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Target setting for restoration priorities in the South Australian Murray Mallee

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Introduction

Landscape Assessment [1, 2] has been applied to the Murray Mallee IBRA Sub-region (Version 6.1) in South Australia [3, 4], providing a situation assessment for the conservation requirements of landscapes (where landscapes used in landscape assessment have similar management requirements and co-occur geographically, they have been lumped together and are termed management landscapes in this report). Table 1 provides a coarse-filter conservation assessment of the South Australian Murray Mallee IBRA Sub-region. In each case where restoration is required to maintain the current biodiversity of an area, the assumption has been made that insufficient habitat area is the primary cause of decline, and that alleviating decline will require an increase in habitat area [e.g. 5]. Two methods were used to set targets for total area of habitat required (= ecosystem in desirable state and/or condition):

- focal species
- 30% of potential extent

The focal species approach advocates selecting a subset of 'focal species' whose requirements for persistence define the attributes that must be present in the landscape for all species to persist [6]. While originally envisaged as a focal species umbrella, encompassing a range of threatening processes, the concept is used here only to select the species most limited by habitat area from each of the landscape response groups, defined in [3, 4]. Focal species as an approach to target setting in conservation has generated a lot of debate in the literature [6, 7, 8, 9, 10, 11], but the concept when used sensibly can be of use in guiding the required management actions [8].

The 30% 'rule' has evolved from a number of habitat fragmentation studies, both theoretical and applied, in which landscape thresholds become apparent when cover of vegetation falls below 10-30% [e.g. 12, 13, 14]. Below this level of vegetation cover, some indicator of desirable landscape function falls dramatically compared to small changes above the threshold. The use of the 30% threshold in this report differs from other cases where generic thresholds are used or advocated [e.g. 11, 15] in that here it is used as a target for the restoration of a landscape component determined *a priori* as at risk.

For conservation goals where suggested regional investment is given as high in Table 1, this report defines areas of the landscape in which restoration activities are most likely to contribute to each conservation goals. The results presented here, and particularly their interpretation, focus on remaining sensible and ecologically intuitive.

Table 1: Summary of coarse-filter conservation assessment across the Murray Mallee IBRA Sub-region in South Australia

Region	Management Landscape	Environmental setting	Conservation coarse-filter	Best spatial representation	Conservation status	Trajectory	Conservation goal	Generic action	Suggested regional investment
Murray Mallee IBRA Sub-region	All	All	Native vegetation	Whole region	Least concern	Stable	Maintain	Reliance on policy mechanisms	Low
Murray Mallee IBRA Sub-region	All	All	Critical weight-range mammals	Whole region (and most of Australia)	Extinct	Stable	Learn about processes impacted through experiments in similar systems (e.g. Scotia, Yookamurra) and restore those processes if necessary/possible	Research	None
Murray Mallee IBRA Sub-region	Western Murray Mallee	All	Grazed/browsed stratum	Whole landscape	Threatened	Declining	Restore stratum to maintain landscape function	Invest in programs to initiate restoration trajectory	High
Murray Mallee IBRA Sub-region	Northern Murray Mallee	H2 soils	Triodia mallee	H2 soils of [16]	Extinct	Stable	Maintain good remaining patches, if any	Support for interested community groups/members, if any	Low
Murray Mallee IBRA Sub-region	Northern Murray Mallee	H2 soils	Shrubby mallee	H2 soils of [16]	Threatened	Declining	Restore ecosystem to maintain landscape function	Invest in programs to initiate restoration trajectory	High
Murray Mallee IBRA Sub-region	Southern Murray Mallee	A4, B2, B3, F2 soils	Open mallee woodland	A4, B2, B3, F2 soils of [16]	Threatened	Declining	Restore ecosystem to maintain landscape function	Invest in programs to initiate restoration trajectory	High
Murray Mallee IBRA Sub-region	Western Murray Mallee – Fragmented	A4, some B2 soils	Open mallee woodland	A4, some B2 soils of [16]	Extinct	Stable	Maintain good remaining patches, if any	Support for interested community groups/members, if any	Low
Murray Mallee IBRA Sub-region	Western Murray Mallee – Fragmented	H2, G4 soils	Shrubby and/or Triodia mallee	H2, G4 soils of [16]	Extinct	Stable	Maintain good remaining patches, if any	Support for interested community groups/members, if any	Low
Murray Mallee IBRA Sub-region	Western Murray Mallee – Fragmented	Drainage lines	Drainage lines	Pre-European mapping vegetation IDs MN0011PE, MN0007PE	Threatened	Declining	Restore ecosystem to maintain landscape function	Invest in programs to initiate restoration trajectory	High

Methods

Spatial Information

All spatial information was retrieved from the South Australian Department of Environment, Water and Natural Resource's corporate spatial database (SDE EgisDATA) during the 2011/2012 financial year (dates varied depending on analyses), unless specified below.

Target quantification

Focal Species

Area limited focal species were selected from landscape response groups [defined elsewhere - 3, 4]. Table 2 lists the species used. All records of these species in the FAUNA.Supertable layer were mapped with the following criteria:

- date accuracy not equal to 'T' (decade) or 'C' (century)
- date of record greater than 01/01/2000
- spatial accuracy of record better than 1 kilometre (ReliabNR < 5)
- method of record not equal to inactive nest – to exclude Malleefowl mounds that were not active at the time of the record being taken (MethodNR <> 48)

These records had a buffer of 20km added (maximum 40km between records). All buffers that overlapped the landscape of interest or other buffers that overlapped the landscape of interest were selected and used to create an estimate of 'population area'. If this 'population area' overlapped the coastline it was clipped to the state border layer.

