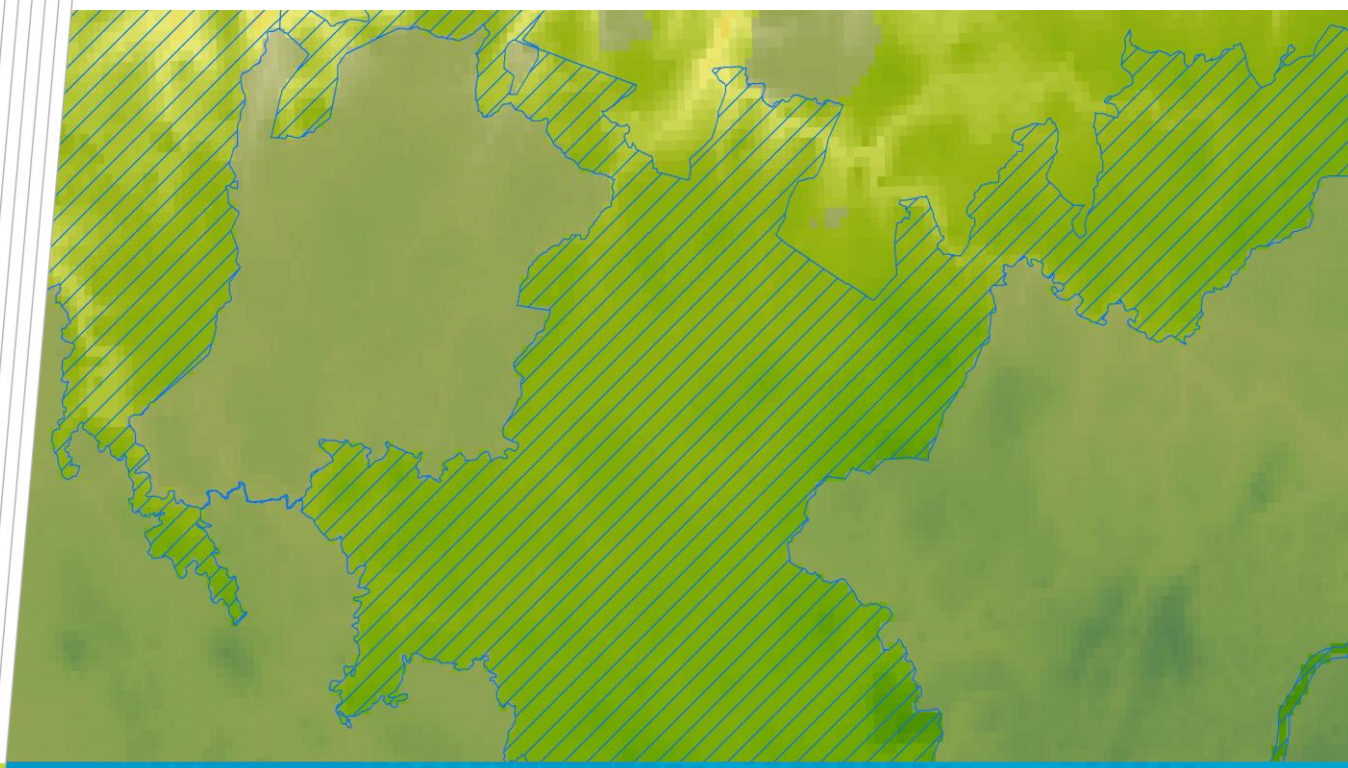

An assessment of the representation of vascular-plant compositional diversity in reserves under the Tasmanian Forests Intergovernmental Agreement

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DRAFT Report to the Tasmanian Forest Agreement Independent Verification Group

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1. INTRODUCTION

Under the Tasmanian Forests Intergovernmental Agreement (IGA) (07/08/11) a number of potential new reserves have been identified. This study applies an existing generalised dissimilarity modelling (GDM) based approach (Ferrier et al, 2004, Ferrier et al 2007) to assess the extent to which these proposed additions to the National Reserve System (NRS) contribute to improving the representation of vascular-plant compositional diversity in reserves. Modelling was conducted at a resolution of 0.0025º (≈ 250 m) for the whole of Tasmania, and results are mapped and summarised within broad forest types on public land.

2. METHODS

The analysis was carried out strictly in accordance with the brief provided by the Independent Verification Group (IVG). First, a GDM model of vascular-plant compositional turnover across the whole of Tasmania was developed. This was then used to generate indices of reserve representativeness based on: 1) the current NRS; and 2) the NRS with additional reserves as proposed under the IGA. These indices were then mapped and summarised within four broad types of native forest. The shift in representativeness between these two scenarios indicates the contribution that the IGA reserves make to improving representation of compositional diversity in reserves.

2.1 Scope

The study was designed to generate an assessment for each of four major native forest types, using the *TASVEG 2.0* classification. On the advice of the IVG, *TASVEG* Broad Categories were used, but communities within these which had been treated as "non-forest" for other analyses conducted by the IVG were excluded. The four native forest categories are shown in Table 1.

Native Forest Type	***TASVEG* Broad Category**	**Excluded *TASVEG* Vegetation Communities**
Dry eucalypt forest and woodland	Dry eucalypt forest and woodland	
Wet eucalypt forest and woodland	Wet eucalypt forest and woodland	
Non eucalypt forest and woodland	Non eucalypt forest and woodland	NBA,NLN
Rainforest and related scrub	Rainforest and related scrub	RKS,RKX,RFE,RFS,RLS

Table 1: Definition of Native Forest Types used in the analysis.

Reporting of results was restricted to public land as defined in the *ivg_tenure_14.shp* layer supplied by R. Knight (Natural Resource Planning Pty Ltd). The distributions of the four native forest types on public land are mapped in Figure 1.

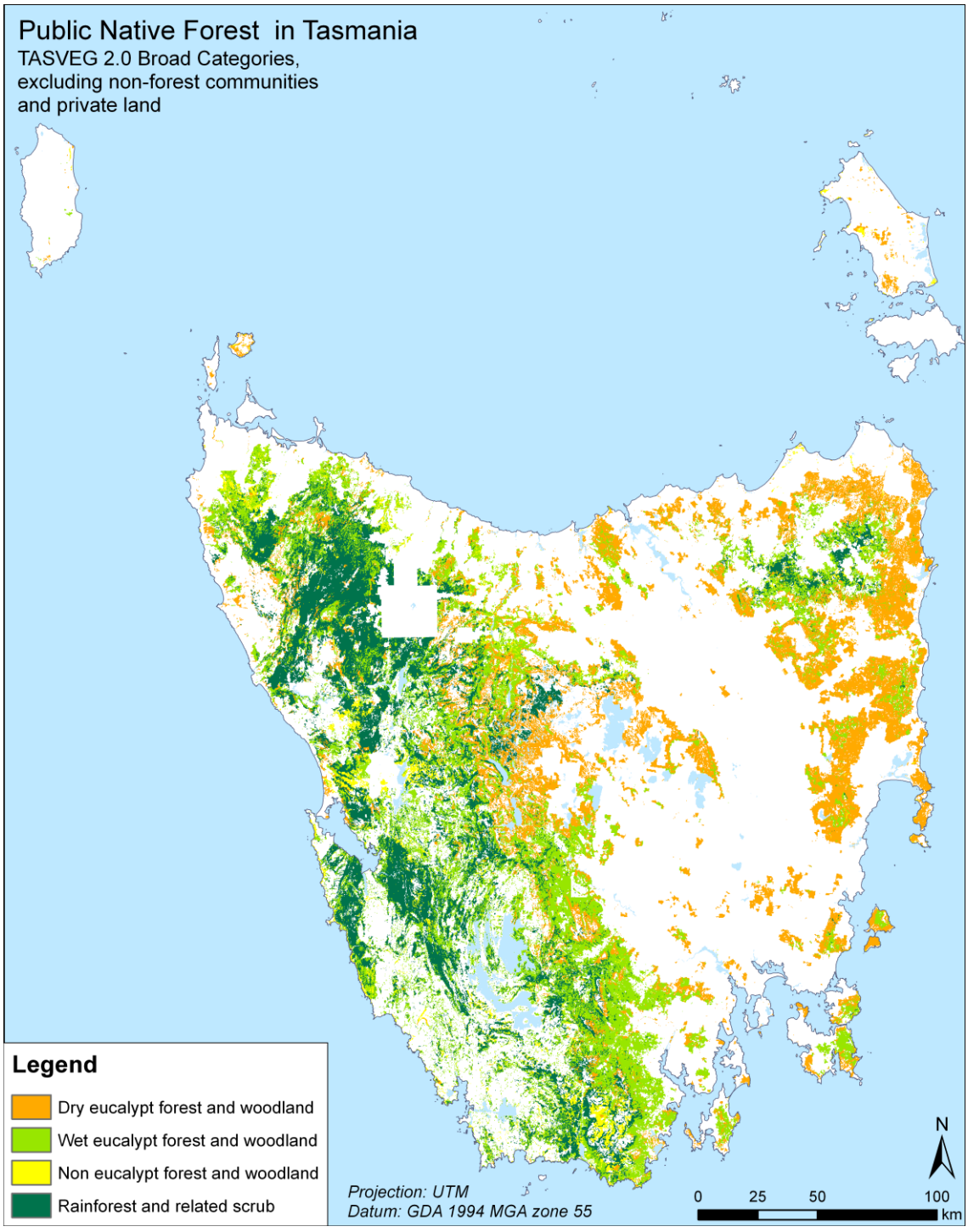

Figure 1: The distribution of native forest types on public land (derived from *TASVEG 2.0*).

The GIS layer *ivg_tenure_14.shp* was further used to provide the definition of the existing reserve system, i.e. the NRS, in 2011 and the proposed additional IGA reserves, as the basis of reporting reserve representativeness. These are mapped in

Figure 2, which also shows the extent of public land used to mask the distribution of Native Forest Types.

