Taylor, S., Drielsma, M., Taylor, R., & Kumar, L. (2016). Applications of Rapid Evaluation of Metapopulation Persistence (REMP) in Conservation Planning for Vulnerable Fauna Species. *Environmental Management, 57*(6), 1281-1291.
http://dx.doi.org/10.1007/s00267-016-0681-7

Applications of Rapid Evaluation of Metapopulation Persistence (REMP) in Conservation Planning for Vulnerable Fauna Species

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Abstract

In many regions species are declining due to fragmentation and loss of habitat. If species persistence is to be achieved, ecologically informed, effective conservation action is required. Yet it remains a challenge to identify optimal places in a landscape to direct habitat reconstruction and management. Rather than relying on individual landscape metrics, process-based regional scale assessment methodology is needed that focuses primarily on species persistence. This means integrating, according to species' ecology, habitat extent, suitability, quality and spatial configuration. The Rapid Evaluation of Metapopulation Persistence (REMP) methodology has been developed for this purpose. However, till now no practical conservation planning application of REMP has been described. By integration of expert ecological knowledge, we extended REMP's capabilities to prioritize conservation action for a highly modified agricultural region of central NSW, Australia based on the metapopulation ecology of 34 fauna species. The region's current capacity to support the species was evaluated in relation to the pre-European state for which there was known viability. Six of the species were found to currently have insufficient habitat to support viable populations. Seeking locations to maximize overall improvement in viability for these species, we prioritized conservation action to locations near the threshold of metapopulation persistence.

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Keywords**:** REMP, Metapopulation Capacity, Spatial Biodiversity Prioritization, Occupancy, Conservation Planning, Multi-species evaluation

Introduction

Biodiversity loss arises directly or indirectly from pressures such as habitat loss, invasive alien species, overexploitation and climate change impacts (Butchart et al. 2010). Habitat fragmentation and loss resulting from these pressures have contributed to population decline for many Australian species (Australian State of the Environment Committee 2011; IUCN 2012). There is considerable debate over the relative impact of individual landscape attributes (such as patch size, habitat quality and landscape connectivity) and how changes in landscape structure affect biodiversity (Doerr et al. 2011; Hodgson et al. 2011; Hodgson et al. 2009). However, it may be more useful for conservation planning to focus on ways to integrate these attributes, with practical methodologies that reflect how habitat pattern in all its forms influences the issue of central concern, biological persistence (Nicholson and Ovaskainen 2009). Currently the prevalent modelling approaches largely fail to integrate these attributes; instead it is common practice to favour one over others, or to sum, or weight attributes as if they were independent.

Metapopulation capacity (MPC) (Hanski and Ovaskainen 2000) and metapopulation occupancy mapping (Day and Possingham 1995; Hanski 1999a; Hanski 1999b) provide estimates of metapopulation persistence at landscape and regional scales (Calabrese and Fagan 2004; Moilanen 2011). Importantly these methodologies focus on the tension between two key ecological processes critical to determining persistence of populations, rather than on individual landscape attributes:

1. Local extinctions in response to the quantity, quality and spatial arrangement of habitat available at a spatial scale relevant to the species' foraging behaviour;

2. Colonisation of vacant patches in response to the quantity, quality and spatial arrangement of habitat accessable at a scale relevant to the species' dispersal behaviour.

Persistence is predicted for a species if the metapopulation capacity of the landscape is greater than a threshold value determined by the properties of the species, with occupancy occurring in places where MPC is above threshold (Hanski and Ovaskainen 2000).

The ‘rapid evaluation of metapopulation persistence’ (REMP) (Drielsma and Ferrier 2009) extends methodologies for occupancy mapping and MPC analysis by making them applicable to spatially complex, variegated habitat configurations (Fischer and Lindenmayer 2006; McIntyre and Barrett 1992) using a raster data structure (Moilanen 2011). Structurally complex landscapes are relevant for many species and/or populations, both naturally and as a result of anthropogenic habitat modification (Fischer and Lindenmayer 2007). Such is the case for the sheep-wheat belt of central New South Wales, Australia (McIntyre and Barrett 1992) which is the focus of this study. Until now the practical application of REMP to real-world conservation planning has not been published.

Our work considered the landscape-scale metapopulation processes of 34 declining and/or threatened woodland dependent fauna species (Table 1) within a region in central NSW, Australia, known as the Western Woodlands Way. We undertook a conservation evaluation of the current viability of the 34 species, and developed novel spatial prioritization aimed at directing conservation and habitat repair towards maximizing overall improvement to the species’ persistence.

Table 1: List of species included in the WWW case study.

