.

Key people identified for this process would include the following:

- Weeds: Michael Askey-Doran/Tim Rudman, DPIPWE
- Fire: Adrian Pyrke/David Taylor DPIPWE
- Genetics: Brad Potts, UTS Plant Science
- Threatened species : TSU staff, DPIPWE
- General flora and fauna: DPIPWE Biological Monitoring Section.
- Diseases: Tim Rudman DPIPWE, Tim Wardlaw FT, Caroline Mohammed UTas, CRC Forestry
- Exotic Fauna: Greg Hocking DPIPWE
- Freshwater: Danielle Hardie, DPIPWE, Peter Davies Freshwater Systems
- Connectivity: Biophysical Naturalness: Rod Knight
- *Phytophthora*: Rod Knight, Tim Rudman DPIPWE

Results of discussions

A number of issues arose from discussions with the above experts, with respect to preparing business rules for refugia:

Identify the type of refugium

Past, contemporary and potential future refugia all exist in Tasmania and so there needs to be a clear exposition of which of these is under consideration and what type of refugium is being discussed.

Thus the refugia identified by Kirkpatrick and Fowler (1998) are areas in which species appear to have survived past glaciations.

In the case of contemporary refugia, these may represent current refugia from past processes, as is found with the disjunct and/or relict distributions of some plant species such as *Eucalyptus globulus* and *Cyathea cunninghamii*. These locally restricted populations probably represent refugial populations of the presumed more extensive distributions in SE Tasmania which have been eliminated by the post-glacial rise in sea level. Thus they represent refugial populations in the sense that they offer opportunities for recolonisation if the previously flooded areas or other suitable habitat became available under future climate change.

Similarly, the Western Central Plateau contains areas of active speciation in a number of different plant groups (Epacridaceae (Jarman and Crowden 1978, Menadue and Crowden 1983), Ranunculaceae (Menadue and Crowden 1985), Haloragaceae (Orchard 1975, 1986), Plantaginaceae

(Brown 1991) and *Eucalyptus* (e.g. Potts and Reid 1985ab). Much of the region was covered in an ice sheet in glacial periods (e.g. Kiernan 1990). Thus it is not a glacial refuge, but is now an area of high genetic diversity and can be viewed as a current refugium offering a potential reservoir of genes from which radiation may occur under future climate change scenarios.

Other contemporary refugia can also be similarly defined based on the occurrence of concentrations of endemic species, especially local endemic species, from areas of high beta diversity (i.e. containing diverse vegetation communities or ecosystems) and gamma diversity (high turnover of biophysical environments or domains).

These areas may represent contemporary refugia from past events or areas with the potential to be refugia from future adverse conditions or from which radiation or rehabilitation can occur in future more benign environments.

Equally important are areas which offer contemporary refugia from current adverse conditions such as from invasion by pests, weeds and diseases, and inappropriate fire regimes.

The other types of current refugia are the islands of native vegetation that are important areas of native ecosystems and habitats surrounded by cleared land or inundated areas which provide potential source areas from which rehabilitation/recolonisation can occur.

Scale dependence of refugia

The above examples highlight the issue of scale in considering refugia. In the case of *Cyathea cunninghamii* cited above, the individual gullies in which the populations occur are the refugia, whereas for many endemic plants and animals as well as more widespread species such as the larger dasyurids, bandicoots and *Nothofagus cunninghamii*, all or most of Tasmania provides a refugium from the past and present threatening processes that have resulted in their demise or widespread depletion on the Australian mainland. Thus refugia operate at a range of scales, depending on the organism and/or attributes under consideration, and planning will have to take account of this. Some broad- scale refugia may be able to be identified using surrogates and remote sensing techniques, whereas some threatened species or fire-sensitive habitats may operate at very local scales and these will require detailed mapping of single values, environments or sites. Such needs could be initially identified through a series of expert workshops, and subsequently progressed by the project team.

Research needs

Whilst it is clear from the discussions with experts that some current refugia can be identified on maps now, there is a considerable body of research and development needed to cover the subject area comprehensively. This R&D will need collaboration between climatologists, geomorphologists, ecologists, biologists and people with spatial systems skills, as well as land managers who can provide a reality check on the draft outputs. It will require collaboration across land management agencies and research institutions, The R&D needs arise in part because the climate futures models are unresolved as yet, so it is not possible to allocate land parcels into putative refugia without testing proposals against climate change scenarios.