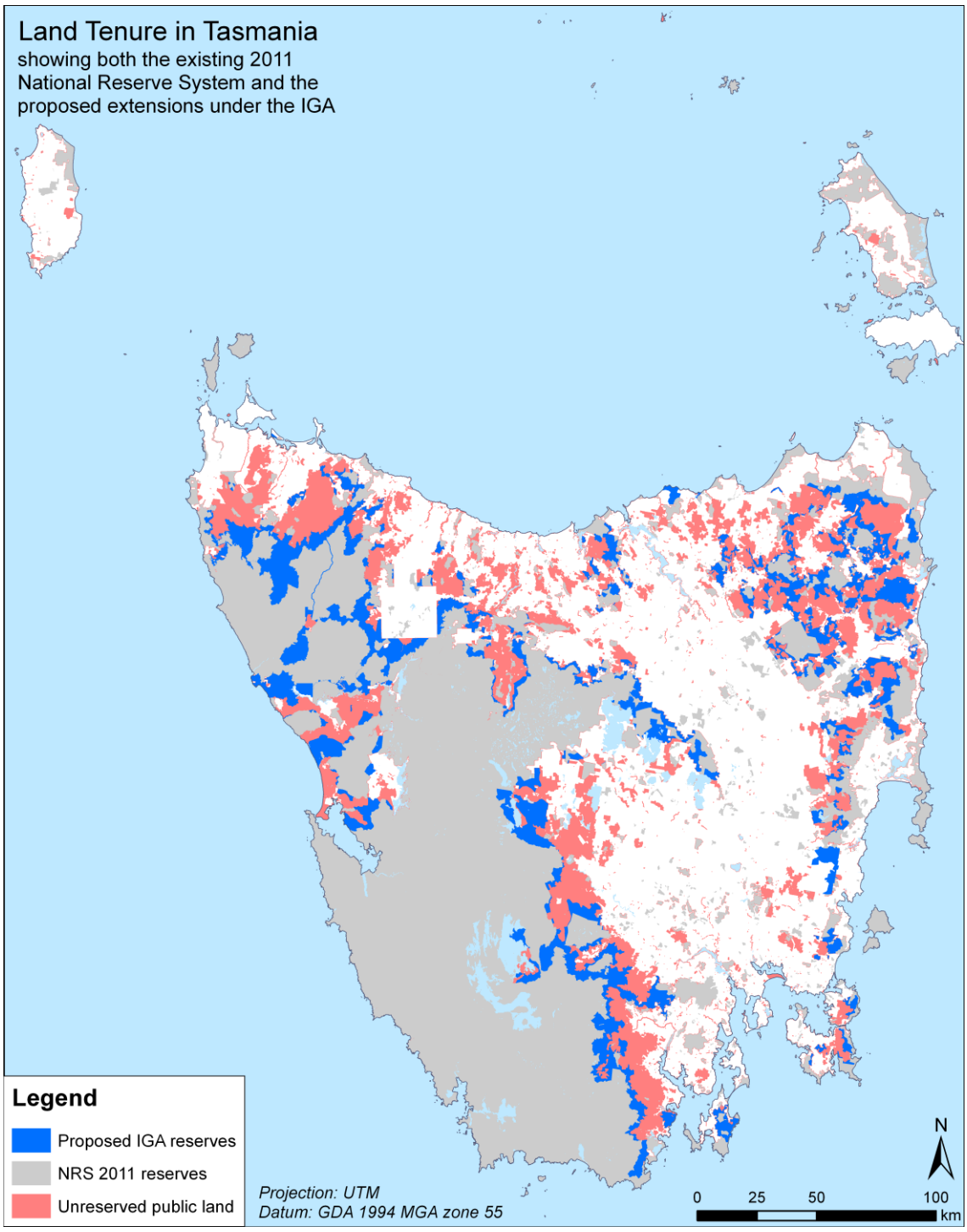

Figure 2: Current and proposed reserves and public land in Tasmania, as defined in *ivg_tenure_14.shp.*

In all cases, conversion from ArcMap shapefiles to raster grid was conducted using the "cell centre" option to ensure no overlap between categories.

2.2 Development of GDM model of vascular plant compositional turnover

Estimates of compositional dissimilarity (Sørenson index; Sørenson,1948) between 0.0025º grid cells were obtained from 562,772 point occurrence records of native plant species (2,051 species) in Tasmania from 1970 – 2010 (Tasmanian Natural Values Atlas). The observed compositional dissimilarity between pairs of 0.0025º grid cells was modelled as a function of five environmental variables (selected from a larger pool of variables, based on statistical significance testing – see below) and geographic distance between cells (Table 2). To account for the effects of under-sampling on the number of species observed in each grid cell, only grid cells where ≥40 species had been observed were assessed. From these data, under-sampling was further accounted for by assuming a simple function of the probability of a grid cell being under-sampled.

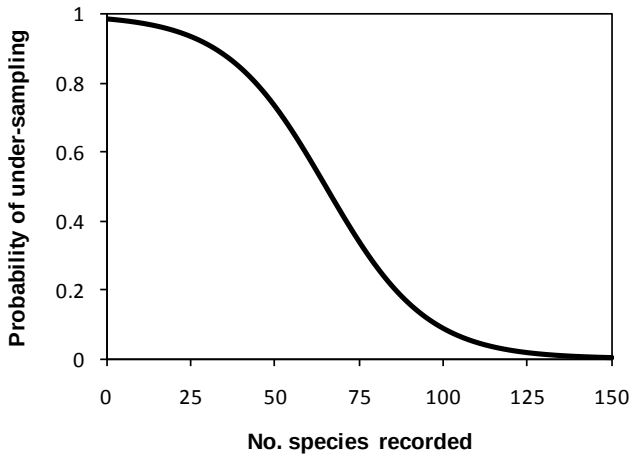

Figure 3: The assumed change in the probability that a grid cell (*i*) has been under-sampled (P_i) as the number of species recorded in the grid cell (S_i) increases. Specifically, $P_i = 1 / (1 - a^{((Si-b)c)})$, where a = 1.25, b = 65, and c = 0.3.

The under-sampling probability function (Figure 3) was used to randomly sub-sample the data. The model of compositional dissimilarity was derived based on multiple random subsets of the occurrence data using generalized dissimilarity modelling (GDM; Ferrier *et al*. 2007). An interactive backward variable selection process was used, with 10 random subsets of occurrence data applied in each step of the backward selection process. Forty-one climate, terrain and substrate variables, mapped at the 0.0025º resolution were initially selected for testing from a larger pool. Variables were then gradually omitted based on variable significance (obtained through Monte Carlo randomisation testing, repeated 1000 times), and variable contribution to deviance reduction. The final model contained six variables, all of which were significant (Table 2). The amount of deviance in compositional dissimilarity explained by the final model was 54.04% (Figure 4). The functions fitted to each of the six predictors in the GDM model are depicted in Figure 5. For full explanation of the different types of graphs presented in Figures 4 and 5, see Ferrier et al (2007).

The five environmental variable used in the GDM were the Wilford Weathering Intensity Index (Wilford, 2011) produced by GeoSciences Australia, which provides a characterisation of soil structure and chemistry, and four climatic variables generated using ANUCLIM 6.1 (Xu & Hutchinson, 2011), taking the GEODATA 9 second DEM (ANU, 2008) as input: Total January Radiation, July Minimum Temperature (MTHCLIM), Isothermality (BIOCLIM, 3), and Precipitation:PET ratio, derived as Annual Precipitation (BIOCLIM 12) / the sum of all monthly Evaporation grids (MTHCLIM).

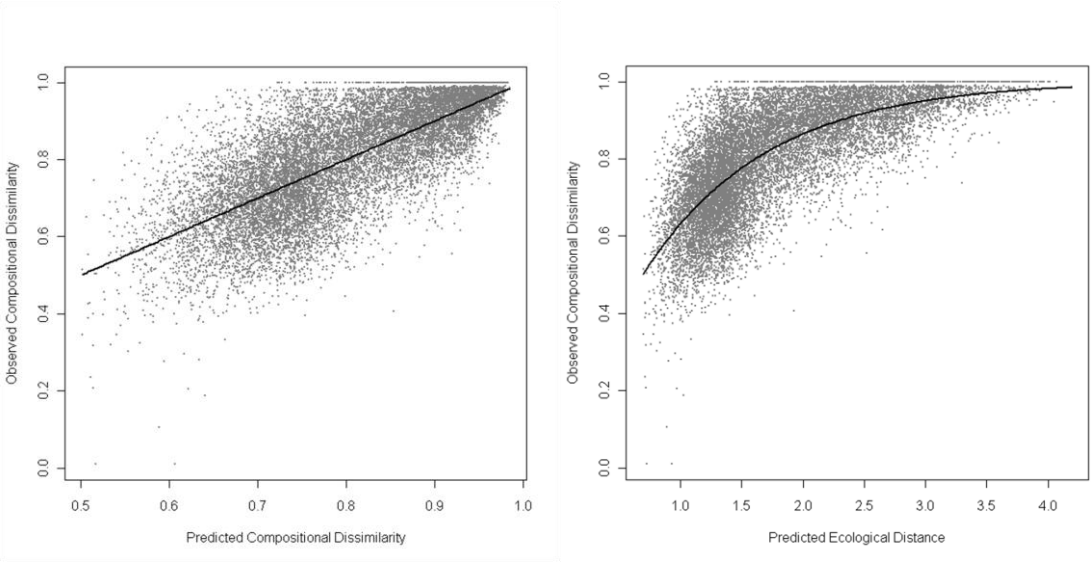

Figure 4: The fit of the final GDM model of compositional dissimilarity. The model was generated using all site pairs from 175 sites (= 15,225 site pairs), which were randomly selected using the undersampling function, with parameters a = 1.25, b = 90, and c = 0.3. The final GDM was significant ($P < 0.001$) and explained 54.04% of the deviance, with an intercept of 0.6913.