Common Name	**Scientific Name**
Birds	
Barking Owl	*Ninox connivens*
Black-chinned Honeyeater	*Melithreptus gularis*
Brown Treecreeper	*Climacteris picumnus*
Crested Shrike-tit	*Falcunculus frontatus*
Diamond Firetail	*Stagonpleura guttata*
Dusky Woodswallow	*Artamus cyanopterus*
Gilbert's Whistler	*Pachycephala inornata*
Grey-crowned babbler	*Pomatostomus temporalis*
Hooded Robin	*Melanodryas cucullata*
Jacky Winter	*Microeca fascinans*
Little Lorikeet	*Glossopsitta pusilla*
Painted Button Quail	*Turnix varia*
Painted Honeyeater	*Grantiella picta*
Red-capped Robin	*Petroica goodenovii*
Restless Flycatcher	*Myiagra inquieta*
Rufous Songlark	*Cincloramphus mathewsi*
Speckled Warbler	*Chthonicola sagittata*
Superb Parrot (breeding)	*Polytelis swainsonii*
Superb Parrot (non-breeding)	*Polytelis swainsonii*
Turquoise Parrot	*Neophema pulchella*
Reptiles	
Carpet Python	*Morelia spilota variegata*
Coral Snake	*Brachyurophis australis*
Dwyer’s Snake	*Parasuta dwyeri*
Eastern Bandy Bandy	*Vermicella annulata*
Five-clawed worm skink	*Anomalopus mackayi*
Green tree snake	*Dendrelaphis punctulatus*
Pale-headed Snake	*Hoplocephalus bitorquatus*
Patternless Delma	*Delma inornata*
Proximus Blind Snake	*Ramphotyphlops proximus*
Red-bellied Black Snake	*Pseudechis porphyriacus*
Spotted Black Snake	*Pseudechis guttatus*
South-eastern Slider	*Lerista bougainvillii*
Mammals	
Greater Long-eared Bat	*Nyctophilus timoriensis*
Koala	*Phascolarctos cinereus*
Squirrel Glider	*Petaurus norfolcensis*

Materials and Methods

REMP Methodology

The REMP modeling methodology and software (Drielsma and Ferrier 2009) was used to perform an evaluation of population viability for 34 declining fauna species. REMP, unlike prioritization tools such as Marxan recognizes the heterogeneity of the landscapes by utilizing raster (grid-cell) spatial data at relatively high resolution as opposed to polygonal (patch) data. Furthermore, unlike packages such as Marxan (Ball and Possingham 2000) and Zonation (Moilanen and Kujala 2008; Lehtomäki and Moilanen 2013), REMP is not intended as an optimization tool for making decisions about top-down design of reserve networks but is most useful in supporting decision-making (Drielsma and Ferrier 2009). Compared to these other approaches REMP is a relatively new, undeveloped tool, presently not well supported with user documentation.

Hanski (1999a) used the patch based approach to describe the amount of resources available to a species using patches of habitat in fragmented landscapes where the intervening country (matrix) had no value for the species. In the REMP approach, the landscape is split into grid cells where the habitat value of each cell for a given species is assigned based on the combination of land-use and vegetation community that occurs there. Similarly, the ability of the species to move across each cell is based on the land-use and vegetation community combination present in each cell along a prospective path. Thus, the landscape is not represented as patches of habitat and non-habitat, but a mosaic of various levels of resources as perceived by the species of interest.

The REMP methodology assumes that individuals perceive the landscape at finer spatial scales for home range movements compared to the longer distances involved when dispersing (Drielsma and Ferrier 2009). Therefore, the spatial analysis is undertaken at varying grid cell resolutions to accommodate species with different movement abilities, with the upper limit (highest resolution or smallest cell size) set by the resolution of the vegetation community mapping (1 ha). As such, finer grained grids are used for less mobile species while coarser grained grids are used for more mobile, space demanding species. A similar approach is taken with different spatial processes whereby fine grained grids are used for home range movements and coarse grained grids are used for dispersal.

The following biological parameters are used in REMP for each species. This information is gathered from a range of sources including published material and expert knowledge (Ellis et al. 2007).

1. **Minimum Viable Habitat area** - Minimum area (in hectares) of 'ideal' habitat needed to support a viable population (ignoring major calamities).
2. **Habitat suitability** (on a scale between 0 and 100) for every combination of land-use and vegetation community. Within REMP this information is used to assign an individual habitat value (i. e. habitat suitability for the species of interest) to each grid-cell.
3. **Average day-to-day movement ability in metres** through every combination of land-use and vegetation community. Average day-to-day movement refers to movement within home range.
4. **Average dispersal movement ability in metres** through every combination of land-use and vegetation community.

Two raster-based spatial inputs: vegetation community (may also be referred to as vegetation type, or ecosystem); and habitat condition, are required for the REMP analysis. The vegetation community is used as a surrogate for potential habitat suitability and permeability to movement. This potential is then modified subject to land-use, which is used as a surrogate for vegetation or habitat condition (Gibbons and Freudenberger 2006; Parkes et al. 2003; Zerger et al. 2006). The following two outputs are produced by REMP:

1. a continuous surface of predicted occupancy, and
2. an estimate of metapopulation capacity (MPC) for each species.

Occupancy mapping is a spatial probability surface where each raster grid-cell is attributed with the probability of the species occupying that grid-cell based on Hanski's incidence function (Hanski 1999a). Occupancy levels are dependent on the biology of the species and the following landscape habitat characteristics: habitat type, habitat condition and the spatial arrangement of habitat (shape, size and connectivity to other habitat). The occupancy rate of each grid-cell is a function of:

1. the local extinction rate, which is in turn determined by the habitat availability at that grid-cell, subject to the species' home-range movement abilities, and
2. the colonization rate at that grid-cell which is determined by the habitat value of the cell, its connectivity to neighboring habitat as well as the occupancy of those neighboring grid-cells. Colonization rate is also subject to the species' dispersal movement abilities.