Based on a meta-analysis estimate of minimum viable population for birds [3742 individuals - 17] and estimates of the area requirements of individuals of each species [18, 19, 20, 21], an estimate of the total area for a viable population was made. The proportion of a viable population required within a landscape was then set as equivalent to the proportion of the management landscape to the 'population area' of the species. Multiplying this number of individuals by the area requirements of an individual gave an estimate for the target area of habitat required within a management landscape (Table 2).

Maps of the 'population area' for each species are given in Appendix 1.

Table 2: Inputs to calculate area targets based on focal species approach

Landscape	Species	Ref	Landscape area (hectares)	Species 'population area' (hectares)	Proportion	Landscape contribution to minimum viable population (individuals)	Individual area requirement (hectares)	Target (hectares)
Western Murray Mallee	Malleefowl	[18]	289,430	2,742,762	0.1055	395	110	43,436
Northern Murray Mallee	Gilbert's Whistler	[19]	780,921	3,608,020	0.2164	810	90	72,893
Southern Murray Mallee	Restless Flycatcher	[20]	719,800	4,705,725	0.1530	572	150	85,858
Western Murray Mallee – fragmented	Diamond Firetail	[21]	267,758	2,715,276	0.0986	369	16	5904

30% of potential extent

The amount of the target environmental setting present in each management landscape was multiplied by 0.3 (see Amount of target below).

Table 3: Inputs to calculate area targets based on 30% of potential extent of ecosystem

Management Landscape	30% of ecosystem (hectares)
Western Murray Mallee	46329
Northern Murray Mallee	53300
Southern Murray Mallee	122657
Western Murray Mallee – fragmented	5205

Marxan

Marxan is software used to support decision making [22]. The software uses simulated annealing to find a good answer to a spatial problem, defined by the user, involving a set of targets and costs generated for a surface of planning units [23, 24].

In the analyses used here targets were potential habitat – defined by the environmental setting on which the ecosystem to be restored occurs and different for each management landscape. Two costs were combined to produce the cost surface: distance cost and remnancy cost.

For each problem given to Marxan, the settings used are given in Table 4. The species penalty factor was iteratively increased from 1 to ensure the solution met the targets established [22].

Table 4: Marxan parameters used for each analysis

Parameter type	Parameter	Value
Problem	repeat runs	100
Problem	boundary length modifier	0
Run Options	simulated annealing	1
Run Options	heuristic	0
Run Options	normal iterative improvement	1
Annealing	number of iterstions	1000000
Annealing	temperature decreases	10000
Annealing	adaptive annealing	1
Annealing	initial temperature	-1
Annealing	cooling factor	6
Input	block definitions	none
Input	boundary length	none
Miscellaneous	starting proportion	0

Planning Units

A hexagonal grid was place over the Murray Mallee IBRA Sub-region and cut to management landscape boundaries. Each of the original hexagons was 10,000 hectares, although many of these were cut down by landscape boundaries.

Distance cost

A planning unit close to an area of the landscape in which all the species of a declining landscape response group have been recorded recently incurred a low distance cost. The distance from each planning unit to the nearest, recent record of each species was calculated. The mean of all these (standardised from 0 to 1) was the distance cost. A planning unit that contained a recent record of all species in the landscape response group would incur a cost of 0, while a planning unit 20 kilometres or more from recent records of all species in the landscape response group would incur a cost of 1. Species records were accessed from the FAUNA.SupertableUnfiltered layer, located within a 20 kilometre buffer of the management landscape boundaries and filtered with the following criteria:

- date accuracy not equal to 'T' (decade) or 'C' (century)
- date of record greater than 01/01/1990
- spatial accuracy of record better than 1 kilometre (ReliabNR <= 5)
- method of record not equal to inactive nest – to exclude Malleefowl mounds that were not active at the time of the record being taken (MethodNR <> 48)

Remnancy cost

While there are a plethora of statistics available for classifying landscape structure [e.g. 25], the analyses used here included only one landscape structure attribute – proportion of native vegetation cover. This is the simplest, most intuitive of the many statistics and, as a surrogate for habitat area, its loss has consistently been found to have negative effects on biodiversity [13, 14, 26, 27, 28, 29, 30]. Restoring patches of an ecosystem at risk in areas of the landscape that retain higher levels of native vegetation cover are more likely to contribute to restoring ecosystem function within that landscape than restoring patches in areas that retain little native vegetation cover. Thus, remnancy cost was lowest (0) if a planning unit was entirely vegetated and highest (1) if it was entirely cleared, based on the VEG.NativeVegetationCover layer.

Planning unit cost

Planning unit cost was the mean of distance cost and remnancy cost.

Amount of target

The amount of target environmental setting within each planning unit was generated from some combination of LANDSCAPE.Biophysical_L5SoilLandscapes, VEG.PEVegetation and/or VEG.SAVegetation spatial layers from SDE EgisDATA, as specified in Table 5.

To generate a layer of soil subgroups, soils information was linked to the LANDSCAPE.Biophysical_L5SoilLandscapes layer using the LANSLU field and a copy of the subgroup soils analysis data table [31]. The area of soil in an area was estimated by multiplying the proportion information for each polygon in the L5 Soil Landscape layer by the area of that polygon and aggregating as appropriate. Soil subgroup information is now available directly from SDE EgisDATA via the LANDSCAPE.SALAD_Soil_Subgroup layer.

