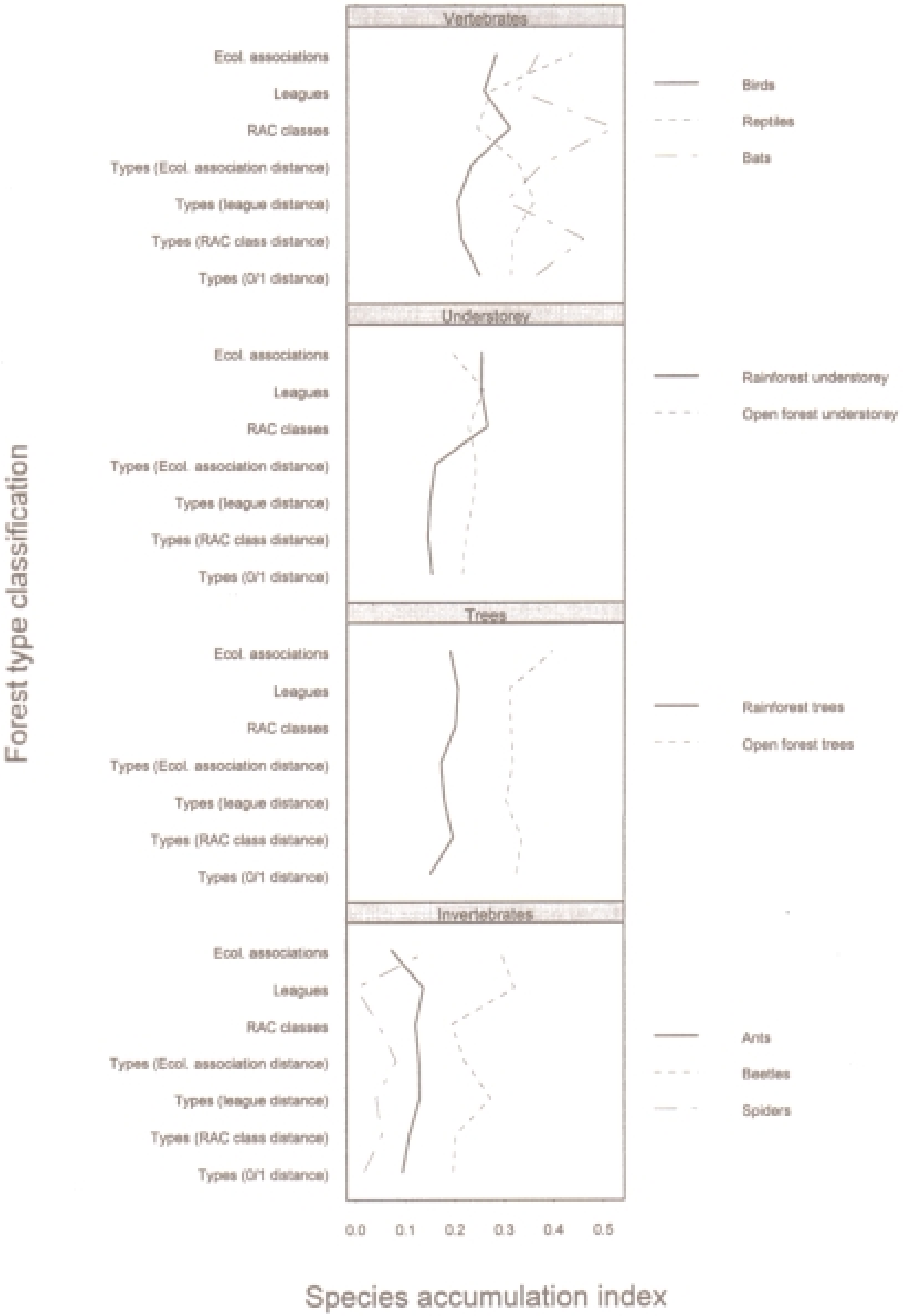


Figure 4.18 Effect of different types of classification on surrogate performance of forest type mapping.

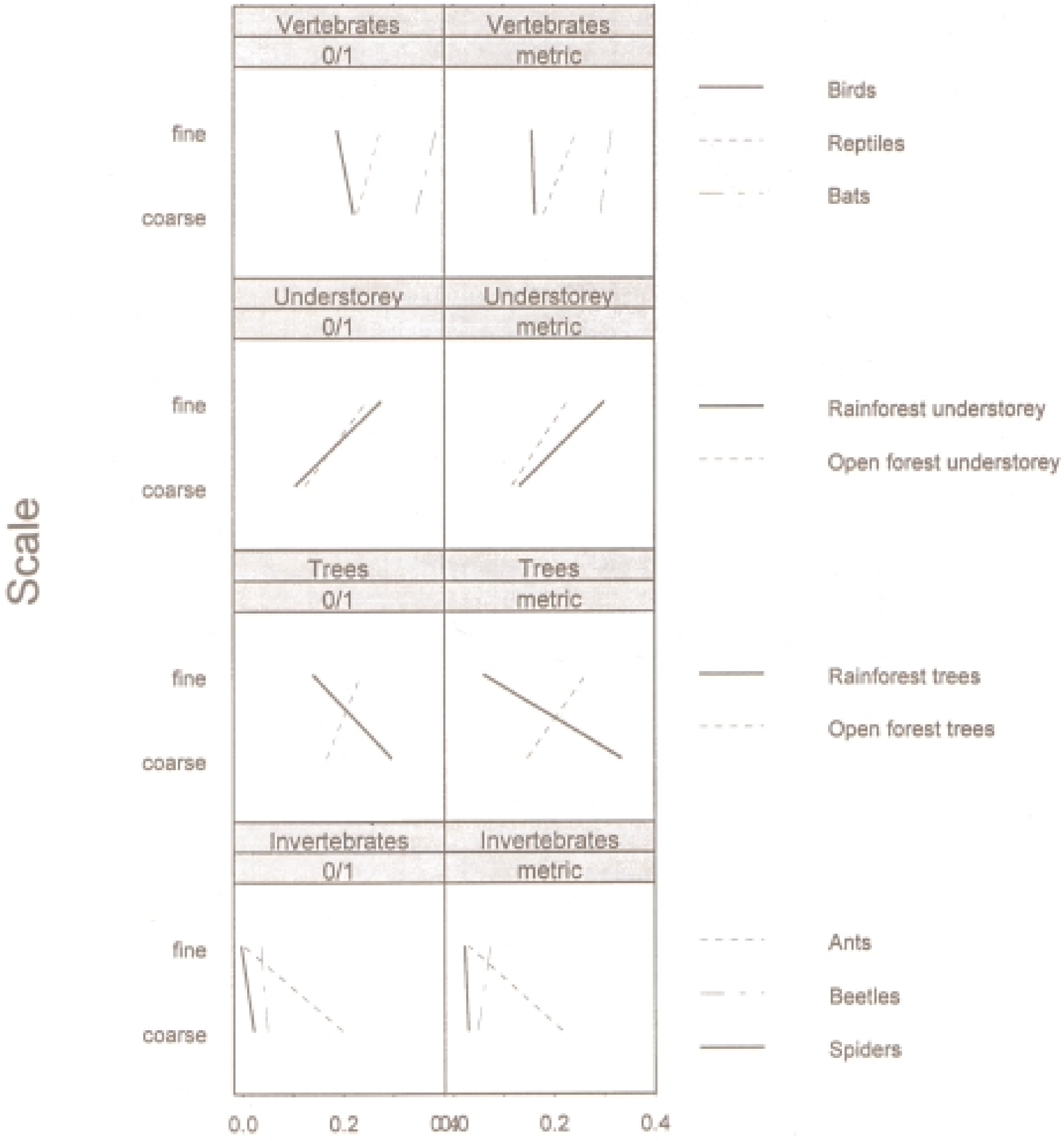


Figure 4.19 Effect of scale of environmental data, and type of distance measure, on surrogate performance of environmental unit classifications.