The MPC is a single value that describes the ability of the region to support a viable population and it is determined by the quantity and spatial distribution of habitat in relation to each species' habitat requirements and movement abilities. Clusters of cells with identical MPC value (as recorded in a grid of MPC values produced by REMP) can be interpreted as being connected into a single metapopulation while distinct clusters with different MPC values can be interpreted as separate metapopulations. A single regional MPC is routinely derived which represents the MPC for the most robust metapopulation within the region. However, more than one metapopulation can be present in a large study region that contains distinct clusters of habitat which are functionally disconnected for a species. These additional metapopulations contribute to the overall robustness of habitat systems providing additional backup should a single metapopulation be extinguished from a catastrophic event such as from fire or disease. A manual interrogation of the MPC grid can be undertaken to ascertain the existence of and the viability of other multiple metapopulations.

Based on the biological parameters provided, REMP also calculates the extinction threshold MPC for a species as the MPC of idealized habitat in maximum condition with an area equal to the minimum viable habitat. By comparing the MPC of any single metapopulation (from a real landscape or landscape scenario) to this threshold, a landscape's capacity to support viable metapopulations can be assessed. The more an MPC exceeds the MPC threshold, the more that functionally connected habitat exceeds the minimum level required to support a viable metapopulation; the more the MPC falls short of the threshold, the greater the deficit. A detailed description of the REMP methodology can be found in Drielsma and Ferrier (2009).

Western Woodlands Way (WWW)

Overview

The Western Woodlands Way (WWW) study (Fuller et al. 2012; Taylor and Drielsma 2012) was conceived as a landscape reintegration project for the terrestrial ecosystems in the north of the sheep wheat belt zone in NSW, Australia. This is a region in NSW that has been highly developed for agriculture, with much of the original native vegetation having been cleared or largely modified for that purpose (Drew et al. 2002; Seddon et al. 2002). A continual decline in fauna species, especially those associated with the relatively fertile soils originally supporting grassy woodlands has been observed (Barrett et al. 2007; Reid and Cunningham 2008). The study region boundaries were selected to include the larger areas of remaining native vegetation, many of which are held in various types of crown land reserves (Fuller et al. 2012) (Figure 1).

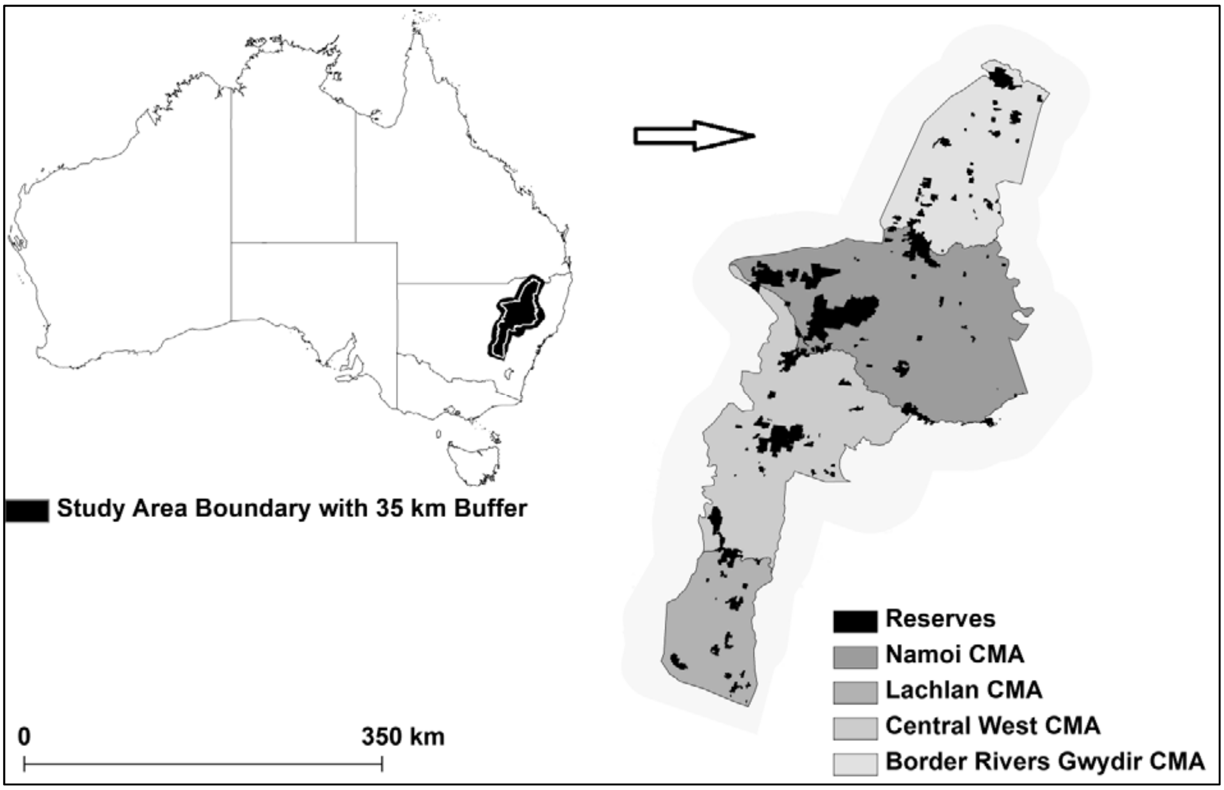

Figure 1. The Western Woodlands Way study region including reserves and boundaries of catchment management authorities (CMA) from which vegetation datasets were used in the study.