Due to the way vegetation (both Pre-European and current) information is stored, the amount of the vegetation type in an area was always generated from the primary vegetation type listed for a polygon (PE_Veg_ID1 for Pre-European vegetation mapping and SA_Veg_ID1 for current vegetation mapping). i.e. No attempt was made to calculate the proportion of different vegetation types in a polygon and aggregate on that basis, due to issues with data storage, even where there was an indication that the polygon contained a mosaic of different vegetation types.

Table 5: Spatial layers used to estimate amount of target in each planning unit

Management Landscape	Layer	Criteria for target
Northern Murray Mallee	LANDSCAPE.Biophysical_L5SoilLandscapes	H2, H3
Southern Murray Mallee	LANDSCAPE.Biophysical_L5SoilLandscapes	A4, A5, A6, B1, B2, B3, C1, C3, C4, D2, D3, F2,
Western Murray Mallee	VEG.PEVegetation and VEG.SAVegetation where no Pre-European vegetation exists	SP0012, SP0013, NP0004, NP0028, MM3801PE, MN0034PE, WM6501PE
Western Murray Mallee – Fragmented	VEG.PEVegetation and VEG.SAVegetation where no Pre-European vegetation exists	WM1401, WM1501, MN0011PE, MN0007PE, MM0601PE, SE0006PE

Results

Targets

Table 6 shows the targets calculated for each management landscape using each method and the corresponding conservation penalty factor (or species penalty factor, spf [22]) required to ensure the target was reached in the best solution. Table 7 shows an example of the iterative runs of increasing spf to ensure that the target was reached in the best solution.

Table 6: Targets used for each analysis

Management Landscape	Focal Species Target (hectares)	30% potential extent target (hectares)	spf for 30%
Northern Murray Mallee	72893	53300	2
Southern Murray Mallee	85858	122657	2
Western Murray Mallee	43436	46329	5
Western Murray Mallee - Fragmented	5904	5205	2

Table 7: Iterative use of spf to ensure that the desired target is reached in the best solution

Management Landscape	Target (hectares)	Target achieved in best solution (hectares)	spf	Target reached?
Northern Murray Mallee	72,893	36,875	1	0
		72,886	2	0
		72,892	3	0
		72,852	4	0
		72,898	5	1
Southern Murray Mallee	85,858	53,150	1	0
		85,516	2	0
		85,834	3	0
		85,834	4	0
		86,239	5	1
Western Murray Mallee	43,436	19,611	1	0
		43,362	2	0
		43,362	3	0
		43,362	4	0
		43,362	5	0
		43,362	6	0
		43,362	9	0
		43,362	10	0
		43,362	11	0
		43,858	12	1
Western Murray Mallee - Fragmented	5,904	4,512	1	0
		5,710	2	0
		5,710	3	0
		5,710	4	0
		5,710	5	0
		6,076	6	1
		6,076	7	1
		6,076	10	1

Marxan

For each Marxan solution, the results are presented as the number of times a planning unit was selected in the best solution out of 100 runs. Thus if a planning unit was selected 100 times, restoration of patches within that planning unit are likely to contribute to the conservation outcomes desired for that landscape. If a planning unit was never selected in the 100 runs, restoration of patches within that planning unit are unlikely to contribute to desired conservation outcomes.

The presentation of results within Management Landscape maps follows these rules:

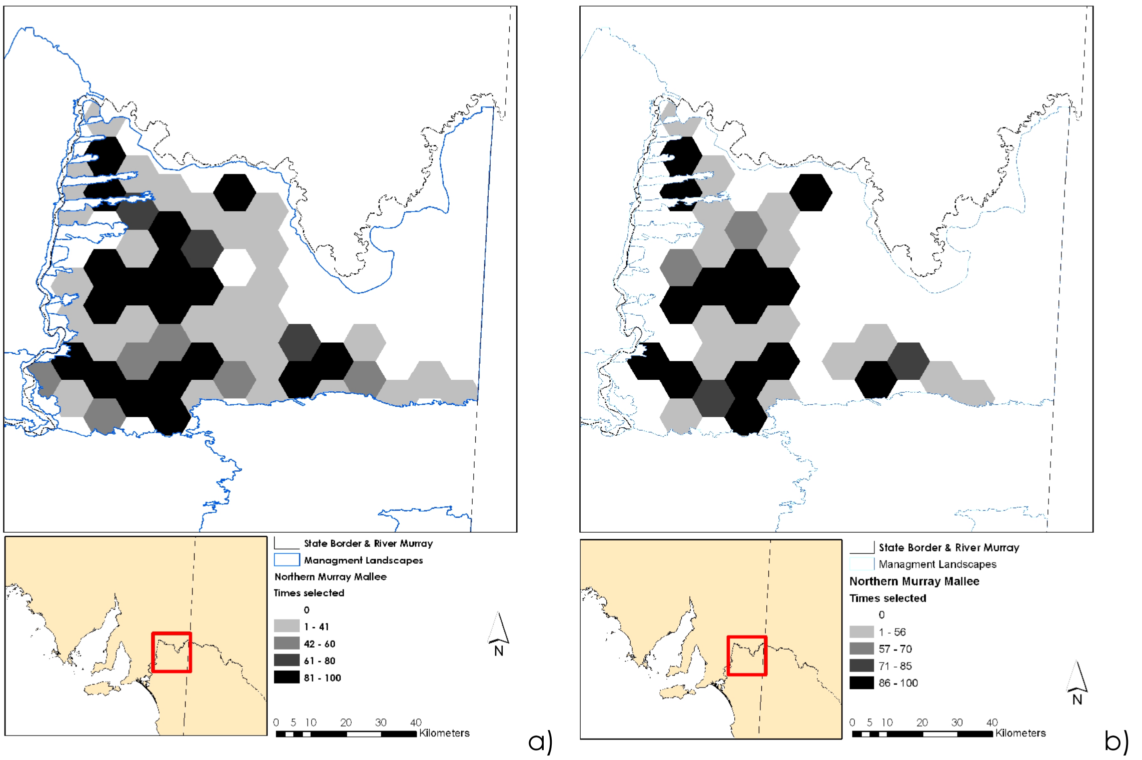
- the darkest three shades represent the planning units required to reach the target, split into three evenly spaced groups
- the lightest shading (other than no shading) represents planning units that were chosen in at least one of solutions from 100 runs, but that are not required to meet the target
- planning units which never in the solution are mapped as white (0).