Development of a plan and process for defining refugia and developing criteria

There area two elements to a proposed plan and process for defining refugia and developing criteria. The first of these is the pragmatic one of proceeding from the information presented here to identify refugia as outlined below. The second as outlined above, is to compile and evaluate the outputs of research programs currently in progress and to use this information and a gap analysis of current information to identify further R&D needs and subsequently to instigate a collaborative program.

Criteria on which to define potential refugia from what is known now

The criteria on which to define potential refugia can be derived from a combination of the direct list of types given above by Morton *et al*. (1995), together with other important repositories of the following biodiversity attributes in the landscape:

- Phylogenetic distinctiveness
- Keystone species
- Species richness
- Areas of high genetic heterogeneity
- Key hybrid zones
- High ecosystem diversity
- High habitat/environmental diversity
- Areas free from disease and weeds
- Landscape features such as those identified by Morton *et.al* (1995)
- Fire sensitive species

Who needs to be involved

Project steering committee and associated staff, together with appropriate expertise as identified in Process section below.

Nature and format of workshop(s)

Workshop needs are outlined in the Processes section below.

Processes for developing and refining criteria and approach to refugia definitions and spatial selection

The range of different criteria that can be used to compose a refugia layer are complex. Each layer should be compiled and prepared separately. The process involves the identification of criteria as outlined above, and the identification of broad-scale places in the landscape containing elements that satisfy these criteria (e.g. 10km x 10km). (NB. A composite coverage of all of the different forms of refugia could then be prepared but is unlikely to be informative given the different scales at which refugia can occur). The process will require the iteration of the layers internally and then using experts to refine and verify the outcomes. Use the scenarios generated under the best available climate models generated by the Climate Futures for Tasmania project at a 14 km gridscale to evaluate the likelihood of persistence of the putative refugia.

1. Identify current refugia from diseases, fire and weeds. To the extent possible make use of existing coverages for this purpose:
    - Disease: e.g. Current *Phytophthora* mapping for sensitive plant species, Mucor fungus for Platypus, Chytrid fungus for frogs, DFTD.

- Fire: Use existing long unburnt areas map (RFA), combined with BRAMS (bushfire risk assessment model system) developed by the Fire Management Branch of PWS.
- Weeds: Use combined information from BCB weed strategy together with the weeds database from the Weeds Section of DPIPWE. Evaluate weeds potential layer used in the FCF program as part of PAPL. This will require work shopping of staff from the three areas together with other BCB staff to assess/assign weed species to be considered.

2. Identify human-induced refugia - islands of suitable size of natural vegetation in otherwise hostile environments as potential colonizing sources. These should be scale dependent, to emphasise likelihood of relative long term persistence. Use a stepped approach identifying areas from say 2 ha, 100 ha, 200 ha and >1000ha. This approach has already been identified by R. Knight and he has a GIS coverage which could be obtained and used.
3. Generate updated environmental domains map, or evaluate potential of using Land Conservation Branch revised land systems/components mapping to provide this.
4. Identify areas of environmental heterogeneity using land systems, land zones (D. Kidd pers. comm.), environmental domains or other suitable landscape classifications.
5. Identify landscape features such as those identified by Morton *et.al* (1995) as potential refugia.
6. Generate ecosystems diversity layer using TASVEG, modified to allow for known issues e.g. scale variation of mapping
7. Identify key micro/cryptic refugia, such as disjunct populations and threatened species habitats. Use existing programs (e.g. background information collected for the PPP process of TSU) to inform priorities for species considerations).
8. The condition of the natural systems within the proposed refugia areas should be assessed. This could be done by an evaluation of the potential viability of all of the above by overlaying proposed areas with an updated biophysical naturalness and connectivity layers. These coverages have already been generated by R. Knight, updating the RFA Biophysical Naturalness layer.

Conclusion and recommendations

The identification of contemporary refugia is a complex task, which must be viewed as a work in progress and almost certainly cannot currently be readily achieved as a single GIS layer, given that:

- There are many biodiversity elements for which refugia are to be identified
- There are many biophysical systems which offer potential refugia
- Refugia are needed to provide protection from many different identified threats and risks
- Refugia are scale dependent from microhabitat to local to statewide
- The requisite mapping, remote sensing and database information is not all available
- The subject area requires much more research, which needs to be multi-disciplinary.

Accordingly the following recommendations are made:

1. A program for the spatial identification of contemporary refugia be undertaken based on current knowledge and with the assistance of appropriate expert inputs.

2. An ongoing program of collaborative, multi-disciplinary research to deal with current unknowns should be established

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