Model Configuration: Species

Thirty four species were selected for the WWW case study based on the criteria of suffering decline due to habitat (vegetation) factors, and sufficient information being available to allow parameter fitting. Separate models for breeding and non-breeding phases were developed for the Superb Parrot, because its mobility varied in the two phases. Expert-defined spatial limits were applied to the areas that were modeled for species that were understood to have never occurred across parts of the study region. These were Gilbert's Whistler, Superb Parrot (breeding), Superb Parrot (non-breeding), Pale-headed Snake, Patternless Delma, South Eastern Slider, Green Tree Snake, Coral Snake and Five-clawed worm Skink. The species included in this analysis were representative of the spatial requirements of a number of other species because they collectively comprised a range of spatial scales in terms of movement abilities, area requirements and habitat preferences.

The experts were provided with a list of vegetation types and land-use classes in the study region and asked to assign habitat value and movement abilities for each combination of vegetation type and land-use. Thus, land-use was used to determine the condition of the vegetation.

Two iterations of expert consultations were conducted to assign habitat suitability and movement values for the selected species. In the second round of discussions, the experts were provided with the habitat suitability maps that were derived on the basis of initial consultations. Following from this the models were further refined, where appropriate. The expert derived parameters for the species used in this study are available from the authors on request.

Spatial Data Inputs

The two main spatial inputs for the REMP analysis were vegetation type and land-use. In the first instance vegetation type was employed as a surrogate for potential habitat suitability and permeability to movement. This potential was then modified downwards for land-uses that are understood to diminish this potential; land-use thereby acting as a surrogate for the condition of habitat (Gibbons and Freudenberger 2006; Zerger et al. 2006). The NSW Office of Environment and Heritage (OEH) Corporate State-wide land-use layer was used to derive land-use coverage.

The land-use classes employed as habitat condition classes for the modeling are shown in Table 2.

Table 2: Land-use classes used as habitat condition classes for REMP modeling for the WWW case study.

Land-Use Class	**Description of Condition**
1	Best condition – managed for conservation
2	State forest (ungrazed)
3	State forest (grazed)
4	Native vegetation strategically or lightly grazed
5	Standard grazing on private land with native vegetation
6	Standard grazing in derived grassland, sometimes with scattered tree cover
7	Devoid of native vegetation (cropped, towns, infrastructure)

A single customized vegetation type dataset for the study region was compiled from a range of regional vegetation community datasets. The final dataset had a raster (grid-cell) structure with a one hectare resolution. A buffer of 35 km was included in the analysis to avoid any edge effects in the modeling results within the WWW envelope. Other technical parameters for configuring the model were also assigned. These parameters govern how the landscape is read within the modelling process and is largely a function of the movement abilities of the species and the spatial arrangement of habitat in the region. These are available from the authors on request.
The vegetation type and land-use datasets together with the expert derived parameters were implemented in the REMP analysis to assess habitat conditions for the 34 species. The current capacity of the region to support the species was evaluated in relation to the pre-European state. The pre-European state was based on the predicted habitat configurations prior to major changes to the region following European settlement. Class one (best condition) land-use was assigned across the region. The results from the current land-use analysis were utilized in further evaluations to map priority areas for conservation (conservation priority mapping) as well as locations where investment in improvement (repair) of vegetation would provide the greatest benefit for each species. Conservation priority mapping was done by combining the metapopulation capacity at each location with the habitat value of that location. This assesses the implications for each species of losing native vegetation at each location. Priorities for repair were considered to be locations that had high MPC value, but also where significant improvement to habitat quality could be achieved. These sites, due to their reduced condition, could function as potential population sinks,

sources of weeds and pests and barriers to movement. An investment in improving these sites could potentially provide additional well connected habitat and facilitate movement, thus improving the viability of the local metapopulation. The results for all species were combined to produce two final conservation and repair priority maps (see Supplementary Material 1 for a more detailed explanation on the development of these two priority maps).

Results

The MPC of the most robust metapopulation and occupancy are shown in Tables 3 and 4 while the combined conserve and repair priority maps for all 34 species are shown in Figures 2 and 3. Individual maps for each species can be obtained from the authors. In general, the pre-European analysis resulted in a higher MPC value compared to the extinction threshold for most species. This difference was quite pronounced for the mammals and birds but not the reptiles, with the Green Tree Snake showing a lower MPC value for the pre-European state compared to the extinction threshold. Six of the species were found to currently have insufficient habitat to support viable populations (Table 3). These were Barking Owl, Gilbert’s Whistler, Superb Parrot (non-breeding), Five-clawed Worm Skink, Green Tree Snake and Spotted Black Snake. Only the most robust metapopulation of each species was assessed in this study (Drielsma and Ferrier 2009). Similar trends were seen with the occupancy values for the pre-European and current states with the pre-European resulting in the highest occupancy for all species (Table 4). A large reduction in occupancy was seen under the current state compared to the pre-European state with this reduction being particularly pronounced for all the reptiles and some birds (Barking Owl, Crested Shrike-tit, Gilbert’s Whistler, Grey-crowned Babbler, Painted Button Quail and Superb Parrot). The priority maps showed some variation in the spatial configuration of the most robust metapopulation for each species. These maps represent the contribution that each location makes to the metapopulation capacity of the region for that species. Figures 2 and 3 identify priority areas for investment in conservation and repair in the western part of the study region.