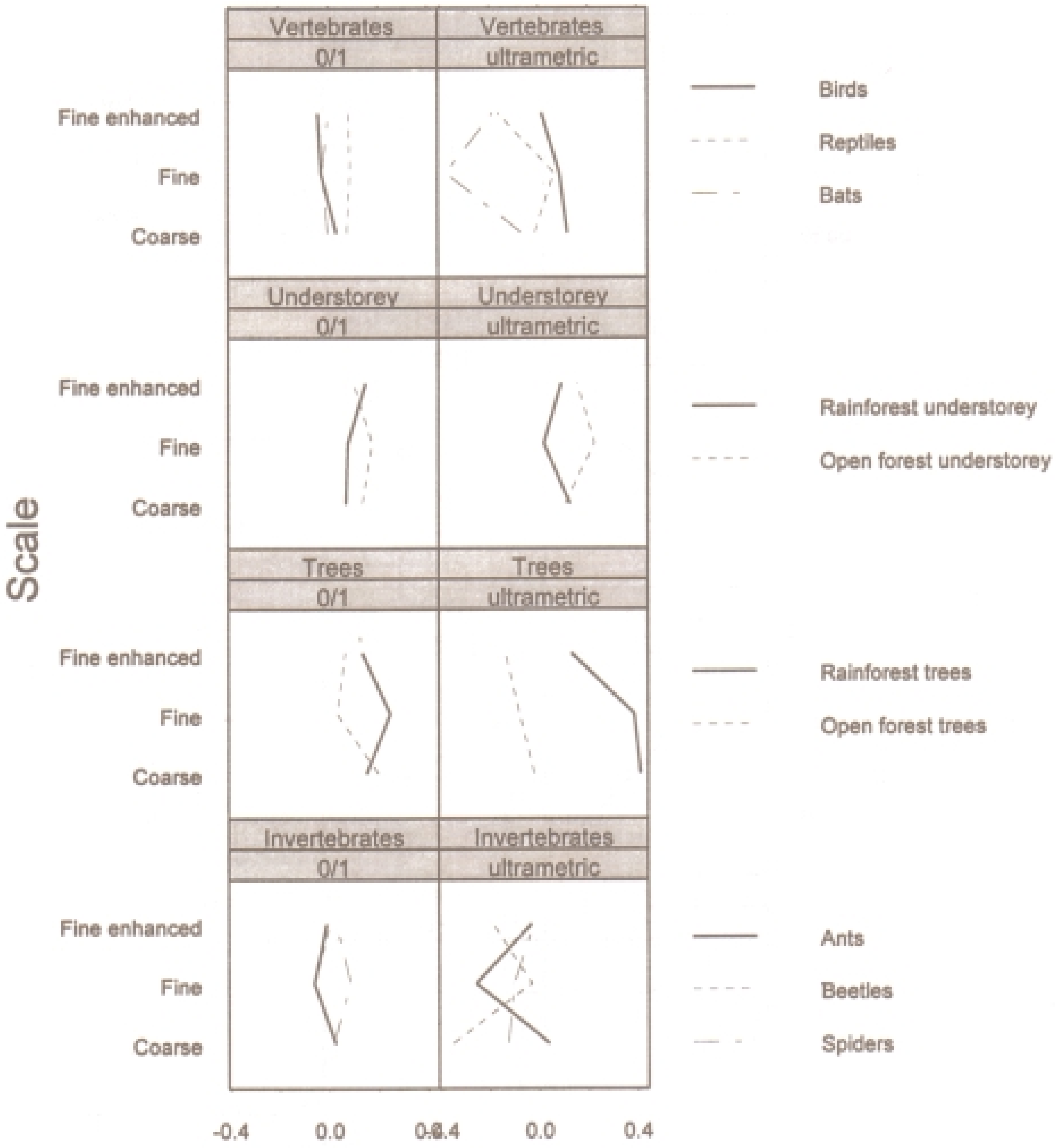


Figure 4.20 Effect of scale of environmental data, and type of distance measure, on surrogate performance of environmental domain classifications.

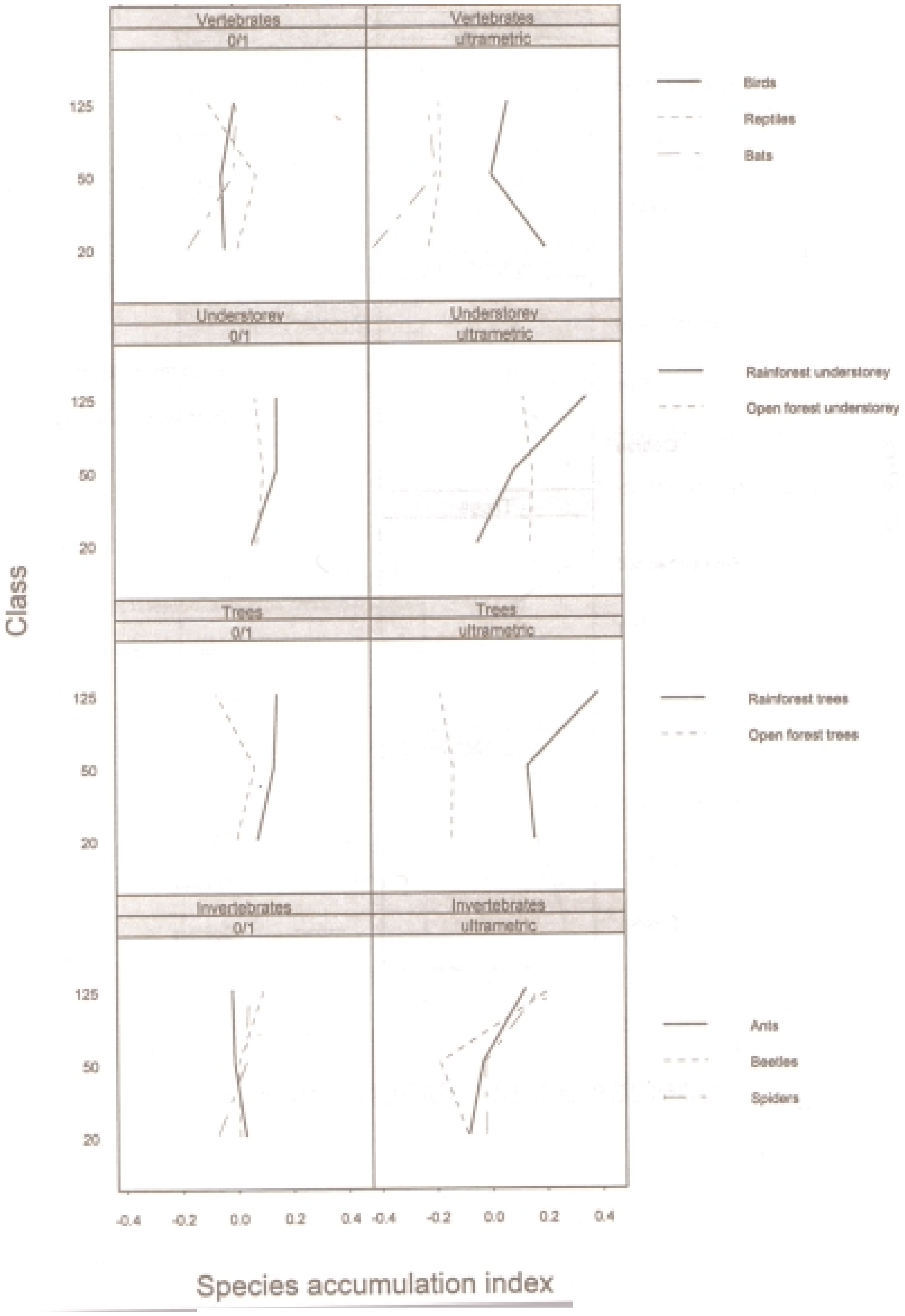


Figure 4.21 Effect of number of classes, and type of distance measure, on surrogate performance of environmental domain classifications.