Northern Murray Mallee

The focal species target was much larger than the 30% target for the Northern Murray Mallee. Correspondingly, in Figure 1a, a much larger proportion of planning units were chosen in at least one solution. Irrespective of target, two patterns are evident in the Figure 1:

- a series of planning units were selected consistently along a north-south axis to the west of the landscape
- and a small group of planning units were consistently selected in the middle-south of the landscape.

Figure 1: Marxan results for the Northern Murray Mallee, based on a) focal species and b) 30% potential extent

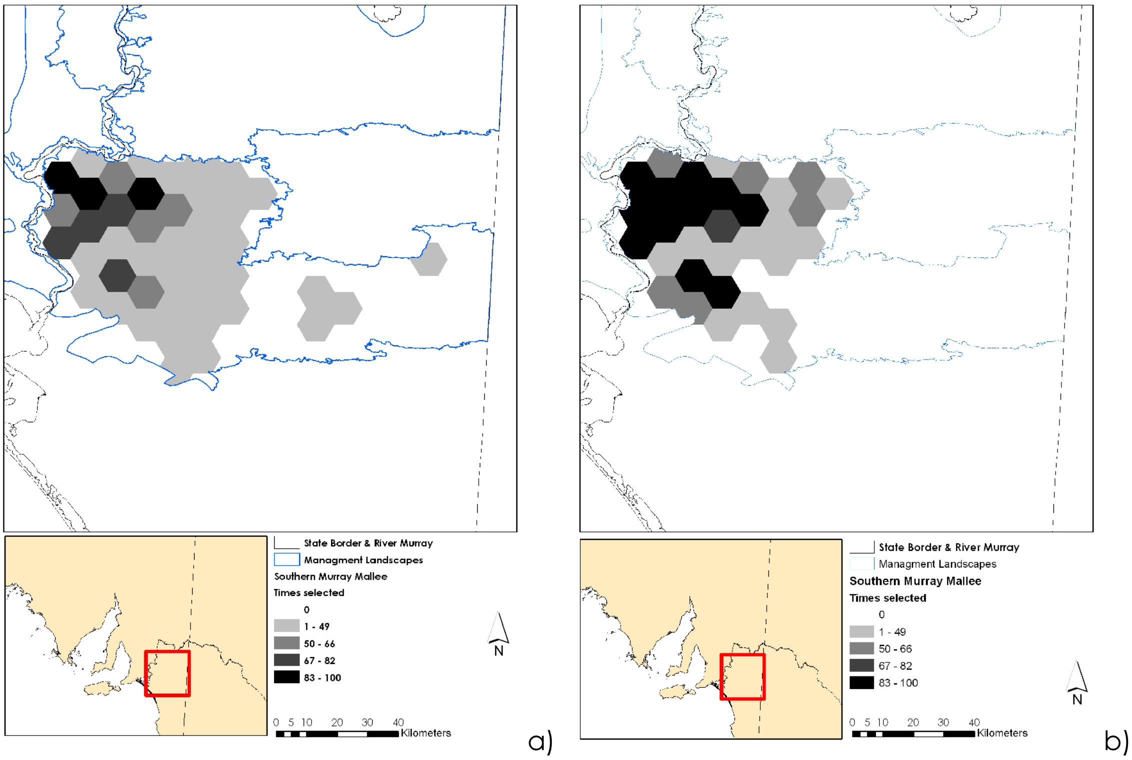


Southern Murray Mallee

For the southern Murray Mallee, the focal species target was much smaller than the 30% target. However, this produced an interesting result with more planning units in the focal species solution selected at least once (Figure 2a), but a tighter cluster of planning units selected more frequently in the 30% solution (Figure 2b), possibly as a result of the overall target being relatively easily met by the distribution of target setting among planning units, even with the larger overall target.

Again the pattern between the two solutions is striking, with the focus of the solution being the north-western corner of the landscape.