Table 3: MPC values resulting from the pre-European and current state together with the values represented as a percentage of the threshold MPC for the 34 species analyzed within the WWW.

Species	**Pre-European MPC**	**Current MPC**	**Pre-European MPC as a % of Threshold MPC**	**Current MPC as a % of Threshold MPC**
Greater long-eared bat	537,770,688,512	239,273,099,264	1000	445
Koala	1,220,649,344	70,338,128	5051	291
Squirrel Glider	32,489,857,024	4,228,696,064	4231	551
Barking Owl	2,960,057,856	396,193,952	367	**49**
Black-chinned honeyeater	15,143,260,160	4,864,202,752	7308	2348
Brown Treecreeper	2,549,444,608	1,749,211,392	1370	940
Crested Shrike-tit	69,230,040	15,666,828	451	102
Diamond Firetail	6,040,639,488	1,029,080,000	5053	861
Dusky Woodswallow	229,935,424	31,581,642	26457	3634
Gilberts Whistler	73,419,768	19,141,880	146	**38**
Grey-crowned Babbler	13,329,905,664	4,269,588,992	442	142
Hooded Robin	2,844,158,208	203,501,424	2393	171
Jacky Winter	2,531,792,896	452,649,248	1586	284
Little Lorikeet	124,350,996,480	82,386,370,560	33328	22081
Painted Button-quail	351,663,328	246,543,296	164	115
Painted Honeyeater	2,455,286,054,912	1,386,306,732,032	36900	20835
Red-capped Robin	8,815,658	4,413,000	2064	1033
Restless Flycatcher	1,846,844,032	372,731,168	5079	1025
Rufous Songlark	3,353,929,216	342,650,976	10013	1023
Speckled Warbler	710,297,664	444,594,752	1185	742
Superb Parrot (breeding)	457,631,498,240	395,254,688	182066	157
Superb Parrot (non-breeding)	6,108,556,558,336	2,021,206,144	4252	**1**
Turquoise Parrot	1,813,448,960	808,960,128	3811	1700
Carpet Python	64,393,996	59,627,072	405	375
Coral Snake	133,047	115,865	136	118
Dwyer's Snake	133,048	119,644	166	149
Eastern Bandy Bandy	133,048	116,024	130	113
Five-clawed work skink	130,732	13,045	123	**12**
Green Tree Snake	100,717	82,956	**86**	**70**
Pale-headed Snake	41,430,548	22,971,862	260	144
Patternless Delma	423,405	155,017	475	174
Proximus Blind Snake	113,851	104,228	131	120
Red-bellied Black Snake	62,587,612	31,850,682	1415	720

Spotted Black Snake	133,045	88,542	113	**75**
South-eastern Slider	133,048	116,212	381	333

Numbers in bold represent species that were identified as having insufficient habitat to support viable populations.

Table 4: Occupancy values resulting from the pre-European and current state for the 34 species analyzed within the WWW.

Species	Pre-European Occupancy (000 Ha)	Current Occupancy (000 Ha)
Greater long-eared bat	2,494	209
Koala	4,847	373
Squirrel Glider	4,501	171
Barking Owl	4,224	2
Black-chinned honeyeater	6,463	1,512
Brown Treecreeper	6,033	587
Crested Shrike-tit	3,186	11
Diamond Firetail	6,605	347
Dusky Woodswallow	6,513	1,949
Gilberts Whistler	269	0
Grey-crowned Babbler	2,244	91
Hooded Robin	6,464	193
Jacky Winter	5,605	225
Little Lorikeet	6,866	4,714
Painted Button-quail	1,322	31
Painted Honeyeater	6,382	3,739
Red-capped Robin	3,426	565
Restless Flycatcher	6,807	1,965
Rufous Songlark	7,104	2,558
Speckled Warbler	5,294	413
Superb Parrot (breeding)	278	11
Superb Parrot (non-breeding)	1,697	0
Turquoise Parrot	5,962	1,242
Carpet Python	3,330	364
Coral Snake	317	5
Dwyer’s Snake	1,431	37
Eastern Bandy Bandy	520	8
Five-clawed worm skink	13	0
Green tree snake	7	1
Pale-headed Snake	229	21
Patternless Delma	1,896	71
Proximus Blind Snake	152	6

Red-bellied Black Snake	5,252	522
South-eastern Slider	2,465	167
Spotted Black Snake	253	9