Variable	deviance reduction	proportion deviance reduction	P-value
Precipitation:PET ratio	157.42	0.622	< 0.000
July minimum temperature	32.29	0.128	< 0.000
Isothermallity	25.55	0.101	< 0.000
Weathering index	15.09	0.060	< 0.000
Geographic distance	13.85	0.055	< 0.000
Total January radiation	8.91	0.035	0.020

Table 2: The relative contribution of each of the six variables included in the final GDM in reducing overall model deviance. The amount of deviance reduced by adding each of the variables to a model containing all 5 other variables was significant ($P < 0.05$) for all variables.

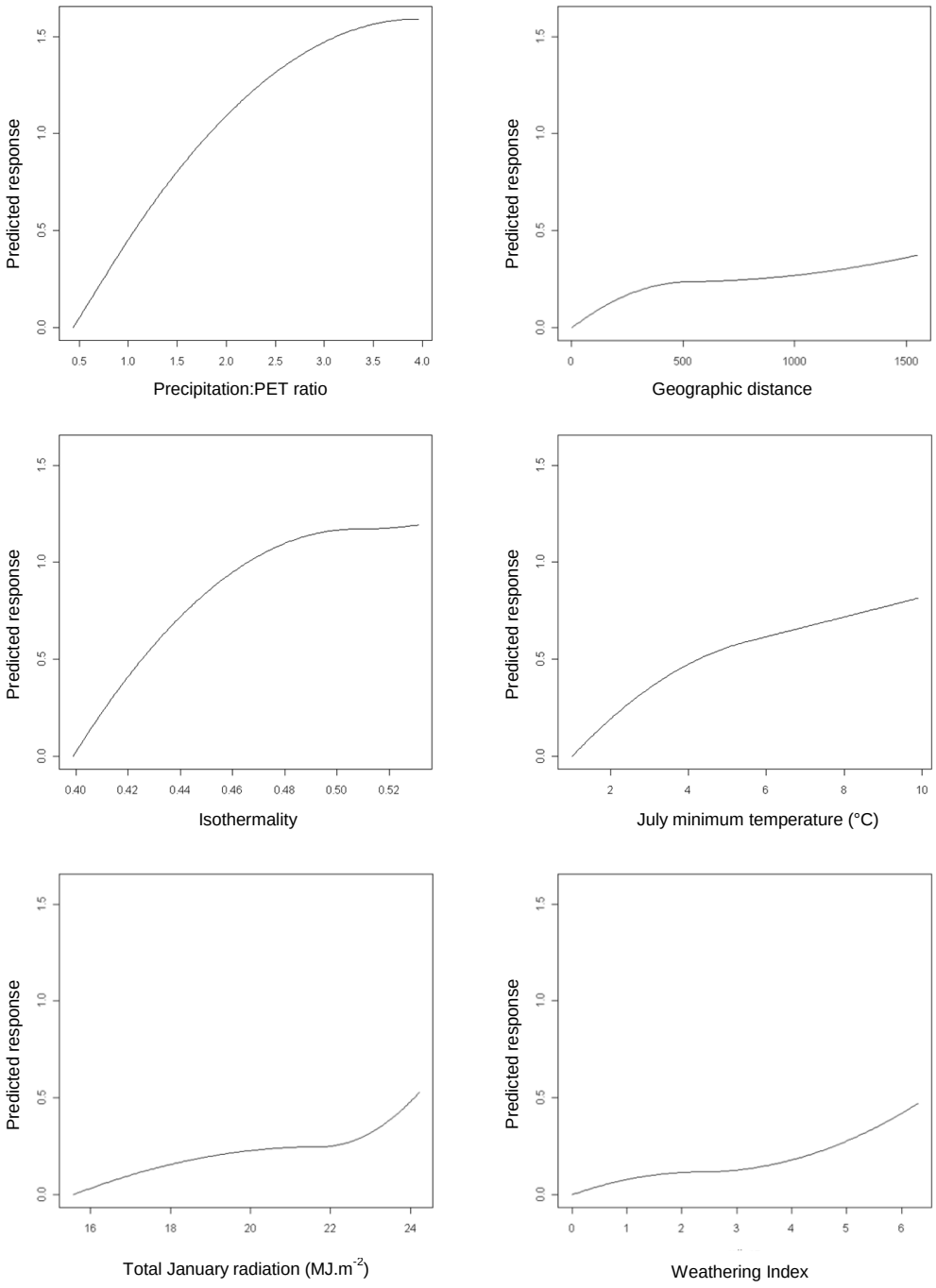

Figure 5: The response function fitted for each of the predictor variables included in the final GDM model. The importance of each variable in determining compositional dissimilarity is indicated by the relative range (height) of the predicted response (y-axis).

2.3 Analysis of reserve representativeness

The fitted GDM model allowed the expected compositional dissimilarity, d_{ij}, and conversely the expected similarity, s_{ij} (calculated as 1- d_{ij}), between any two 0.0025º

grid cells (*i* and *j*), to be predicted as a function of environmental conditions mapped for these cells. These predictions were then used to assess the representativeness of the reserve system (with and without the IGA additions) following the approach described by Ferrier et al (2004) and Allnutt et al (2008). For this analysis grid cells were assigned to one of two habitat states (h_j): reserved (1) or unreserved (0). The proportion (p_i) of species associated with any given cell *i* (if that cell were in a natural state) that are expected to be retained within the reserve system, anywhere within each species' range, was then calculated as (see Ferrier et al 2004, and Allnutt et al 2007 for details):

$$p_{ij} = \left[\sum_{j=1}^{n} s_{ij} \; h_j \Big/ \sum_{j=1}^{n} s_{ij} \right]^z$$

In this formula, the exponent *z* is applied to the contents of the square brackets to invoke the Species Area Relationship (Rosenzweig 1995). We employed a *z* value of 0.25 in this analysis, which is the value most commonly used in a wide range of previous studies of this type (e.g. Brooks et al, 2002, Zurline et al 2002, Ferrier et al 2004).

In the context of the analyses of reserve representativeness presented in this report, we relabel p_{ij} as the Expected Proportion of Species Represented (EPSR) in reserves.

Recent advances in computational capability allowed each cell to be compared with all other cells in Tasmania, rather than against a sample as in previous analyses. This avoids issues of under-sampling in smaller reserves. The analyses were conducted on a single dual hex-core Intel Xeon CPU, on the CSIRO ASC Computer Cluster, running in parallel across all 12 cores using bespoke software.

Two reserve scenarios were assessed: the state of the NRS in 2011; and the proposed future state with the addition of IGA reserves, as shown in Figure 2. EPSR values were generated for all cells in Tasmania, but private land and current NRS reserves were then masked out in the presented maps. These maps therefore depict EPSR values only for currently unreserved public-forest cells, categorised by broad forest type. Histograms were also generated summarising the shift in area of unreserved forest falling in each mapped category of EPSR values, categorised by forest type and IBRA bioregion.

A preliminary evaluation of the predictive performance of the EPSR index was conducted using the data on plant species occurrences from the Tasmanian Natural Values Atlas. An evaluation measure directly comparable to EPSR (i.e. in the same units) could not be derived for a number of reasons. First, because EPSR invokes the Species Area Relationship, this index relates to the capacity of reserves to retain species over the longer term (Rosenzweig 1995, Brooks et al, 2002) which cannot be measured directly using present-day occurrence data. Furthermore the occurrence data are geographically incomplete, and include sampling error and bias. With these caveats in mind, we performed a preliminary evaluation of EPSR by using the data for all 2051 plant species to calculate the proportion of recorded occurrences for each

species that fall within the expanded reserve estate (NRS plus IGA). Then for each 250 m grid cell in unreserved public forest where ≥ 10 species have been recorded (n = 2,137), the proportion of occurrences reserved for each species present in this cell was averaged to yield the mean proportion of occurrences reserved. For each of these cells the mean proportion of occurrences reserved was then plotted against the predicted EPSR, as presented in Figure 6. The linear regression relating these two variables is significant ($P < 0.001$, $R^2 = 0.461$; $y = 0.841x - 0.133$).

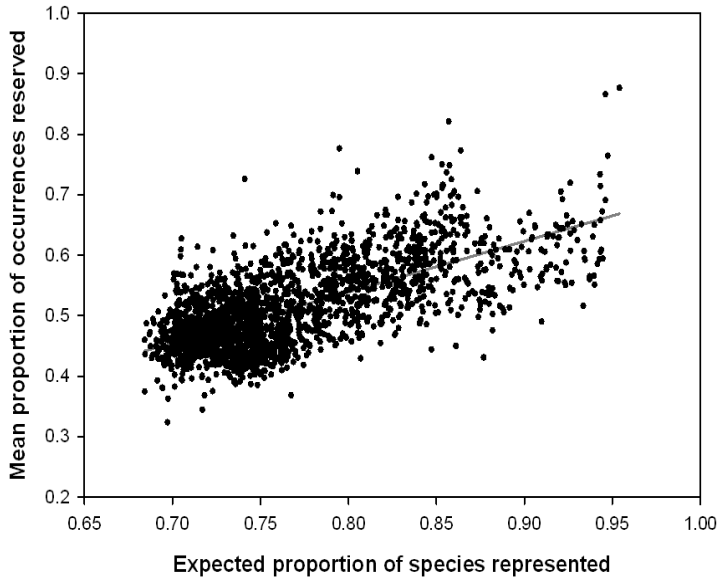

Figure 6: The mean proportion of species occurrences included in reserves, relative to the expected proportion of species represented (EPSR) from the GDM analysis.

3. RESULTS

Values of the EPSR index generated by this analysis ranged between a minimum of 0.647 and a maximum of 0.970 for grid cells within currently unreserved public forest. A literal interpretation of the minimum value is that 64.7% of the plant species associated with a cell exhibiting this value are expected to be represented, and to persist over the longer term, somewhere within the reserve system. For a cell exhibiting the maximum value, 97% of species associated with this cell are expected to be represented, and to persist, within reserves.