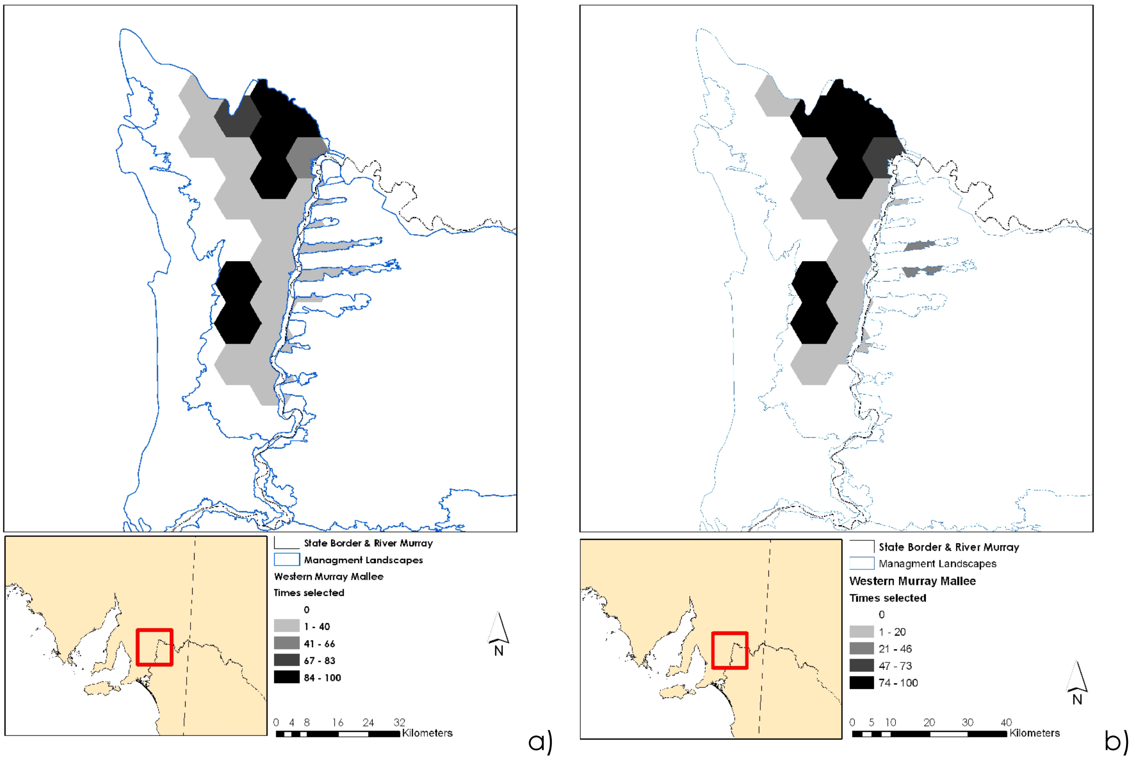
Figure 2: Marxan results for the Southern Murray Mallee, based on a) focal species and b) 30% potential extent



Western Murray Mallee

The two overall targets for the Western Murray Mallee were very close and the Marxan solutions are correspondingly close to identical (Figure 3a and b). Two areas are highlighted as likely to be good for focussing restoration efforts – a larger area in the north of the landscape and a smaller area in the central west of the landscape.

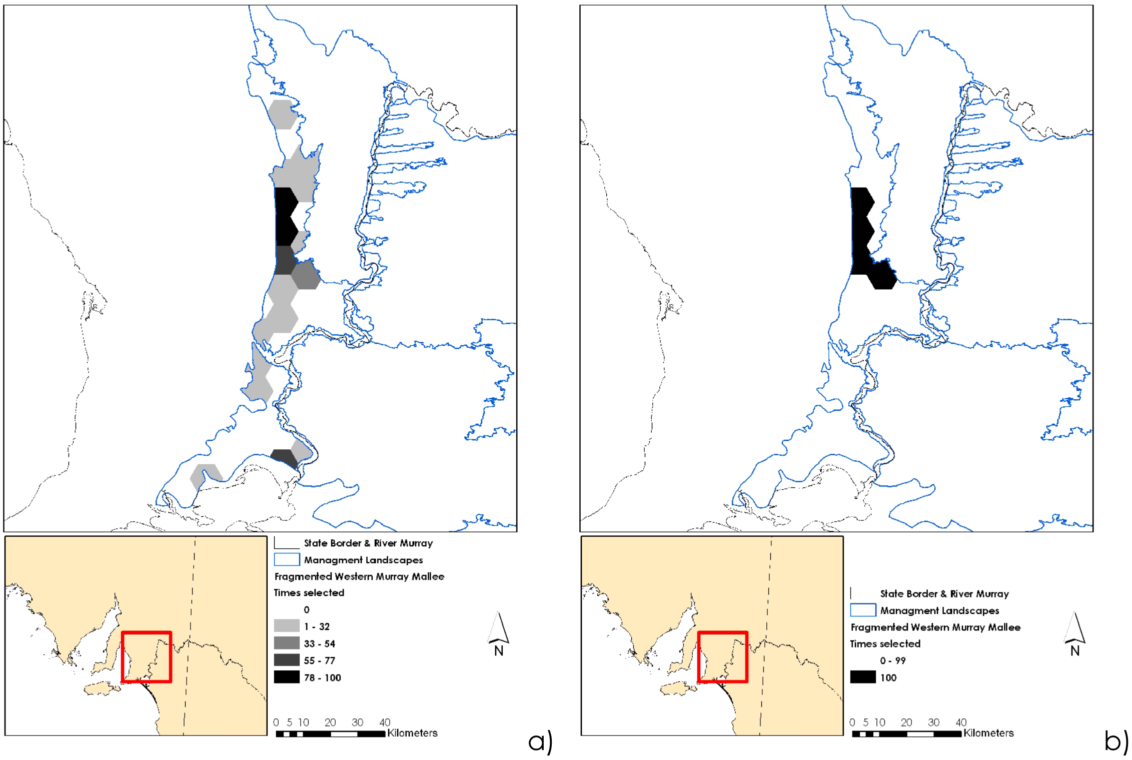
Figure 3: Marxan results for the Western Murray Mallee, based on a) focal species and b) 30% potential extent



Western Murray Mallee – Fragmented

Considering how close the two overall targets for this landscape were (about 700 hectares difference), the solutions show more variation than expected (Figure 4a and b – note that for the 30% solution planning units were only chosen all the time or never). Looking at the target area reached for each spf (see Table 7) there appears to be a very good, stable solution (involving 5700 hectares) only just below the identified target (5900 hectares), indicating that the solution available at spf 2-5 is also probably worth examining. Irrespective of the differences between the two solutions, there is certainly one area in the very centre of the landscape consistently highlighted as likely to be a good area for restoring patches.