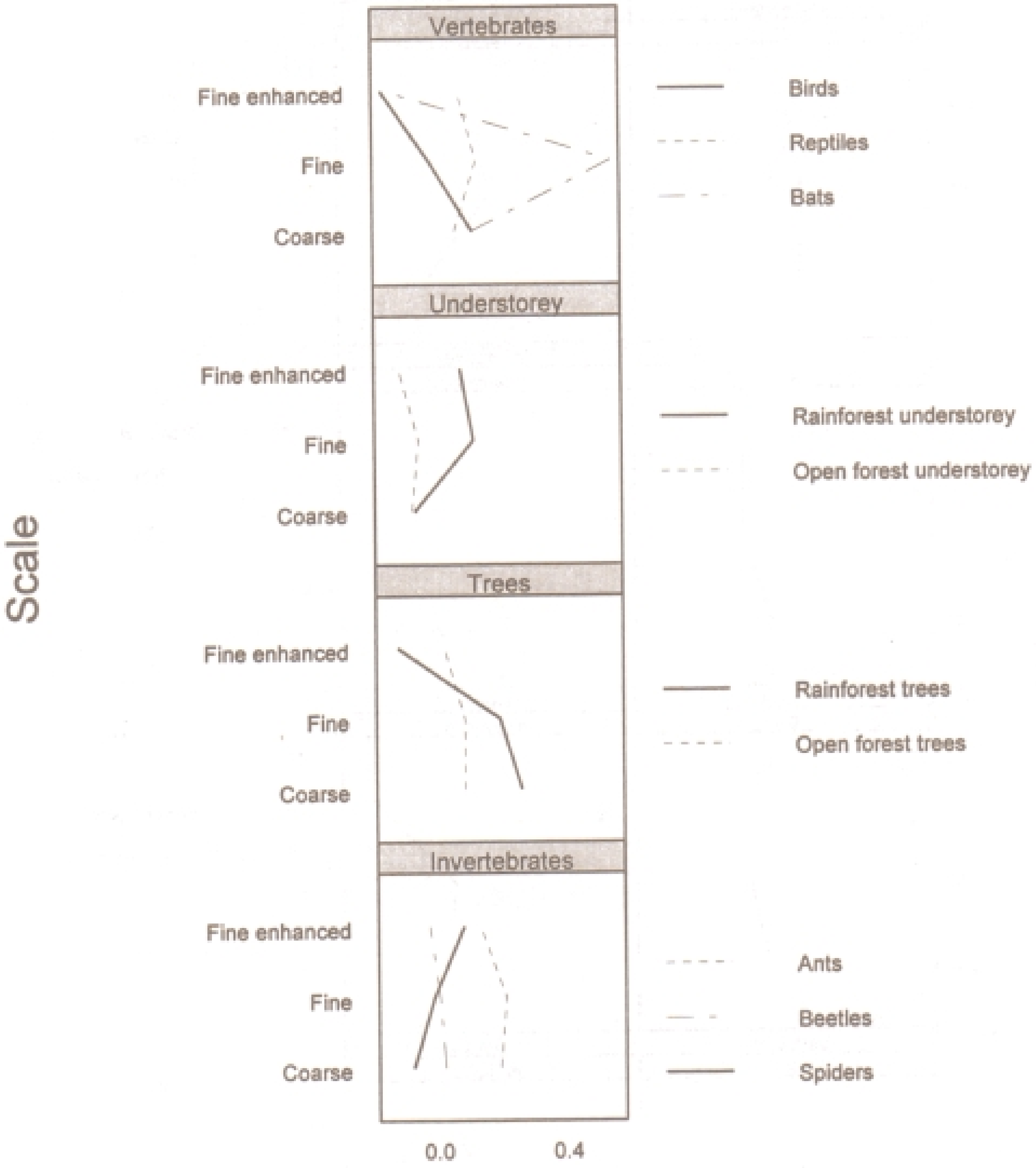


Figure 4.22 Effect of scale of environmental data on surrogate performance of environmental ordinations.

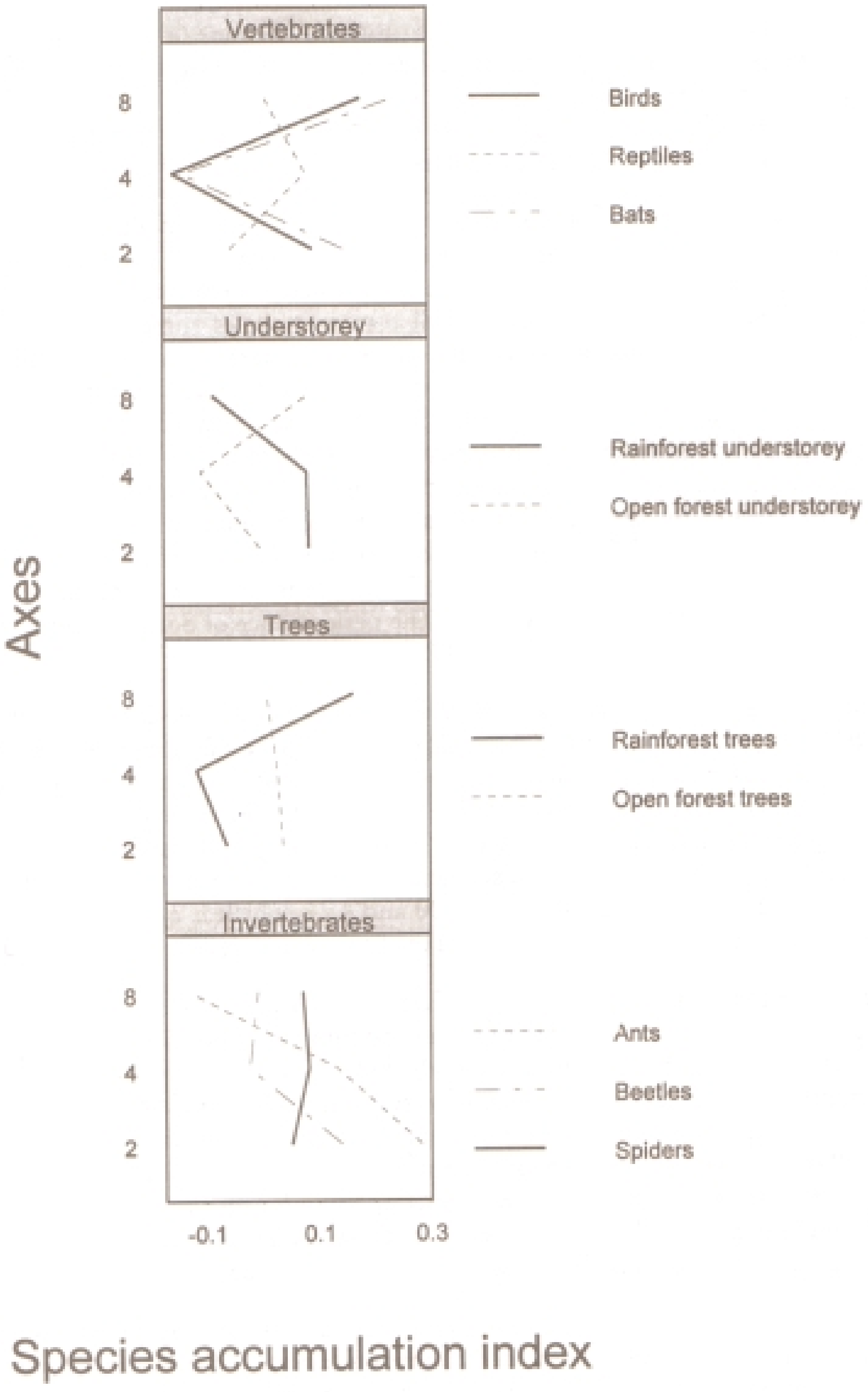


Figure 4.23 Effect of number of fitted axes on surrogate performance of environmental ordinations.

Two parameters were varied in the derivation of abiotic environmental ordinations; scale of environmental data (coarse, fine, enhanced fine) and number of fitted axes (2, 4, 8). Not all combinations of these parameters were evaluated. Two separate ANOVAs were therefore performed, one to assess the effect of varying environmental scale using results from three 4 axis ordinations derived using coarse, fine and enhanced fine data (Table 4.13), and the other to assess the effect of varying the number of axes using results from three enhanced fine scale ordinations derived using 2, 4 and 8 axes (Table 4.14). None of the effects (including biological group) assessed in these analyses were significant ($p > 0.05$). Results are also depicted graphically in Figures 4.22 and 4.23.

The above analyses suggest that variation in parameters used to derive surrogates within the broad types assessed (forest types, environmental units, environmental domains, environmental ordinations) had little effect on the performance of those surrogates. Caution should, however, be exercised in interpreting and extrapolating these results for the following reasons:

- The experimental design adopted in this consultancy was aimed primarily at assessing differences in performance <u>between</u> broad types of surrogates, rather than differences <u>within</u> types. Parameters used to derive some types of surrogates were varied mainly to enable any effect that this variation had on performance to be accommodated in comparisons between broad types.
- Sample sizes within each broad surrogate type were relatively small and the statistical power of the analyses is therefore likely to be low.
- The true effect that varying a surrogate has on performance may not be the same across all biological groups. For example, increasing the number of classes in a domain classification might improve the performance of domains as a surrogate for canopy trees but have no effect (or even a reverse effect) on performance for ground dwelling invertebrates. The significance of such interactions could not be assessed in this consultancy due to a lack of replication within each combination of surrogate and biological group.
- Only selected parameters were varied within each surrogate type. Variation in parameters other than those considered here might have a greater effect on surrogate performance (e.g. use of a completely different vegetation classification as a basis for forest type mapping). Extending parameters beyond the limits imposed in this study might also reveal stronger effects (e.g. use of an even finer spatial scale for environmental data).