To simplify interpretation, presented EPSR values are grouped into 0.05 classes, i.e. 0.60 to 0.65, 0.66 to 0.70 etc. bins of size 0.05, and the same classes and colours are used in both the maps and the summary histograms. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species. With the addition of the proposed IGA reserves, we see at least some improvement in the

EPSR values of all cells, but the level of this improvement is distributed unevenly in space and between forest types.

3.1 Spatial distribution of the EPSR index within forest types

Figures 7 to 14 map the distribution of EPSR values for all 250m grid-cells within currently unreserved public forest, categorised by broad forest type. Two maps are presented for each forest type – one depicting EPSR values indicating representativeness based on existing NRS reserves alone, and the other depicting EPSR values based on existing NRS reserves plus the proposed IGA reserves.

3.1.1 Dry Eucalypt Forest and Woodland

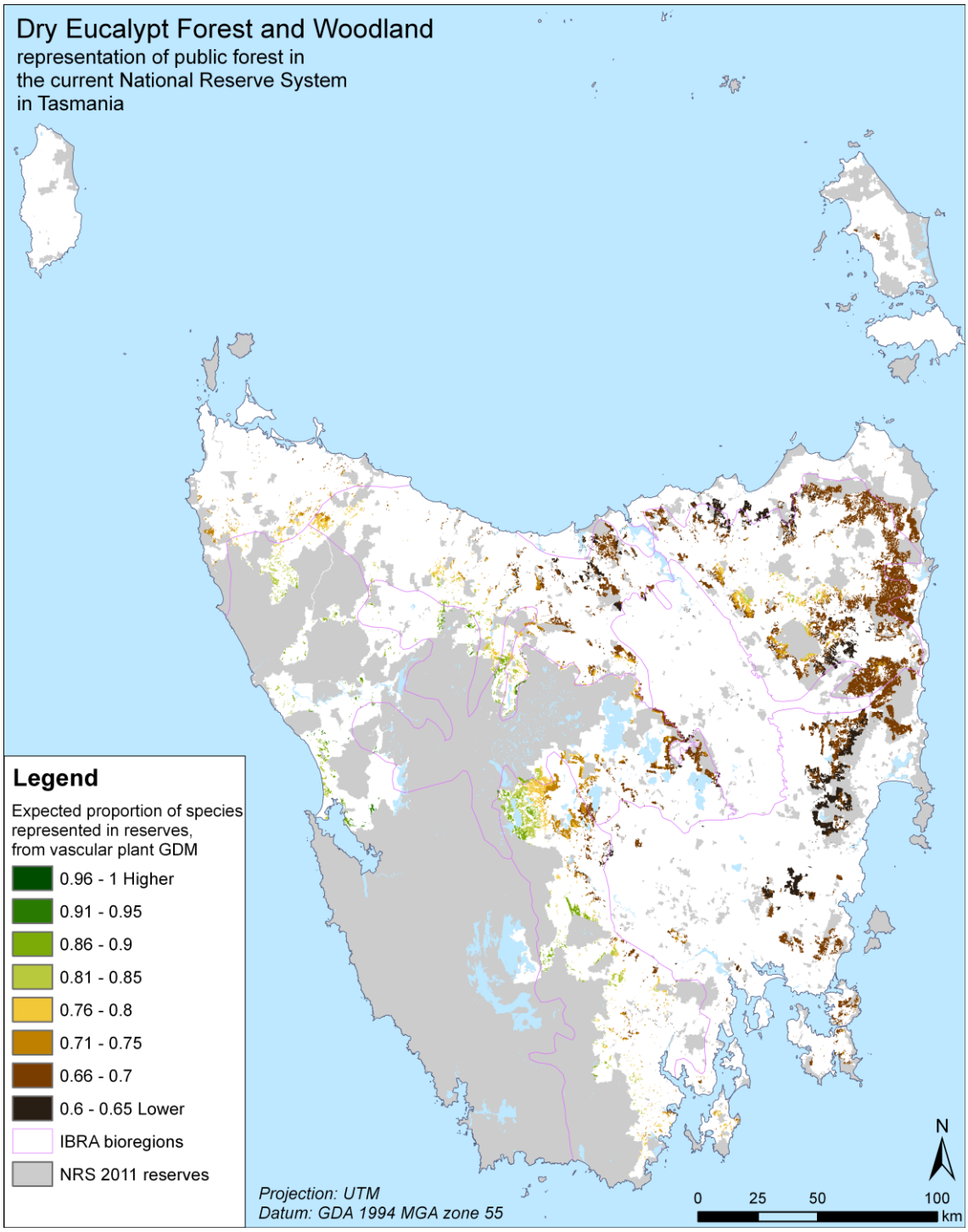

Figure 7: EPSR values, based on existing NRS reserves, for 250m grid cells in Dry Eucalypt Forest and Woodland on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

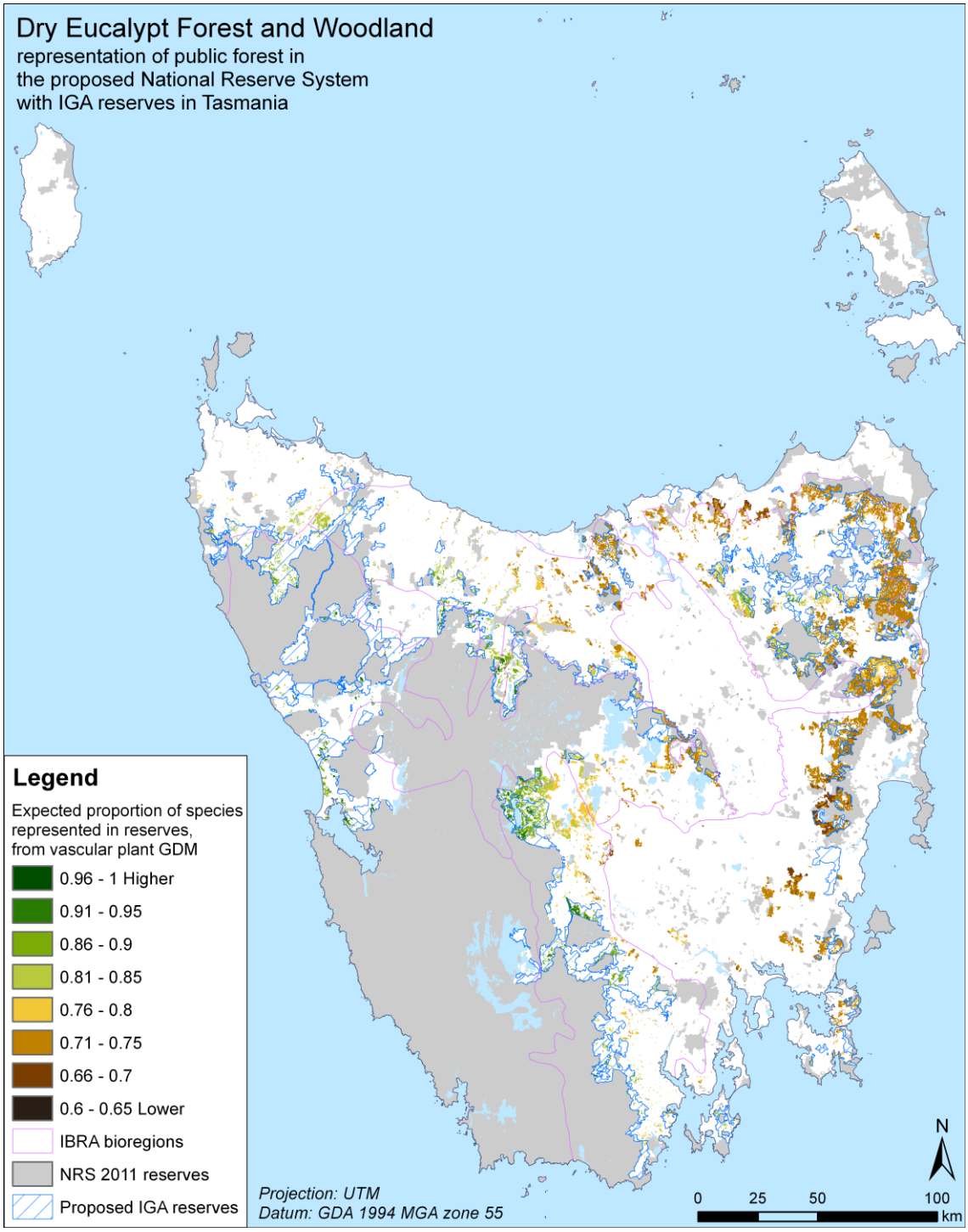

Figure 8: EPSR values, after adding proposed IGA reserves to the existing NRS reserves, for 250m grid cells in Dry Eucalypt Forest and Woodland on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