Figure 4: Marxan results for the Western Murray Mallee – Fragmented, based on a) focal species and b) 30% potential extent



Discussion

Improving outputs

Overall target setting

While the intent behind the focal species approach to target setting is sound, the application, particularly that used here, failed to remain 'sensible'. The 'population area' method, in which a population is defined as a distance of not more than 40km between recent records, can be rightly criticised as fraught with spurious assumptions. Alternative methods involving species' habitat distribution mapping are available [e.g. 32], but the data required to populate such models with sensible information are not currently available and expensive to acquire [e.g. 6, 9, 11].

The 30% of potential extent target finds some support in the literature [5, 12], but can also be criticised as failing to take into account the requirements of any particular system to which it is applied [6]. Relying solely on general principles, such as 30% of original extent, is likely to lead to the situation where investment is too great for some systems and insufficient to conserve others.

The two methods used here to set targets and their criticisms highlight the poorly developed thinking, and unavoidable subjectivity, behind setting targets under coarse-filter conservation goals. However, this is perhaps not as great an impediment to sensible conservation planning given the remarkably similar pattern of results found here, irrespective of the overall target. Thus, rather than focus effort, concern and criticism on the method of target setting under a conservation goal, a more productive approach is perhaps to use a range of targets (say, 10-40% potential extent) for any conservation goal and then examine results for areas of the landscape that are consistently chosen as likely to contribute towards the goal under any level of target. Given the implementation timeframes inherent in restoration ecology, there are decades to centuries to refine the method of deciding 'how much is enough?' anyway [see also 33]. Further, implementation of even the most modest restoration target will take at least decades, again giving plenty of time to refine overall target – so long as confidence can be placed in the other inputs and the same planning units are chosen consistently, implementation can proceed with a reasonable level of confidence.

Another method of setting landscape restoration targets has not been investigated, but may prove useful in target setting is 'area of occupancy'. Repeat visit counts to sites within ecosystems at risk should enable area of occupancy to be calculated for a chosen set of species and then used as the target itself [34]. Area of occupancy estimates are available for bird species within all the management landscapes considered here, particularly the Northern Murray Mallee [35].

Distance cost

The distance cost used in these analyses relied on a filtered subset of recent records of species in FAUNA.SupertableUnfiltered layer. For the Northern Murray Mallee, this is not an unreasonable method, given efforts to search for the landscape response group species over several years [36]. However, for other landscapes, no such efforts have been made. Thus there is a risk that the current distribution of species in the landscape response groups of other landscapes are not adequately known for this analysis. The effect on the Marxan results would be to skew selection of planning units to parts of the landscape in which records have been taken of these species. Ongoing monitoring of the landscapes should both improve the distributional information upon which the distance cost is generated and refine the landscape response groups themselves.

Use of outputs

The analyses used here chose the spatial coverage judged best able to represent spatially the target environmental setting. In no case was there a spatial coverage in which the target environmental setting was directly mapped. Further, there are no available estimates of how accurate and precise the available data are in modelling the real world distribution of the target environmental setting. Again, this is not as much of an impediment to conservation planning as it may appear as the outputs produced here simply indicate areas of the landscape likely to contribute to the overall conservation goal through restoration of patches and the intent has always been to combine the mapping outputs with ground-truthing of patches available for restoration. Where desired environmental setting determined on the ground coincides with areas of the landscape likely to contribute (in or near planning units selected in many runs), investment in on-ground works can be made with relative confidence. This is the sole use for which the outputs are intended. Using the outputs for any other purpose requires the user to consider the appropriateness and limitations of any such use.