Thorough evaluation of variation in performance within any one of these broad types of surrogate would need to be planned and funded as a project in its own right. An example of the rigour required is provided in the detailed evaluation of different predictive modelling techniques presented later in this report (Sections 6 and 7), and in related consultancies performed recently by Pearce and Ferrier (1996) and Austin *et al*. (1995).

Variation in performance <u>between</u> broad types of surrogates

The SAI results from Table 4.6 were used to evaluate differences in performance between the following broad types of surrogates in north east NSW (see Section 4.3 for a detailed description of these surrogates):

- forest type mapping;
- vegetation systems mapping;
- environmental unit classification;
- environmental domain classification;
- environmental ordination;

- raw environmental distance;
- canonical ordination;
- species models (raw predicted probabilities); and
- species models (derived biological distance).

In this analysis, two different approaches were adopted for dealing with broad surrogate types within which more than one version of that surrogate had been evaluated (i.e. forest types, environmental units, environmental domains, environmental ordination). In the first approach, the version that achieved the best median performance across all the biological groups was selected for comparison with the other broad types of surrogate. The surrogates that were selected using this rule were:

- forest types grouped into ecological associations;
- environmental units using fine scale environmental data and a 0/1 distance measure;
- environmental domains using enhanced fine scale environmental data, 125 classes and an ultrametric distance measure; and
- environmental ordination using fine scale environmental data and 4 axes.

In the second approach, instead of selecting any one version of a broad surrogate type, the median performance of all versions of the surrogate was calculated within each biological group. This median value was then used to compare the broad type to other surrogates. The first approach compared surrogates using the best performing version within each type whereas the second approach compared surrogates using the median performance of each type.

A separate ANOVA was performed for each of the two approaches (Tables 4.15 and 4.16). In these analyses, biological group was specified as an error term (Chambers *et al.* 1992). A new variable was then introduced that classified these individual biological groups into four 'broad biological groups':

- invertebrates;
- vertebrates;
- canopy trees; and
- understorey plants.

The ANOVAs presented in Tables 4.15 and 4.16 tested two types of effects. The effects under 'Error: Biol. group' are those that could potentially explain differences in surrogate performance between individual biological groups. These included broad biological group and type of surrogate. The latter was included because the ANOVA design was not completely balanced due to canonical ordination not being applied to understorey plants. The effects under 'Error: Within' are those that could potentially explain differences in surrogate performance within individual biological groups. The effect of most interest here was type of surrogate. The interaction between type of surrogate and broad biological group (indicated by the * symbol) could also be tested in these analyses because individual biological groups were effectively treated as replicates within each broad group.

The results obtained from the two analyses were similar. The effect of type of surrogate on performance (within biological groups) was highly significant ($p < 0.001$), while the effect of broad biological group was significant at the $p < 0.05$ level. There was also a significant ($p < 0.05$) interaction between type of surrogate and broad biological group. The analyses therefore suggest that the mean performance of surrogates not only varies

Table 4.15 ANOVA results from analysis of performance (Species Accumulation Index) of different types of surrogates, using median performance of each type within each biological group.

	df	SS	MS	F.value	P.value
Error: Biol. group					
Surrogate	1	0.0015011	0.0015011	0.17643	0.6890851
Broad biol. group	2	0.2417088	0.1208544	14.20440	0.0053021
Residuals	6	0.0510494	0.0085082		
Error: Within					
Surrogate	8	0.7457140	0.09321425	11.57483	0.00000001
Surrogate * Broad biol. group	23	0.4046878	0.01759512	2.18486	0.01161861
Residuals	47	0.3784998	0.00805319		

Table 4.16 ANOVA results from analysis of performance (Species Accumulation Index) of different types of surrogates, using surrogate within each type that performed best across all biological groups.

	df	SS	MS	F.value	P.value
Error: Biol. group					
Surrogate	1	0.0004193	0.0004193	0.026997	0.8748835
Broad Biol. group	2	0.2301103	0.1150551	7.407435	0.0239515
Residuals	6	0.0931943	0.0155324		
Error: Within					
Surrogate	8	0.6177189	0.07721487	4.769527	0.00024877
Surrogate * Broad biol. group	23	0.6941639	0.03018104	1.864269	0.03525583
Residuals	47	0.7608928	0.01618921		

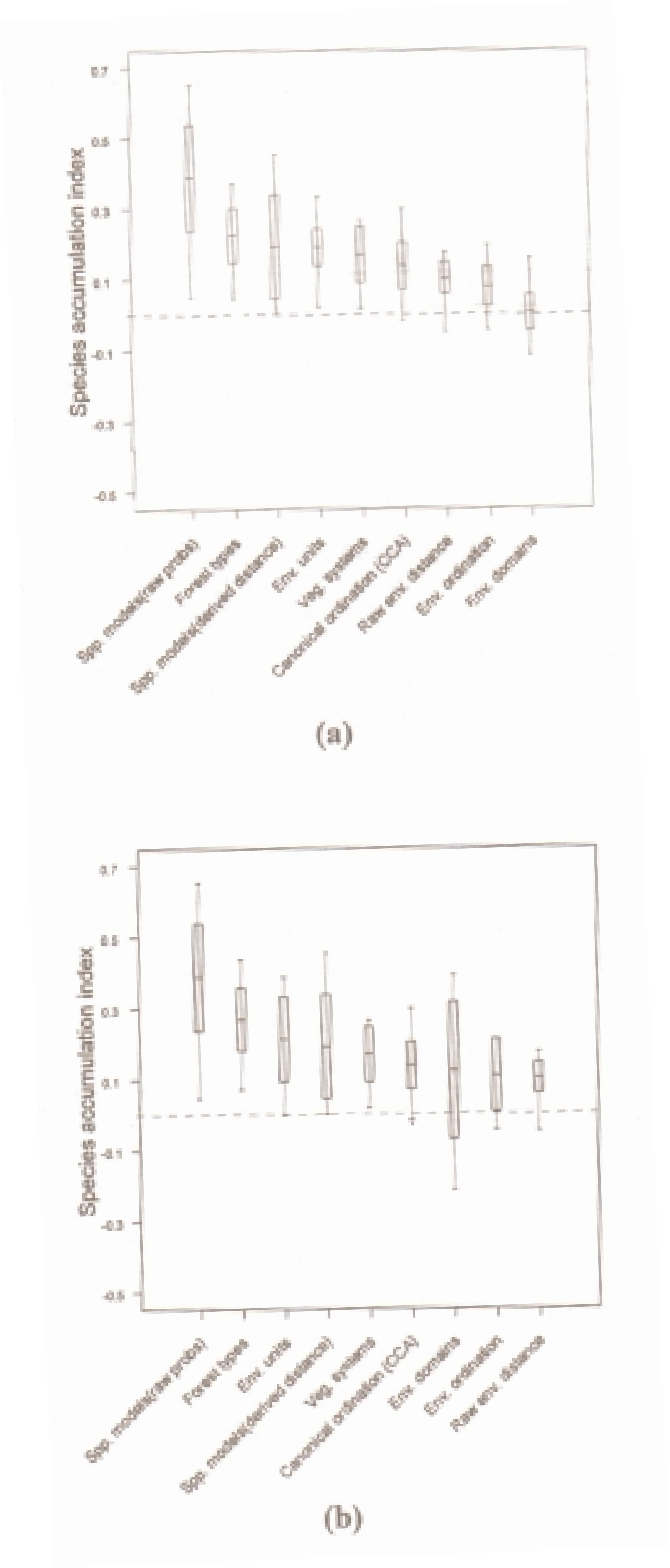


Figure 4.24 Performance of different types of surrogates using (a) the median performance of each type, within each biological group and (b) the surrogatewithin each type that performed best across all biological groups.