3.1.2 Wet Eucalypt Forest and Woodland

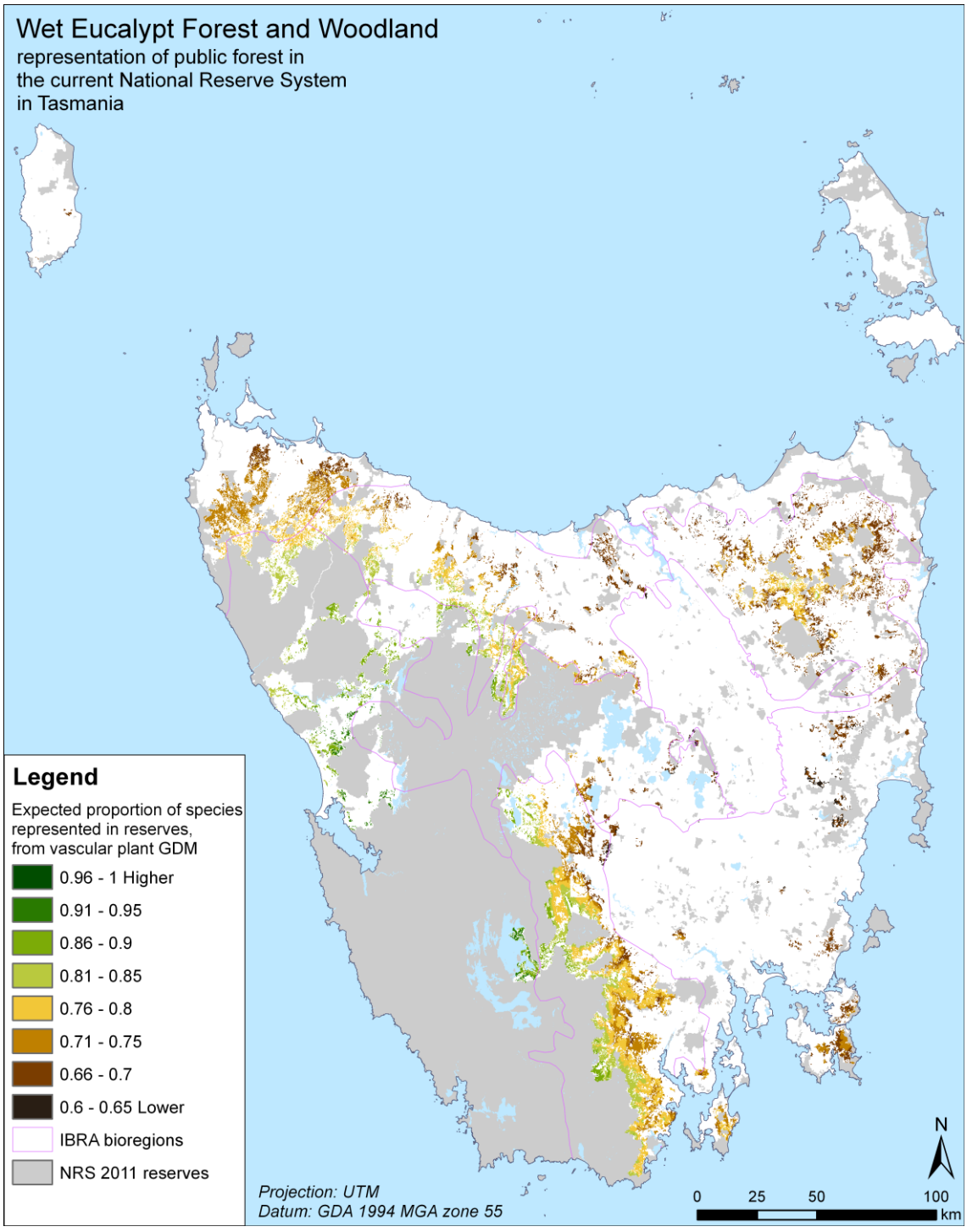

Figure 9: EPSR values, based on existing NRS reserves, for 250m grid cells in Wet Eucalypt Forest and Woodland on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

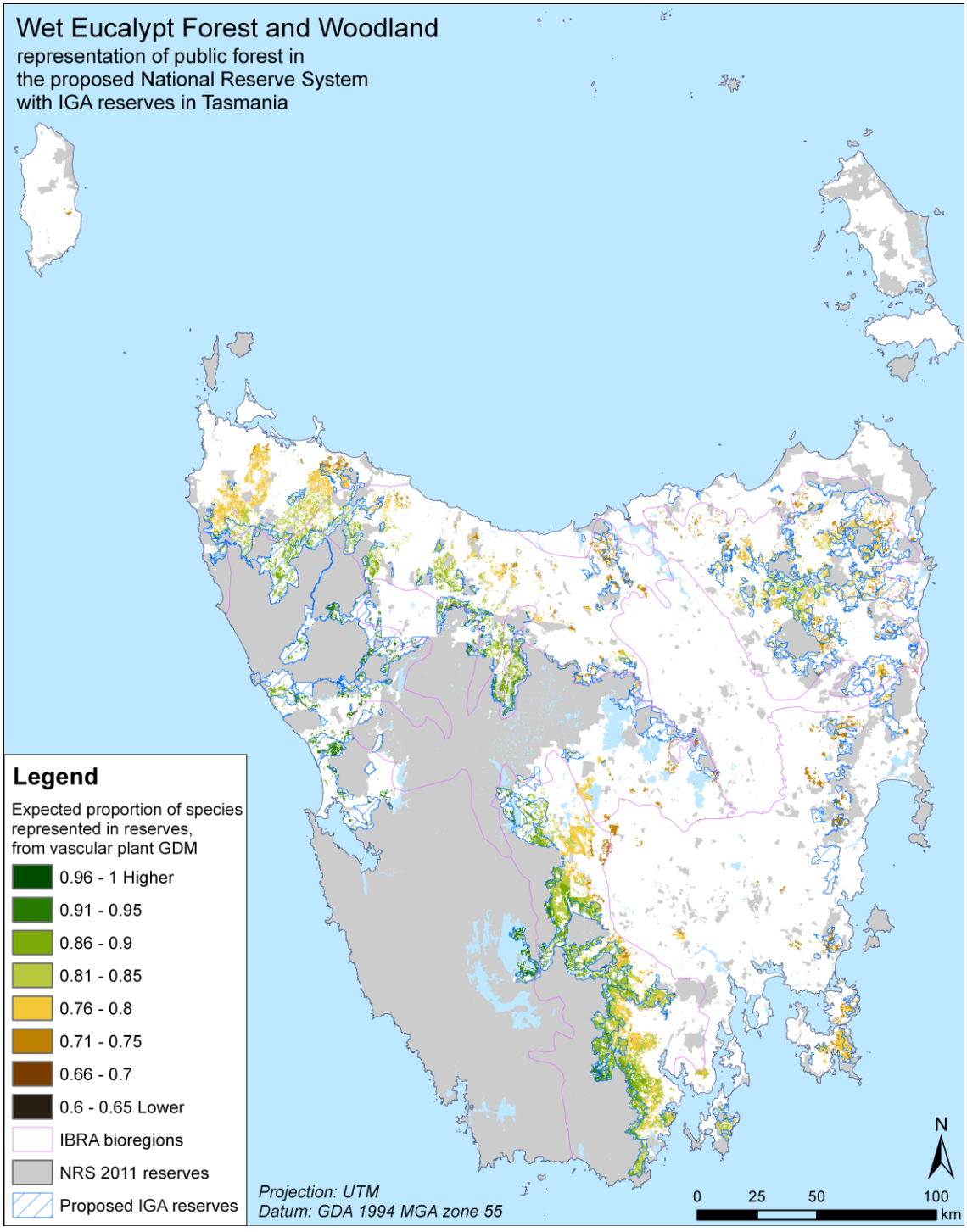

Figure 10: EPSR values, after adding proposed IGA reserves to the existing NRS reserves, for 250m grid cells in Wet Eucalypt Forest and Woodland on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

3.1.3 Non Eucalypt Forest and Woodland

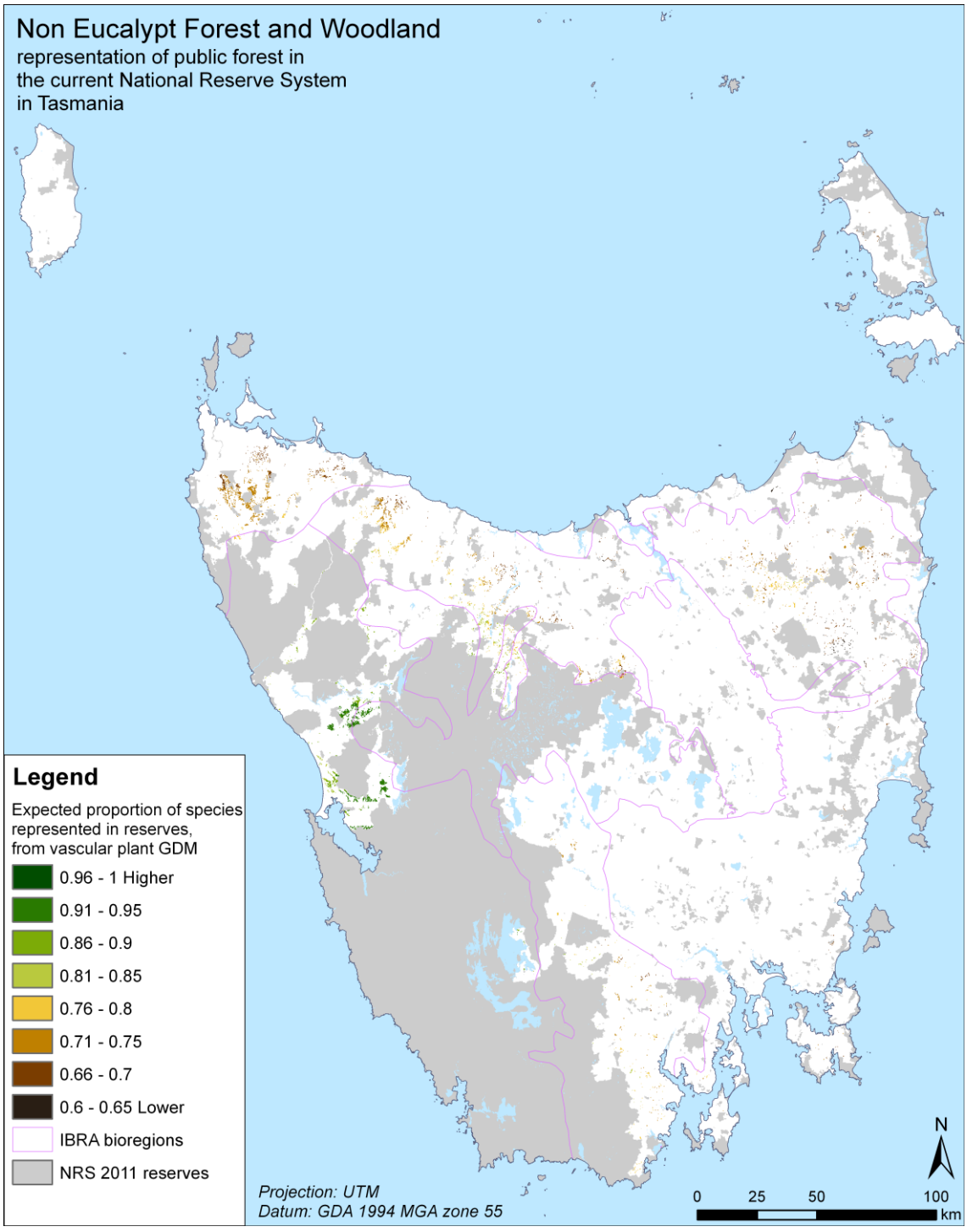

Figure 11: EPSR values, based on existing NRS reserves, for 250m grid cells in Non Eucalypt Forest and Woodland on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