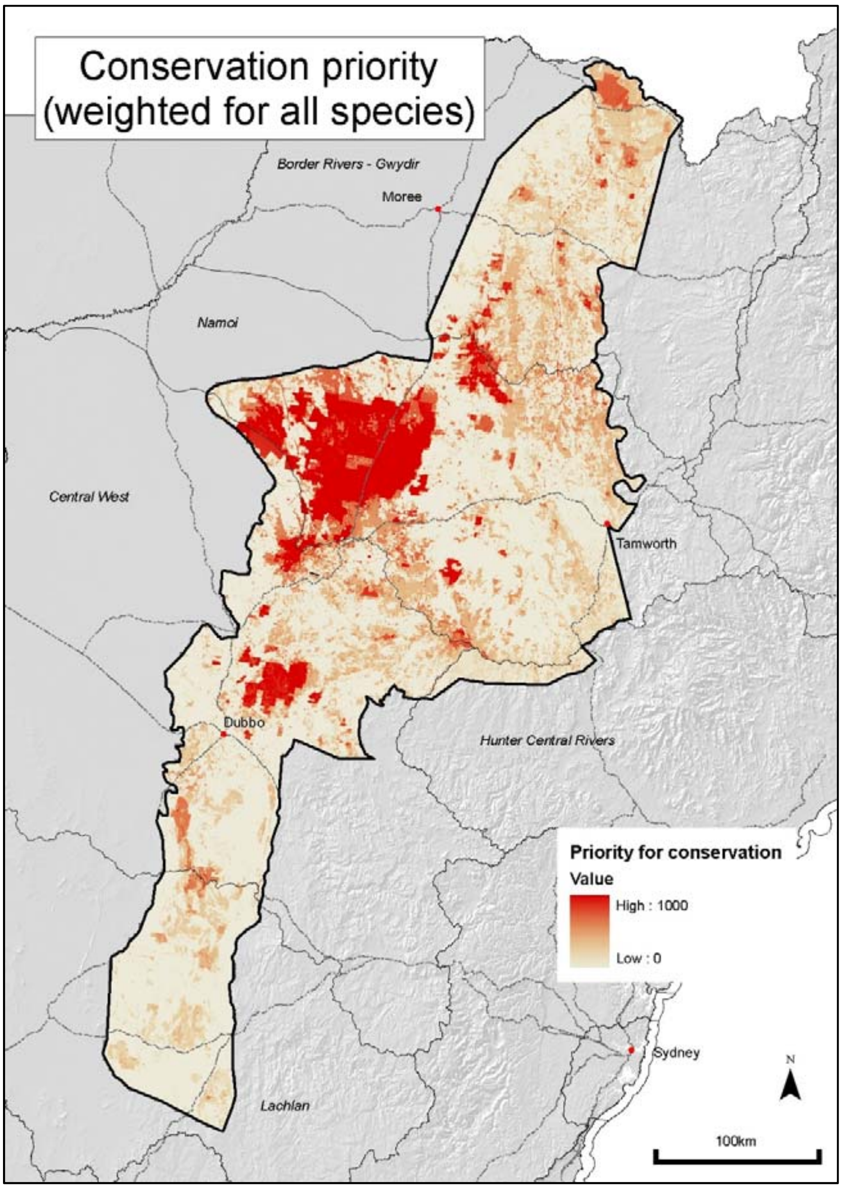

Figure 2. Conservation priority for vegetation based on the aggregated requirements of all declining species included in the analysis.

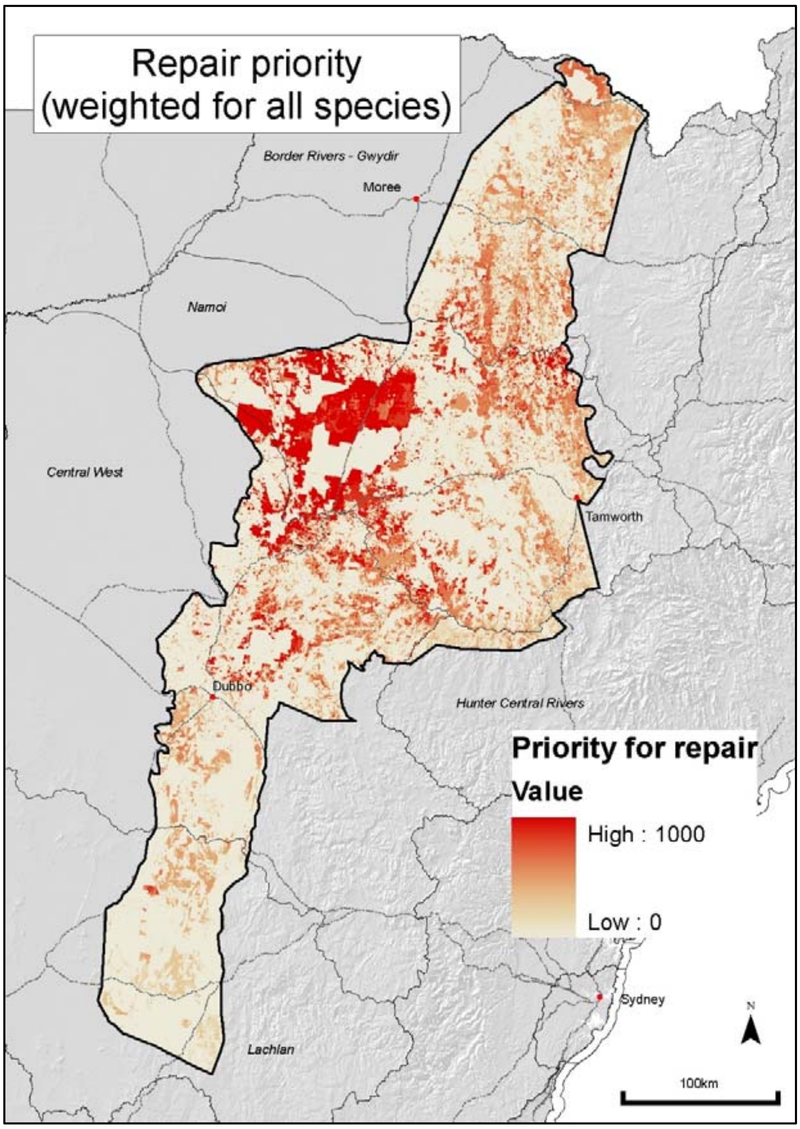

Figure 3. Repair priority for vegetation based on the aggregated requirements of all declining species included in the analysis.