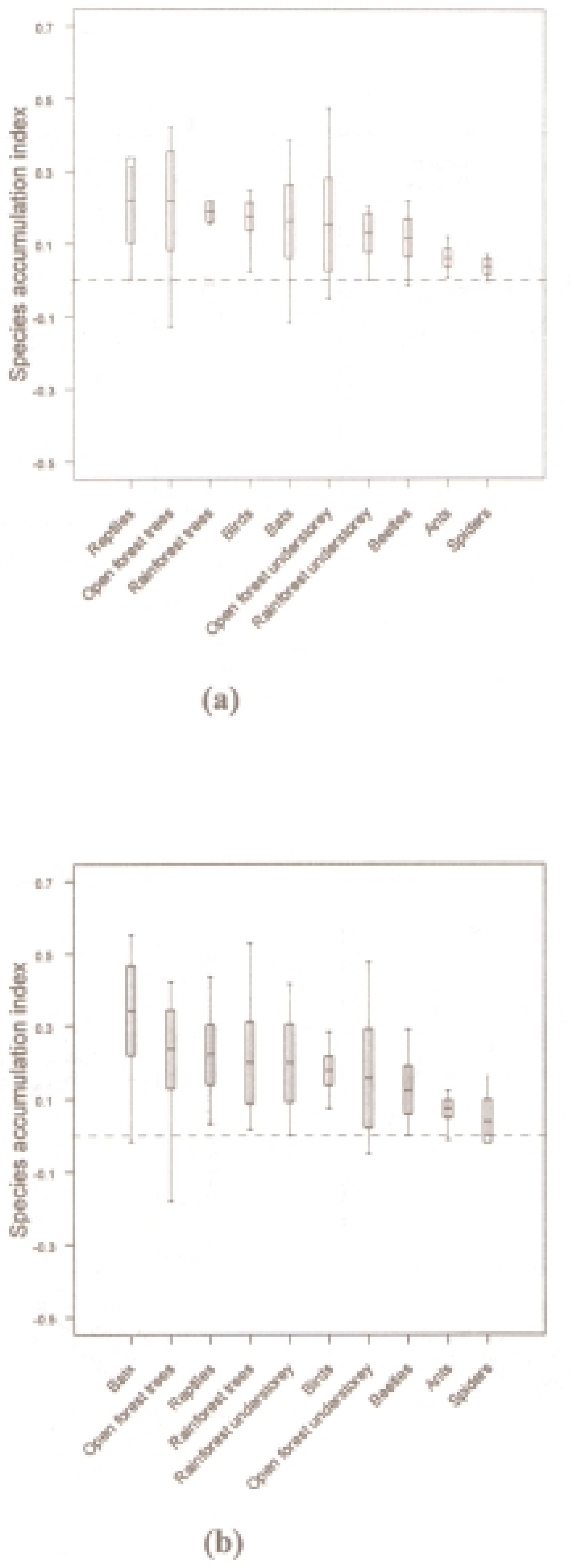


Figure 4.25 Performance of surrogates for different biological groups using (a) the median performance of each surrogate type, within each biological group and (b) the surrogate within each type that performed best across all biological groups.

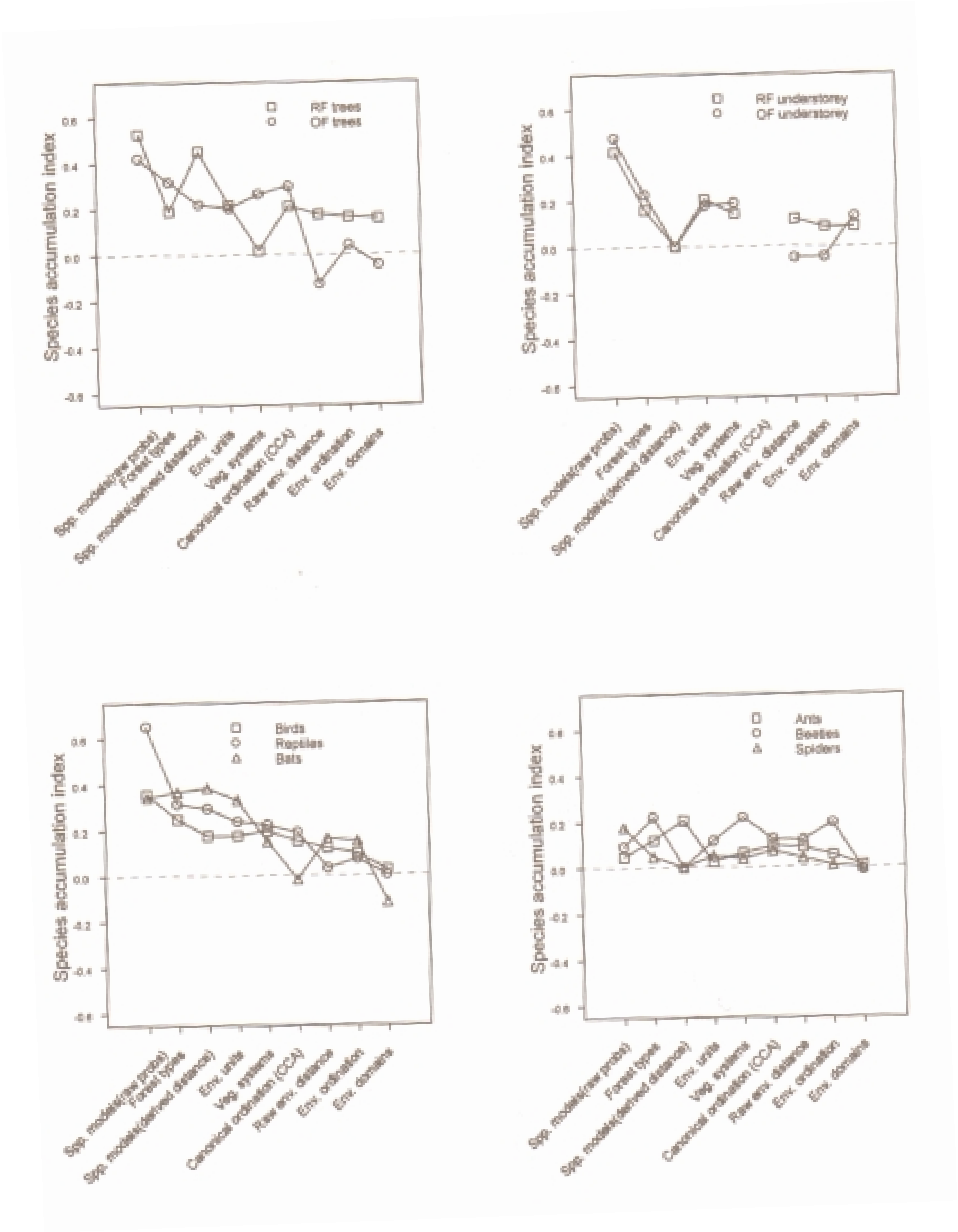


Figure 4.26 Performance of surrogates for all combinations of biological group and surrogate type, using the median performance of each surrogate type within biological group.