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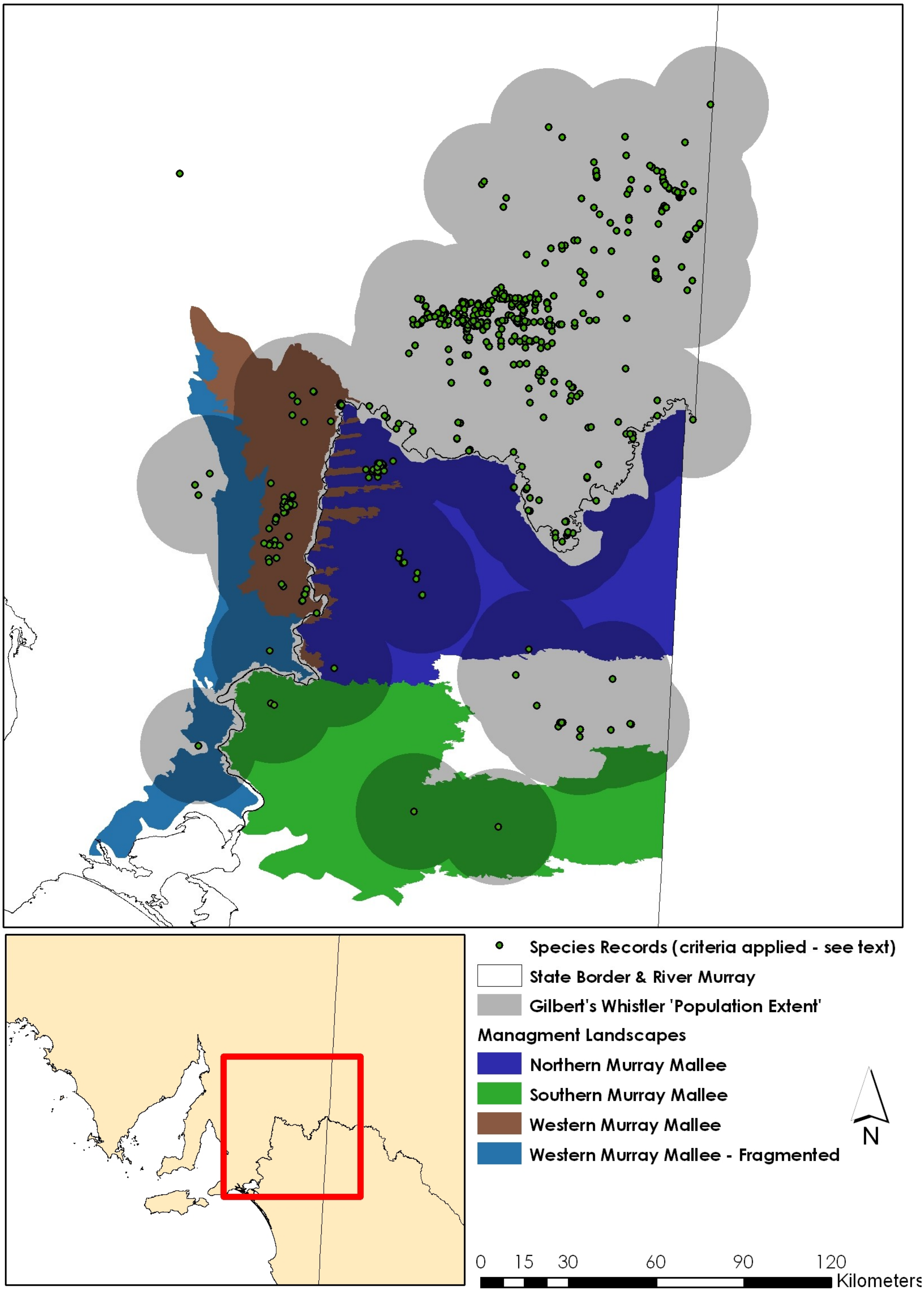
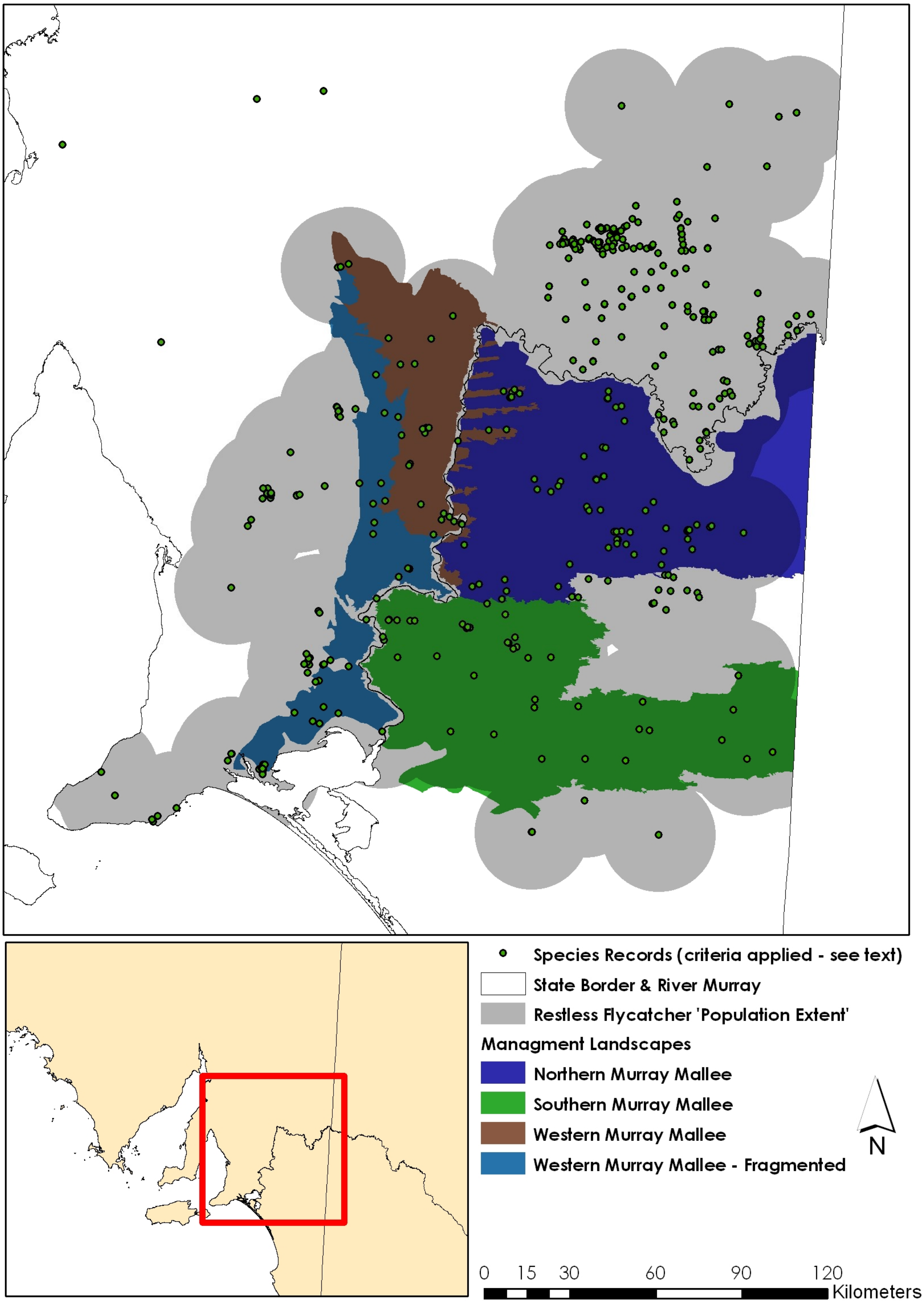
Appendix 1: 'Population area' maps for each focal species