Discussion

Given the scarcity of resources available, greater benefits to conservation will be achieved if cost effective actions, those that maximize benefit across a number of priority species, can be identified and acted upon (Lambeck 1997). This study combined expert knowledge and the REMP modelling methodology to identify priority areas for conservation action in the Western Woodlands region of New South Wales Australia. The prioritization provides useful guidance on where in the region to conserve and repair (improve condition) habitat in order to halt or reverse the decline of 34 declining species in a strategic and cost-effective manner. The prioritization transcended debates over which landscape attributes are of most importance and instead focused on identifying any opportunities that improve viability for the species individually and collectively. Because of the relatively modest input requirements of the approach we adopted, it can feasibly be adapted to the conservation planning needs of other regions and to other species.

The study identified six species that currently have insufficient habitat to support viable populations in the region and are therefore expected to decline under current conditions. These most vulnerable species have some common attributes and can be placed in two distinct groups based on these attributes: the Barking Owl, Gilbert’s Whistler and Superb Parrot require very large minimum viable habitat areas (MVH) which makes them especially susceptible to the impacts of habitat fragmentation; the Five-clawed Worm Skink and Green Tree Snake show high levels of habitat specificity, there being very few vegetation types which provide suitable habitat. This latter group will require intensive management regimes to improve their status. In general, the reptiles appeared highly susceptible to habitat fragmentation (compared to the birds and mammals) and this could be due to two reasons: they show a higher level of habitat specificity, and their day-to-day and dispersal movement abilities are much more restricted.

The study demonstrates for the first time the feasibility of undertaking biodiversity assessment incorporating REMP, which is relatively new to conservation planning. REMP is a valuable tool insofar as it is responsive to species-specific habitat requirements: the amount of habitat, its quality and spatial distribution. However, other factors such as the impact of pests, predators, fire regimes and diseases are not dealt with in the REMP methodology. As such, REMP is most suited to informing broad-scale general conservation strategies, especially as it requires only four parameters per species and modest processing times. Thus, REMP can facilitate rapid assessment of multiple species, including common or less threatened species that may otherwise be dismissed as being ‘common’ but are actually already committed to a path of decline due to inadequate habitat (Lindenmayer et al. 2011). More intensive modelling effort, such as population viability analyses (Possingham et al. 1993; Burgman 2000) which strives to incorporate greater detail on species ecology, is warranted in cases of species at risk of imminent extinction. However, compared with REMP, PVA simulations cannot be as easily applied as they are generally complex to configure and are computationally demanding (Hanski 2004). Where critical cases do arise, the results from this study can feasibly be used alongside or incorporated with more detailed species assessment for the affected species.

Acknowledgements

Funding for the WWW project was provided by Border Rivers/Gwydir, Namoi, Lachlan and Central-West Catchment Management Authorities. The following people provided information on the ecological requirements of the species included in the analysis: George Barrott-Brown, Peter Christie, Hal Cogger, Stephen Debus, Eric and Veronica Doerr, Murray Ellis, Hugh Ford, David Geering, Rod Kavanagh, Cilla Kinross, Brad Law, Greg Lollback, Richard Major, Terry Mazzer, Damon Oliver, Harry Parnaby, Michael Pennay, Darren Shelly, Debbie Saunders, Julian Seddon and Phil Spark. Thanks also to Janeen Robb, Jill Smith, Glenn Manion, Jamie Love and Nereda Christian for technical support.

References

Australian State of the Environment Committee (2011) State of the environment 2011. Australian Department of Sustainability, Environment, Water, Population and Communities, Canberra. (http://www.environment.gov.au/soe/2011/index.html). Accessed July 29, 2013

Ball IR, Possingham HP (2000) Marxan (v. 1.8.6): Marine Reserve Design Using Spatially Explicit Annealing. User Manual: (http://www.uq.edu.au/marxan). Accessed August 2, 2013

Barrett GW, Silcocks AF, Cunningham R, Oliver DL, Weston MA, Baker J (2007). Comparison of atlas data to determine the conservation status of bird species in New South Wales, with an emphasis on woodland-dependent species. Australian Zoologist 34:37–77

Burgman MA (2000). Population viability analysis for bird conservation: prediction, heuristics, monitoring and psychology. EMU 100:347–353

Butchart SHM, Walpole M, Collen B, van Strien A, Scharlemann JPW, Almond REA, et al. (2010). Global Biodiversity: Indicators of recent declines. Science 328:1164–1168

Calabrese JM, Fagan WF (2004). A comparison-shopper's guide to connectivity metrics. Front Ecol Environ 2:529–536

Day JR, Possingham HP (1995). A stochastic metapopulation model with variability in patch size position. Theor Popul Biol 48:1–28

Doerr VAJ, Barrett T, Doerr ED (2011). Connectivity, dispersal behaviour and conservation under climate change: a response to Hodgson et al. J Appl Ecol 48:143–147

Drew A, Freudenberger D, Clayton M (2002). Weddin Catchment Biodiversity Assessment. Canberra: CSIRO Sustainable Ecosystems.