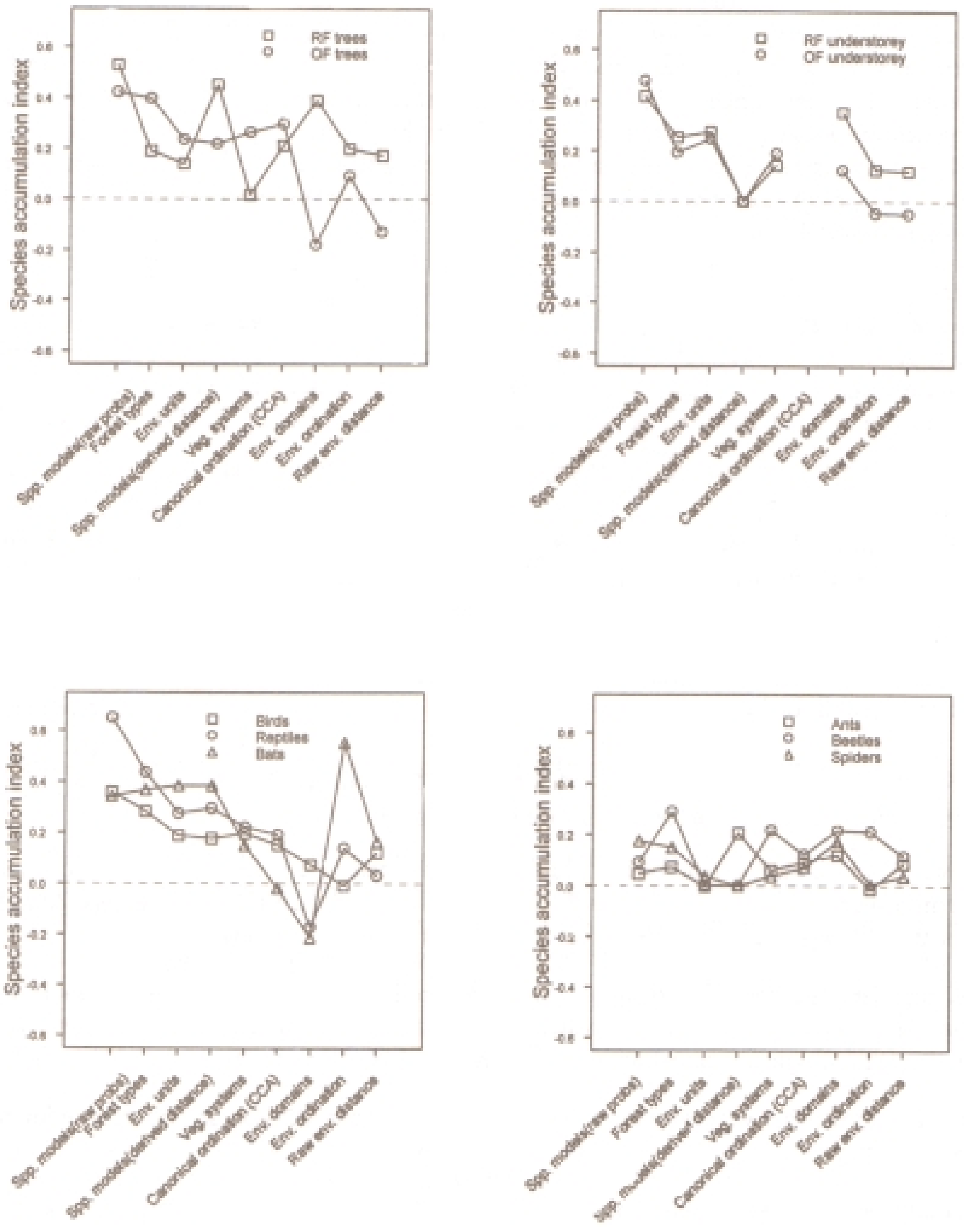


Figure 4.27 Performance of surrogates for all combinations of biological group and surrogate type, using the surrogate within each type that performed best across all biological groups.

significantly between different types of surrogates and between different biological groups, but that these differences may not be consistent across all combinations of surrogate and biological group. A surrogate may perform better (relative to other surrogates) for some biological groups than for others.

The effects of type of surrogate and biological group on performance are depicted graphically in Figures 4.24 to 4.27. In Figure 4.24 surrogates are ranked in descending order of median performance (across all biological groups). This order was reasonably consistent across the two approaches used to compare surrogates. Species modelling (using raw predicted probabilities) was the best performing surrogate in both cases, followed by forest type mapping. Environmental domains, environmental ordination and raw environmental distance performed relatively poorly. The other surrogates displayed intermediate performance. Figure 4.24 suggests that differences in performance between surrogates are more pronounced when based on the median performance of all versions within each surrogate (top graph) rather than on only the best performing version (bottom graph). This is consistent with the relative levels of significance obtained in the ANOVAs (Tables 4.15 and 4.16).

In Figure 4.25 biological groups are ranked in descending order of median performance (across all surrogates). Although this order was less consistent across the two approaches than that for type of surrogate (Figure 4.24) some trends are nevertheless apparent. The best performance of surrogates was obtained for canopy trees and vertebrates. The worst performance was for invertebrates. Understorey plants were intermediate between these two extremes.

Figures 4.26 and 4.27 provide a more detailed view of the performance of surrogates in relation to individual biological groups. The surrogates in these figures are ranked in the same order as in Figure 4.24. The graphs illustrate that, while there are clear similarities between biological groups in terms of the relative performance of surrogates, there are also important differences. The invertebrates in particular stand out as behaving quite differently from all the other groups. None of the surrogates evaluated performed consistently well for invertebrates.

4.4.3 Bootstrapped analysis of surrogate performance based on selected combinations of surrogates and biological groups

Following completion of the initial evaluation described in Section 4.4.2 it was decided to perform a second evaluation to provide further information on the relative performance of surrogates. The second analysis differed from the first in the following ways:

- A smaller number of surrogates was evaluated. Only one version of each broad surrogate type from the initial evaluation (selected on the basis of median performance across all biological groups) was assessed in the second evaluation.
- Species modelling within selected biological groups was assessed as a surrogate for other biological groups.
- Only the SAI was calculated as a measure of surrogate performance, not the MCC.
- Bootstrapping was used to calculate significance levels and confidence limits for SAI estimates.
- All surrogates were evaluated using only half the sites in each biological group. In the initial evaluation, canonical ordination and species modelling had been evaluated using only half of each biological dataset to derive species accumulation curves. The other half dataset was used to fit the canonical ordination or species models (to achieve independence between data used to derive and evaluate surrogates). All other surrogates in the initial analysis were evaluated using full biological datasets. There was concern that use of different numbers of survey sites to evaluate different types of

surrogates may have biased results. This problem was overcome in the second analysis by using half datasets to evaluate all surrogates.

Specific surrogates evaluated in the second analysis included (see Section 4.3 for a detailed description of each surrogate):

- forest types grouped into ecological associations;
- environmental units using fine scale environmental data and a 0/1 distance measure;
- environmental domains using enhanced fine scale environmental data, 125 classes and an ultrametric distance measure;
- environmental ordination using fine scale environmental data and 4 axes;
- canonical correspondence analysis;
- modelling of species within the biological group under consideration (using raw predicted probabilities);
- modelled reptile species as a surrogate for invertebrate groups;
- modelled bird species as a surrogate for invertebrate groups;
- modelled tree species as a surrogate for birds, reptiles, invertebrates and understorey plants; and
- vegetation units derived by numerical classification of modelled distributions of canopy tree species.

SAI estimates obtained for these surrogates are presented in Table 4.17, along with significance levels and confidence limits. The same results are presented graphically in Figures 4.28 and 4.29. In these figures surrogates are ranked in descending order of performance within each biological group. The 95% confidence limits around the estimates provide an indication of the significance of differences in performance between surrogates (overlap in the 95% confidence intervals for two surrogates indicates that the SAI values for these surrogates are not significantly different).

In Figure 4.30 SAI estimates for all evaluated combinations of surrogate and biological group are used to summarise variation in performance between surrogates (across all biological groups) and between biological groups (across all surrogates). Figure 4.31 provides a more detailed view of variation in performance between surrogates, with a separate graph for each biological group. Surrogates in these graphs are ranked in the same order as in Figure 4.30. Modelled reptiles and modelled birds were not included as surrogates in Figures 4.30 and 4.31 because they were evaluated for only a subset of biological groups.

The results obtained in this second analysis were reasonably consistent with those obtained in the initial evaluation. The addition of species modelling within one biological group as a surrogate for other biological groups achieved mixed results. Modelled birds, reptiles and trees did not perform well as surrogates for invertebrates (nor did any other surrogate). Modelled trees, however, did perform very well as a surrogate for understorey plants and birds, and achieved the second highest median performance across all biological groups (Table 4.30). Vegetation units derived from numerical classification of modelled tree distributions also performed well, achieving the third highest median performance across all groups.

Selected examples of species accumulation curves used to derive SAI estimates in this evaluation are provided in Figures 4.32 to 4.36. Each graph shows the optimum curve and mean random curve for a biological group in addition to three surrogate curves based on species modelling (within the group), forest type mapping and environmental domain

Table 4.17 Species accumulation indices and 95% confidence limits for selected combinations of surrogates and biological groups subjected to bootstrapping. Significance levels are indicated by * (p < 0.05) or ** (p < 0.01). Differences in values for indices between this Table and Table 4.1 for some combinations are due to the use of a reduced dataset (see text) and also slight differences in the mean random curves used to derive the Species Accumulation Index.