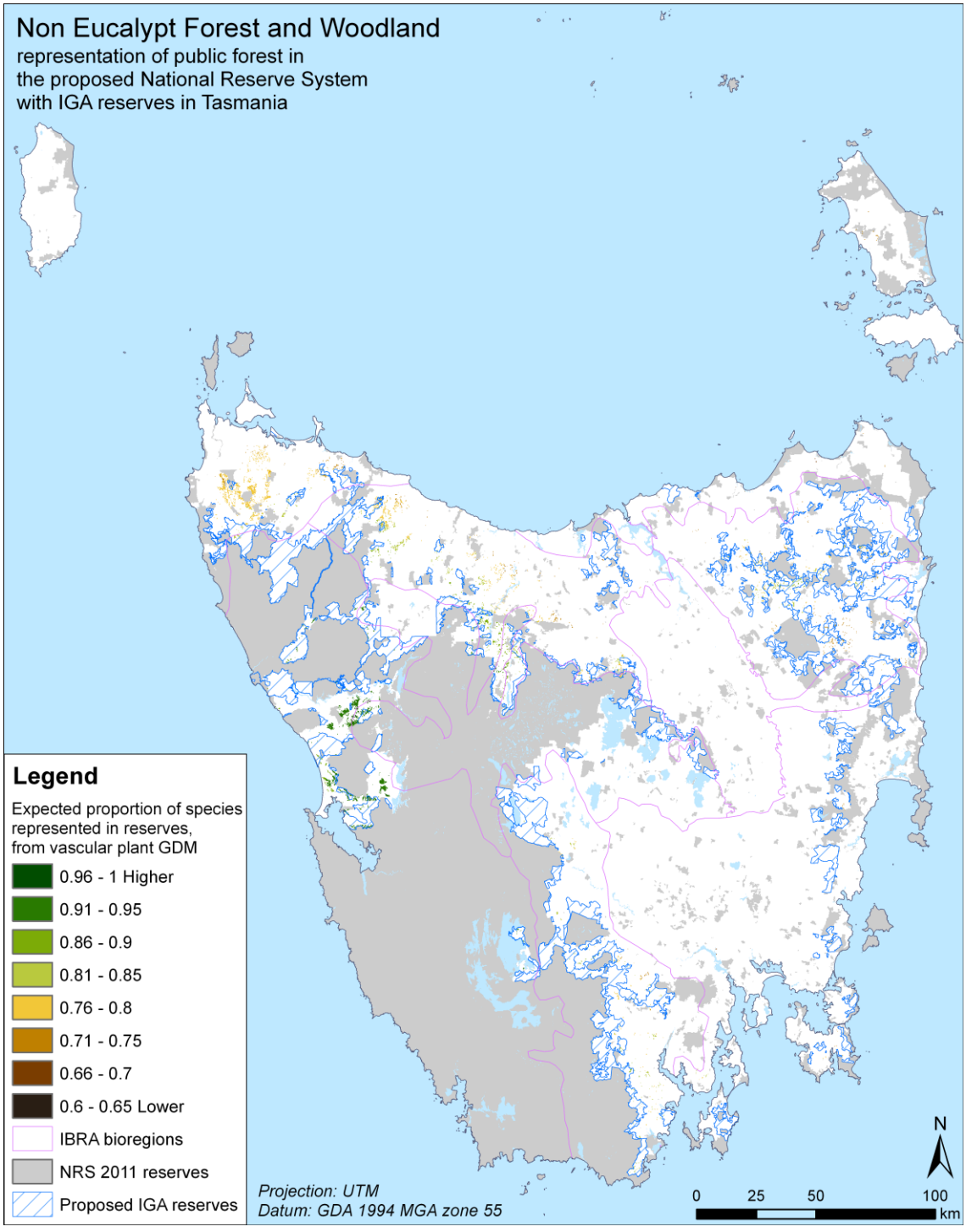

Figure 12: EPSR values, after adding proposed IGA reserves to the existing NRS reserves, for 250m grid cells in Non Eucalypt Forest and Woodland on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

3.1.4 Rainforest and Related Scrub

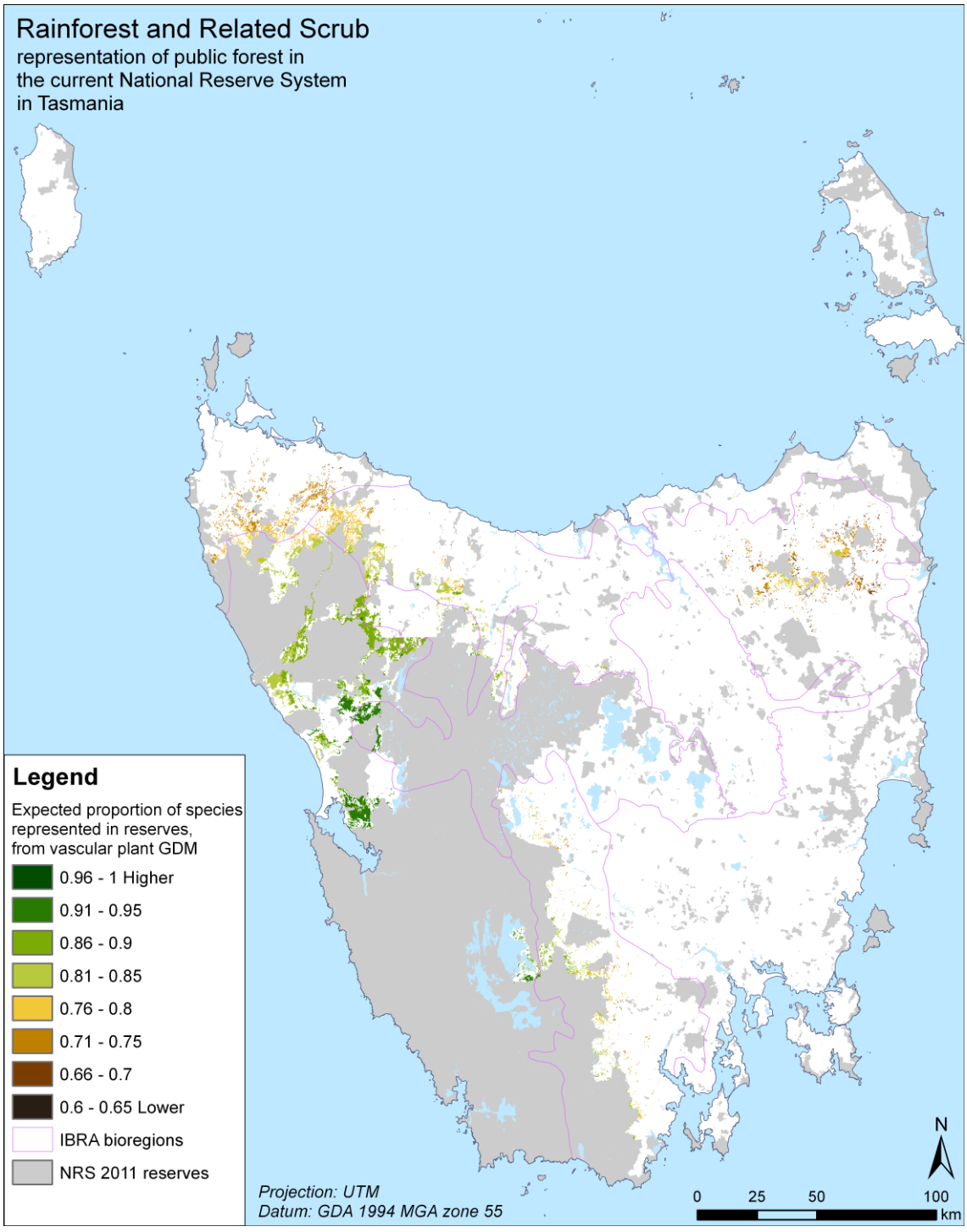

Figure 13: EPSR values, based on existing NRS reserves, for 250m grid cells in Rainforest and related Scrub on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