Drielsma M, Ferrier S (2009). Rapid evaluation of metapopulation persistence in highly variegated landscapes. Biol Conserv 142:529–540

Ellis M, Drielsma M, Mazzer L, Baigent E (2007). Clearing, grazing and reservation: assessing regional impacts of vegetation management on the fauna of south western New South Wales. In: Dickman C, Lunney D, Burgin S (eds) Animals of Arid Australia: out on their own? Royal Zoological Society of New South Wales, Mosman, pp 102–131

Fischer J, Lindenmayer DB (2006). Beyond fragmentation: the continuum model for fauna research and conservation in human-modified landscapes. Oikos 112:473–480

Fischer J, Lindenmayer DB (2007). Landscape modification and habitat fragmentation: a synthesis. Global Ecol Biogeogr 16:265–280

Fuller RA, Drielsma MJ, Watson JEM, Taylor R, Sushinsky J, Smith J, et al. (2012). Western Woodlands Way: Volume 1. Priorities for ecological restoration. Spatial Ecology Laboratory, University of Queensland and Landscape Modeling and Decision Support Section. Brisbane: New South Wales Office of Environment and Heritage.

Gibbons, P., & Freudenberger, D. (2006). An overview of methods used to assess vegetation condition at the scale of the site. Ecol Manage Rest 7:S10–S17

Hanski I (1999a). Habitat connectivity, habitat continuity, and metapopulations in dynamic landscapes. Oikos 87:209–219

Hanski I (1999b). Metapopulation Ecology. Oxford University Press, Oxford

Hanski I (2004). Metapopulation theory, its use and misuse. Basic Appl Ecol 5:225–229

Hanski I, Ovaskainen O (2000). The metapopulation capacity of a fragmented landscape. Nature 404:755–758

Hodgson JA, Moilanen A, Wintle BA, Thomas CD (2011). Habitat area, quality and connectivity: striking the balance for efficient conservation. J Appl Ecol 48:148–152

Hodgson JA, Thomas CD, Wintle BA, Moilanen A (2009). Climate change, connectivity and conservation decision making: back to basics. J Appl Ecol 46:964–969

International Union for Conservation of Nature and Natural Resources (2012) The IUCN Red List of Threatened Species. Version 2012.2. (http://www.iucnredlist.org). Accessed July 29, 2012

Lambeck RJ (1997). Focal Species: A Multi-Species Umbrella for Nature Conservation. Conserv Biol 11:849–856

Lehtomäki J, Moilanen A (2013). Methods and workflow for spatial conservation prioritization using Zonation. Environ Modell Softw 47:128–137

Lindenmayer DB, Wood JT, McBurney L, MacGregor C, Youngentob K, Banks SC (2011). How to make a common species rare: A case against conservation complacency, Biol Conserv, 144:1663–1672

McIntyre S, Barrett GW (1992). Habitat Variegation, An Alternative to Fragmentation. Conserv Biol 6:146–147

Moilanen A, Kujala H (2008). The Zonation conservation planning framework and software v. 2.0: User Manual. (www.helsinki.fi/BioScience/ConsPlan). Accessed September 27, 2013.

Moilanen A (2011). On the limitations of graph-theoretic connectivity in spatial ecology and conservation. J Appl Ecol 48:1543–1547

Nicholson E, Ovaskainen O (2009). Conservation prioritization using metapopulation models. In: Moilanen A, Wilson KA, Possingham HP (eds) Spatial conservation prioritization: quantitative methods and computational tools. Oxford University Press, Oxford, pp 110–121

Parkes D, Newell G, Cheal D (2003). Assessing the quality of native vegetation: The 'habitat hectares' approach. Ecol Manage Rest 4:S29–S38

Possingham HP, Lindenmayer DB, Norton TW (1993). A framework for the improved management of threatened species based on Population Viability Analysis (PVA). Pac Conserv Biol 1:39–45

Reid JRW, Cunningham RB (2008). Statistical analysis of Cowrta woodland birds program's bird database to document trends in individual bird species and functional groups for monitoring and evaluation and to identify targets for habitat management and restoration. Report to Lachlan CMA and Birds Australia. Canberra: Fenner School of Environment and Society, Australian National University

Seddon J, Briggs S, Doyle S (2002). Little River Catchment Biodiversity Assessment. Sydney: NSW National Parks and Wildlife Service

Taylor R, Drielsma MJ (2012). Western Woodlands Way: Volume 2. Priorities for investment in remnant vegetation and connectivity. Dubbo, New South Wales Office of Environment and Heritage

Zerger A, Gibbons P, Jones S, Doyle S, Seddon J, Briggs SV, et al. (2006). Spatially modelling native vegetation condition. Ecol Manage Rest 7:S37-S44