	Ants		Spiders		Beetles	
Forest types	* 0.218	± 0.237	0.199	± 0.313	0.065	± 0.379
Environmental units	0.071	± 0.268	0.055	± 0.355	0.120	± 0.338
Environmental domains	* 0.289	± 0.272	-0.149	± 0.319	-0.234	± 0.370
Environmental ordination	0.060	± 0.163	0.082	± 0.147	-0.267	± 0.238
Species models (within grp)	0.051	± 0.277	0.184	± 0.279	0.080	± 0.346
Canonical ordination (CCA)	0.057	± 0.173	0.082	± 0.153	0.099	± 0.233
Modelled vegetation units	0.102	± 0.238	0.224	± 0.109	0.176	± 0.246
Modelled reptiles	0.114	± 0.365	0.069	± 0.182	-0.078	± 0.399
Modelled birds	0.148	± 0.345	-0.041	± 0.446	-0.114	± 0.374
Modelled trees	0.114	± 0.298	-0.133	± 0.394	-0.180	± 0.416

	Bats		Birds		Reptiles	
Forest types	0.142	± 0.563	0.132	± 0.268	* 0.308	± 0.303
Environmental units	0.097	± 0.555	0.162	± 0.267	-0.055	± 0.266
Environmental domains	0.156	± 0.600	-0.172	± 0.301	-0.074	± 0.289
Environmental ordination	-0.468	± 1.696	0.182	± 0.175	0.125	± 0.190
Species models (within grp)	0.238	± 0.527	** 0.358	± 0.265	** 0.672	± 0.244
Canonical ordination (CCA)	-0.203	± 0.782	0.031	± 0.164	0.226	± 0.184
Modelled vegetation units	0.320	± 0.583	0.201	± 0.230	-0.040	± 0.322
Modelled trees	NA		** 0.304	± 0.248	0.143	± 0.288

	Rainforest trees		Open-forest trees		Rainforest understorey	
Forest types	0.147	± 0.328	** 0.435	± 0.195	* 0.208	± 0.195
Environmental units	* 0.340	± 0.215	0.201	± 0.242	* 0.221	± 0.211
Environmental domains	-.0020	± 0.308	0.117	± 0.238	0.188	± 0.218
Environmental ordination	-0.016	± 0.216	0.083	± 0.171	-0.265	± 0.160
Species models (within grp)	** 0.545	± 0.238	** 0.445	± 0.221	** 0.442	± 0.201
Canonical ordination (CCA)	* 0.244	± 0.162	** 0.306	± 0.139	NA	
Modelled vegetation units	0.203	± 0.261	** 0.400	± 0.184	* 0.205	± 0.210
Modelled trees	NA		NA		** 0.357	± 0.192

	Open forest understorey	
Forest types	0.232	± 0.141
Environmental units	0.174	± 0.149
Environmental domains	0.146	± 0.145
Environmental ordination	-0.058	± 0.094
Species models (within grp)	0.497	± 0.124
Canonical ordination (CCA)	NA	
Modelled vegetation units	0.300	± 0.116
Modelled trees	0.440	± 0.129

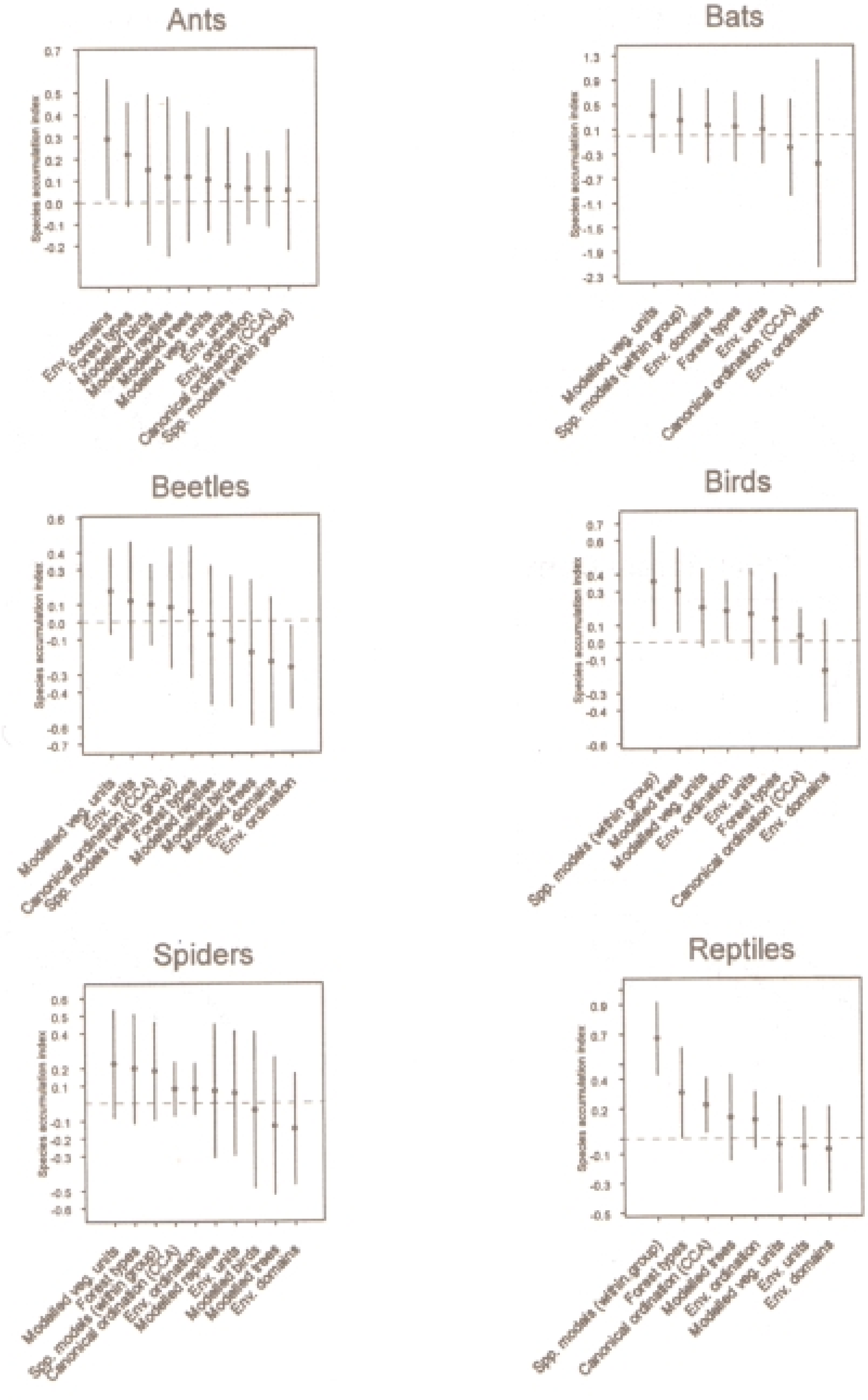


Figure 4.28 Speices accumulation indicies, with 95% confidence limits dervied by bootstrapping, for combinations of selected surrogates and fauna groups.