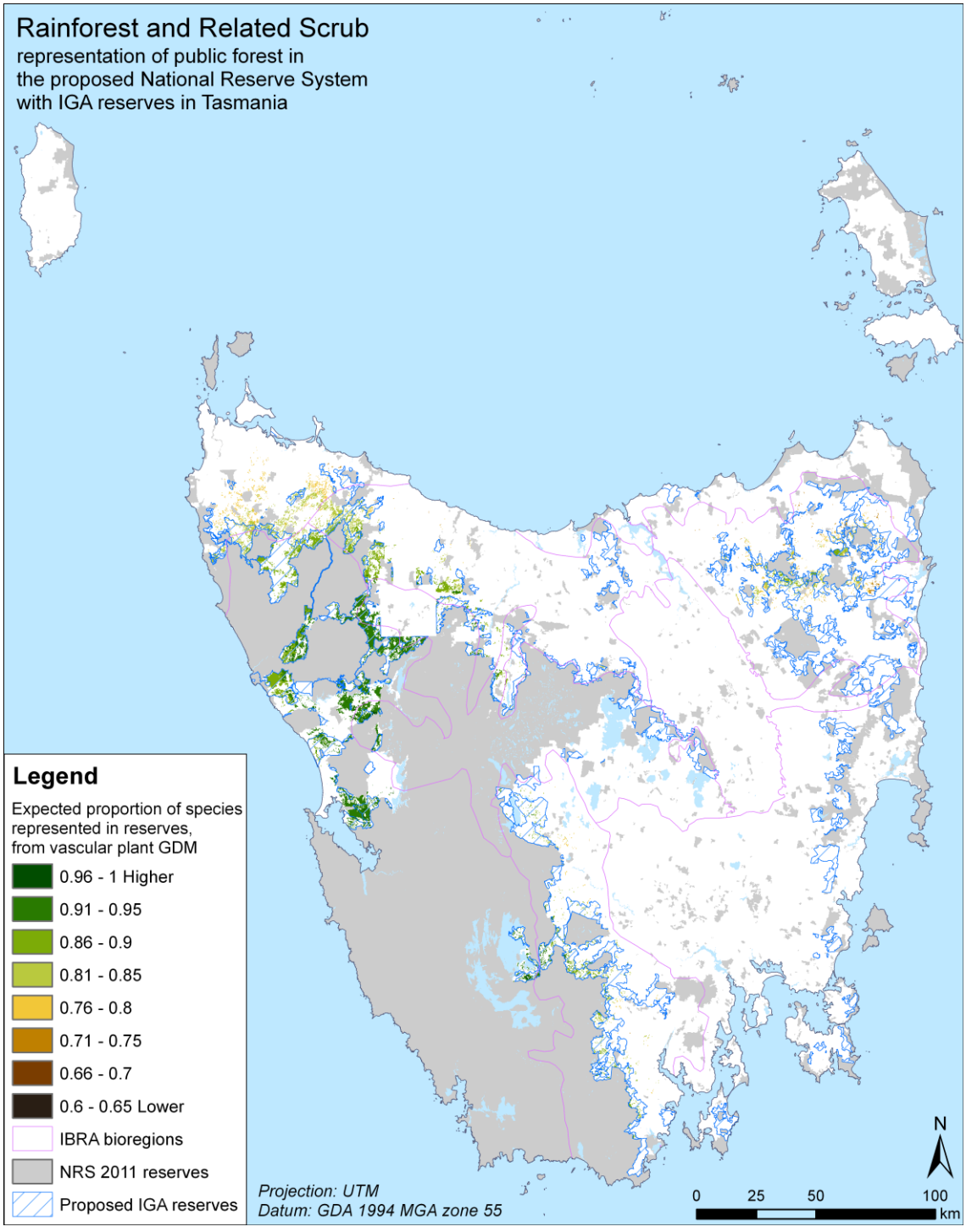

Figure 14: EPSR values, after adding proposed IGA reserves to the existing NRS reserves, for 250m grid cells in Rainforest and Related Scrub on public land. Each value indicates the proportion of vascular plant species (associated with a given cell) that are expected to be represented, and to persist over the longer term, somewhere within the reserve system. Browner colours indicate cells expected to contain species that are relatively poorly represented within reserves, while greener colours indicate cells expected to contain well represented species.

3.2 Histograms of expected change in representation within forest types

Figures 15 to 18 present histograms summarising the area falling within each mapped EPSR category (on currently unreserved public land), for all of Tasmania, and for individual IBRA Bioregions. A separate set of histograms is presented for each broad forest type. Dark Grey columns indicate results based on existing reserves alone. Light Grey columns indicate results after addition of IGA reserves.

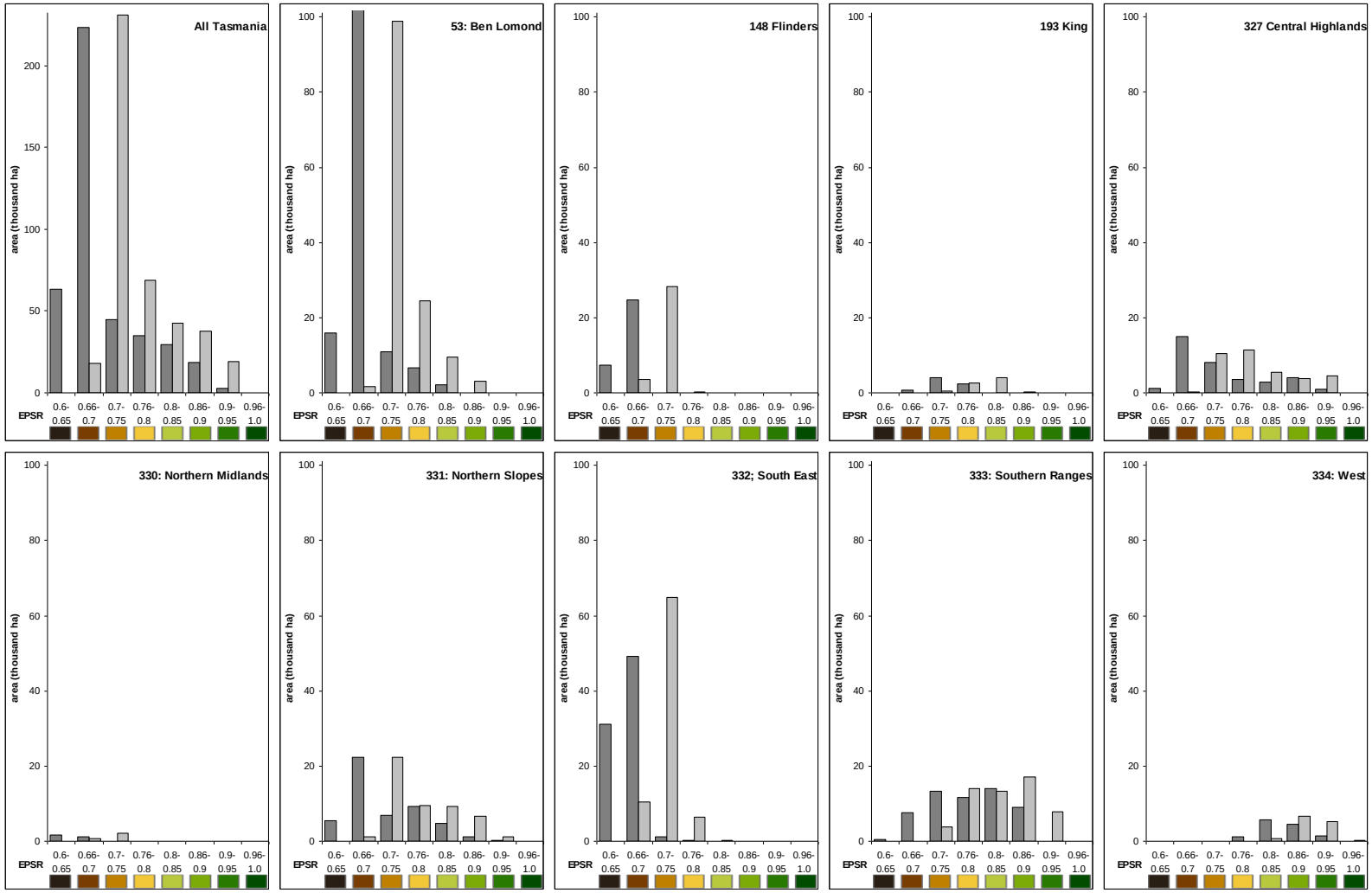

Figure 15: The area of Dry Eucalypt Forest and Woodland within each mapped EPSR category (on currently unreserved public land), for all of Tasmania, and for individual IBRA Bioregions. Dark Grey columns indicate results based on existing reserves alone. Light Grey columns indicate results after addition of IGA reserves.