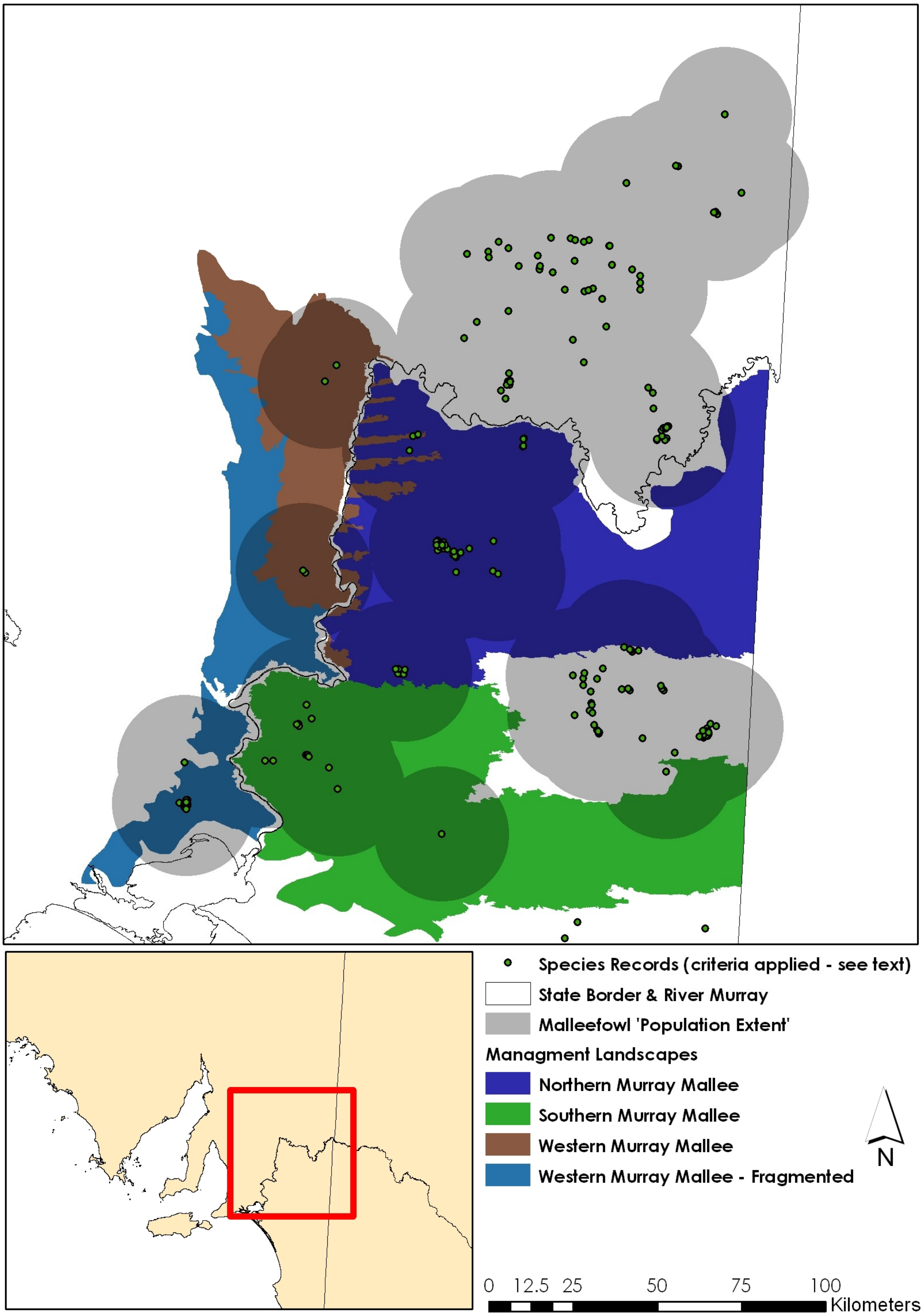
Gilbert's Whistler – used as focal species for overall target setting in the Northern Murray Mallee



Restless Flycatcher – used as focal species for overall target setting in the Southern Murray Mallee



Malleefowl – used as focal species for overall target setting in the Western Murray Mallee



Diamond Firetail – used as focal species for overall target setting in the Fragmented Western Murray Mallee