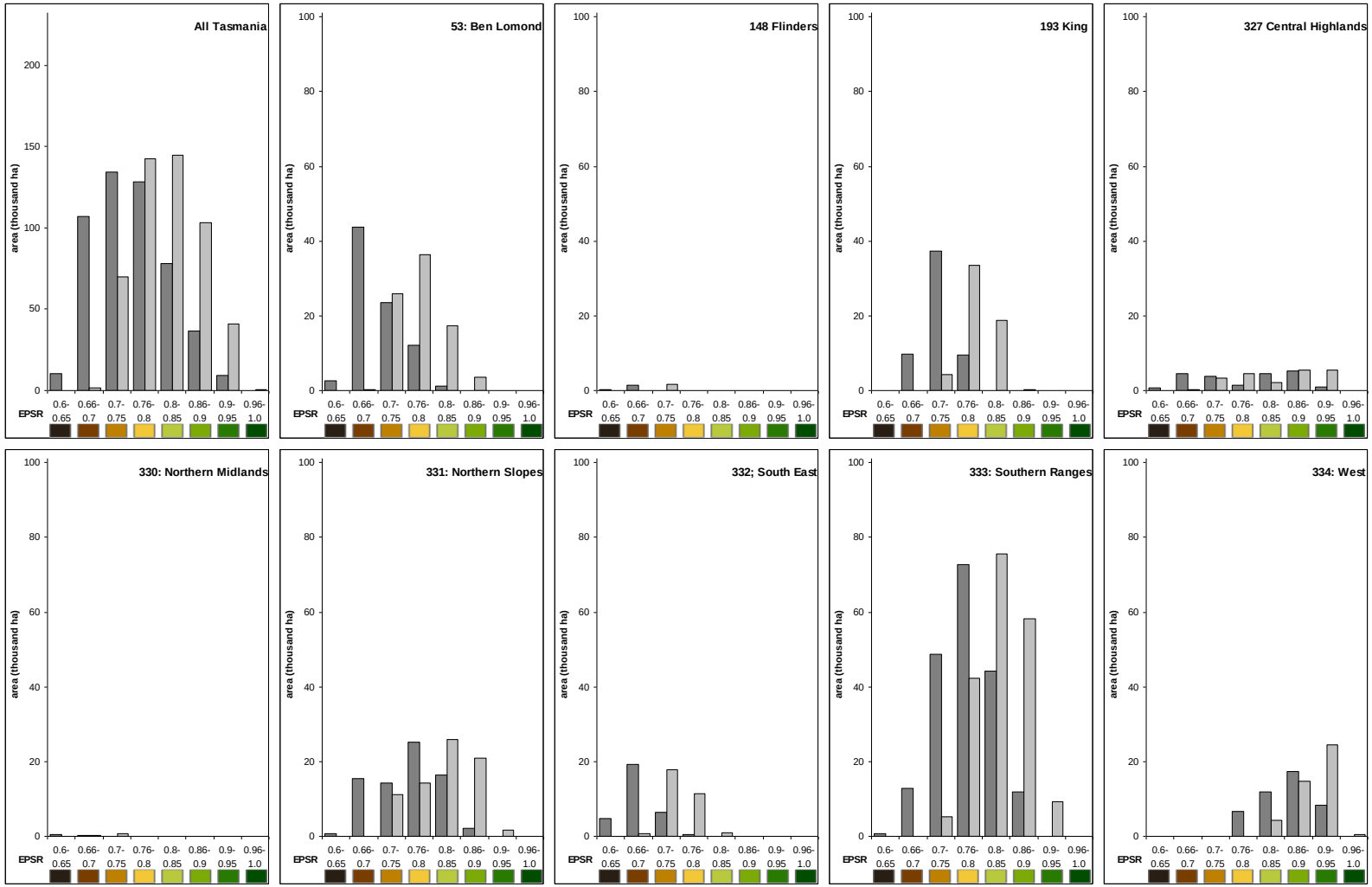

Figure 16: The area of Wet Eucalypt Forest and Woodland within each mapped EPSR category (on currently unreserved public land), for all of Tasmania, and for individual IBRA Bioregions. Dark Grey columns indicate results based on existing reserves alone. Light Grey columns indicate results after addition of IGA reserves.

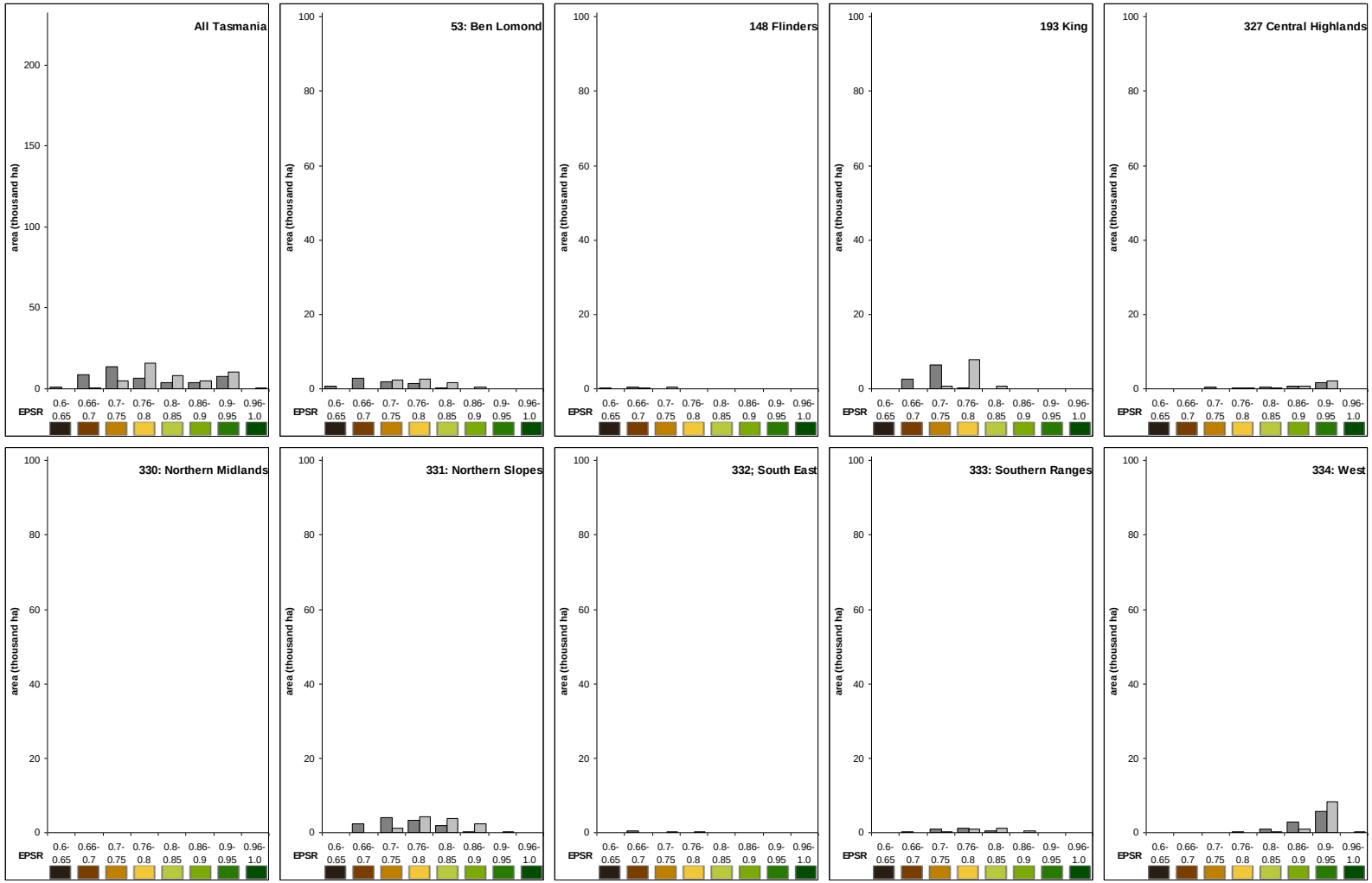

Figure 17: The area of Non Eucalypt Forest and Woodland within each mapped EPSR category (on currently unreserved public land), for all of Tasmania, and for individual IBRA Bioregions. Dark Grey columns indicate results based on existing reserves alone. Light Grey columns indicate results after addition of IGA reserves.

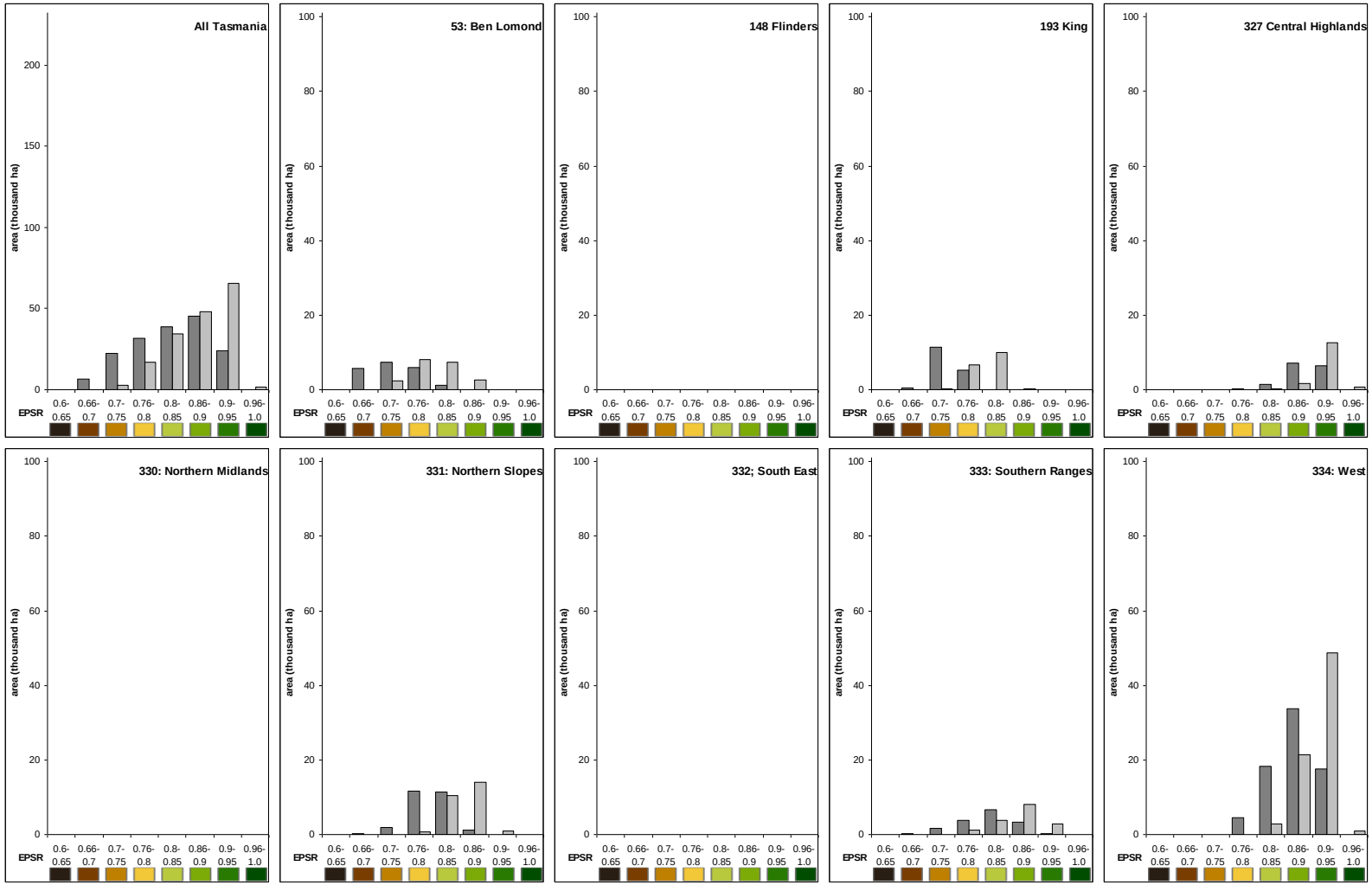

Figure 18: The area of Rainforest and Related Scrub within each mapped EPSR category (on currently unreserved public land), for all of Tasmania, and for individual IBRA Bioregions. Dark Grey columns indicate results based on existing reserves alone. Light Grey columns indicate results after addition of IGA reserves.

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