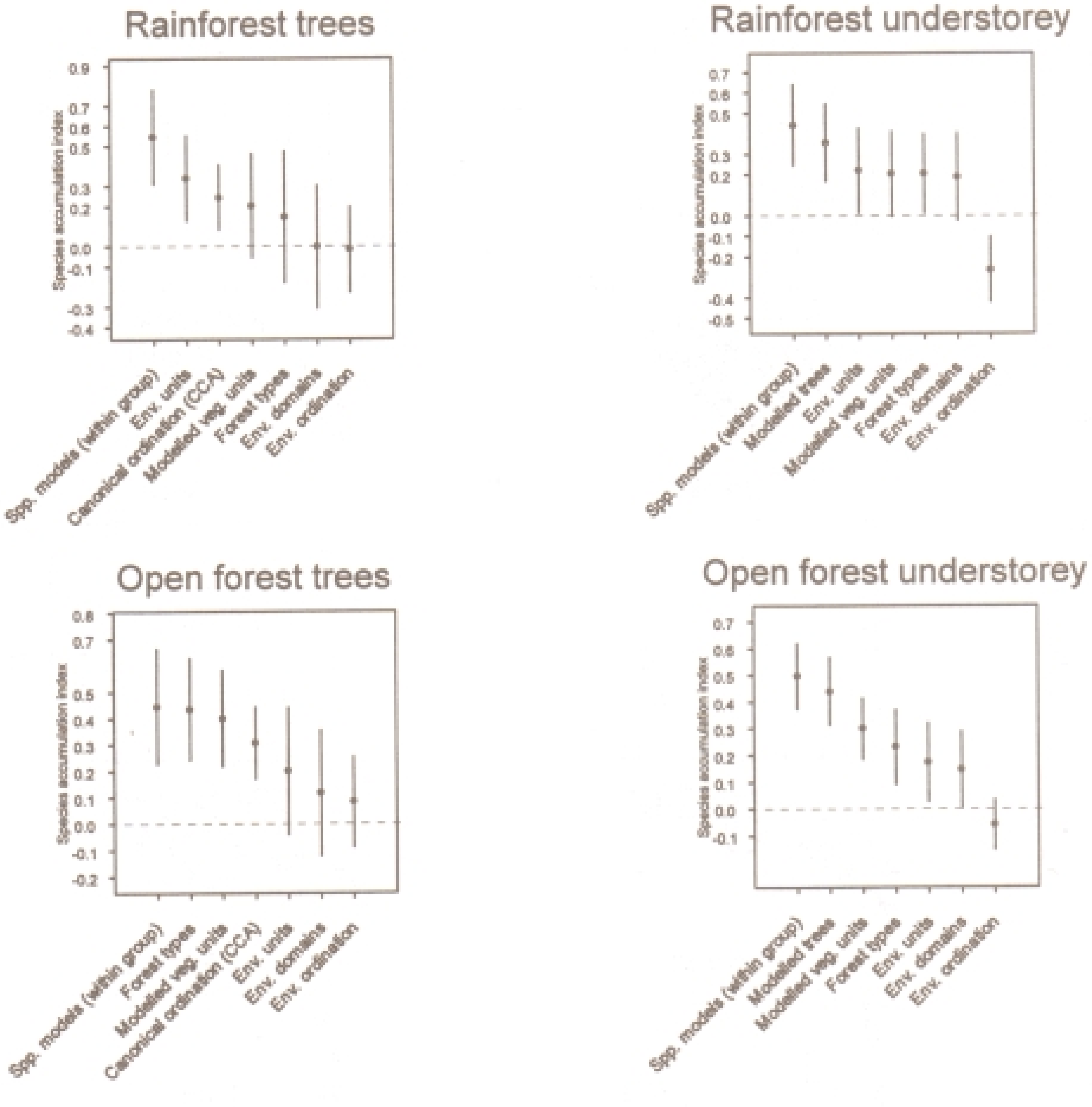


Figure 4.29 Speices accumulation indicies, with 95% confidence limits dervied by bootstrapping, for combinations of selected surrogates and flora groups.

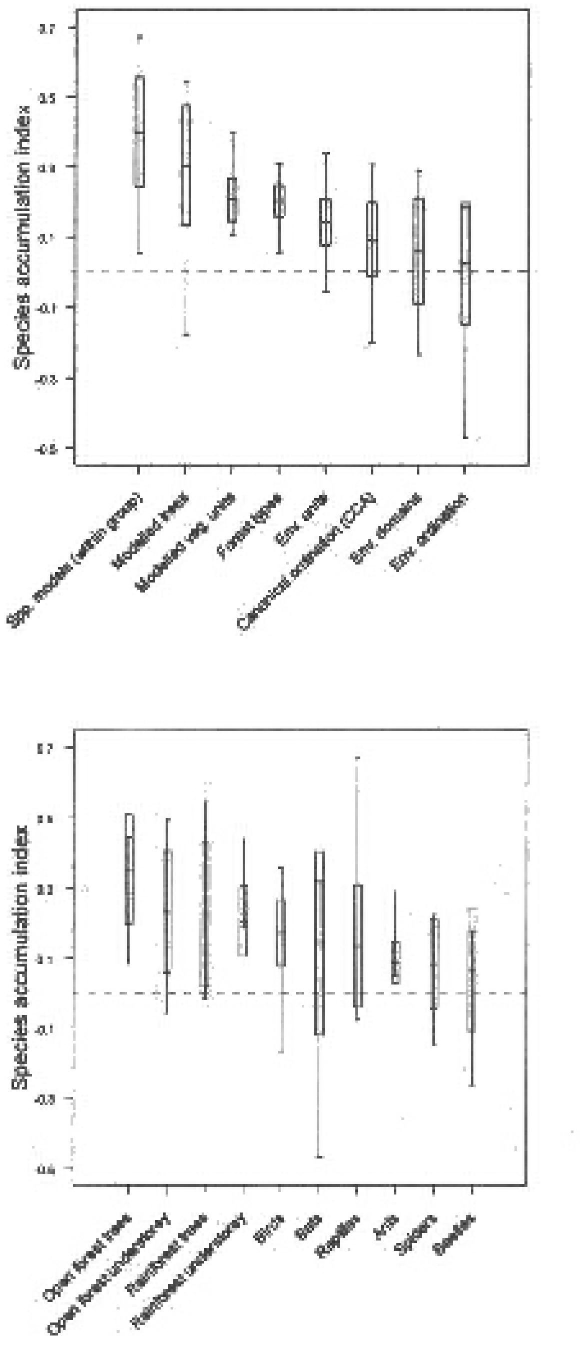


Figure 4.30 Variation in surrogate performance between (a) different types of surrogates (upper graph) and (b) biological groups, based on bootstrapped analysis of selected surrogates (lower graph).

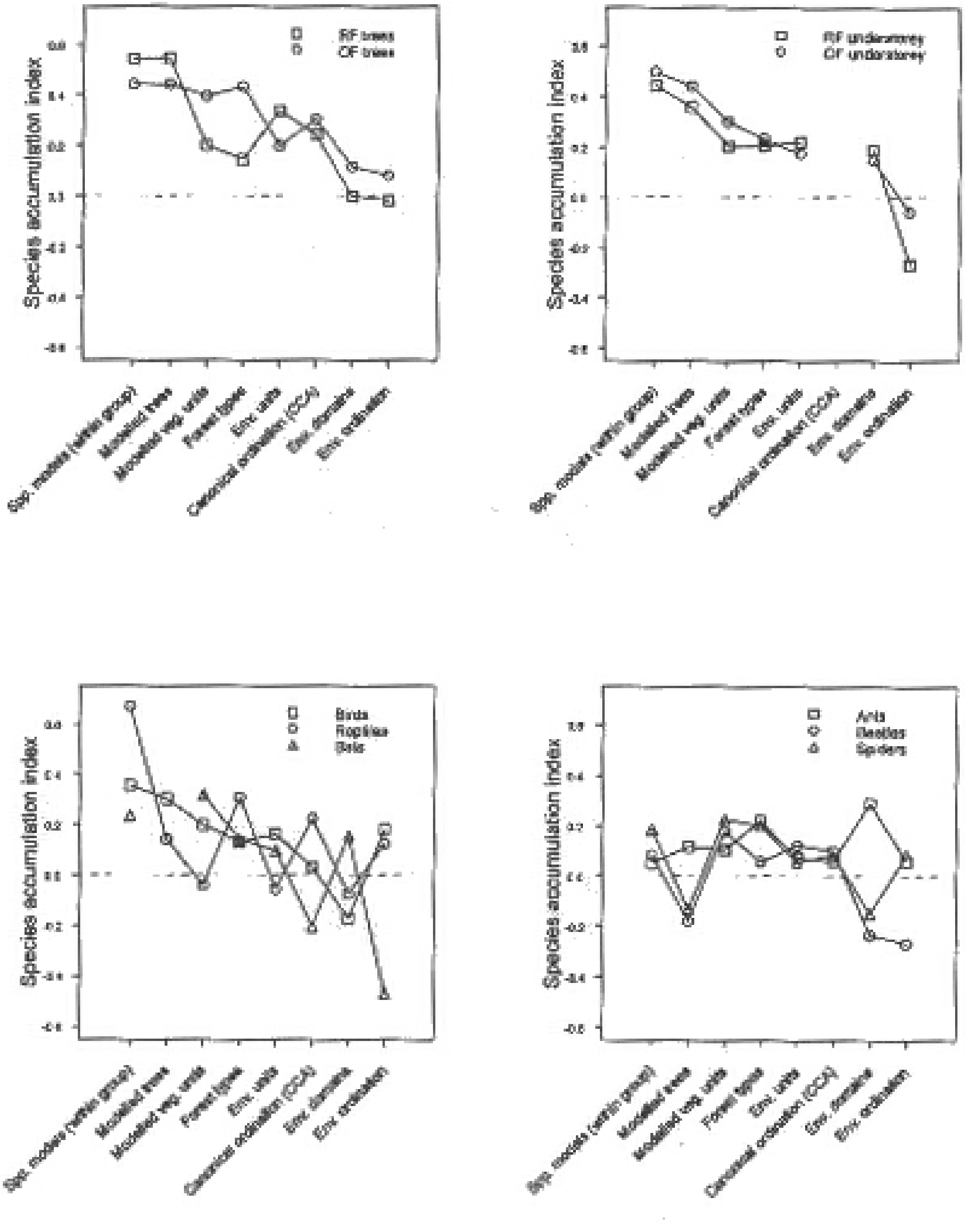


Figure 4.31 Performance of selected surrogates across biological groups, based on bootstrapped analysis.

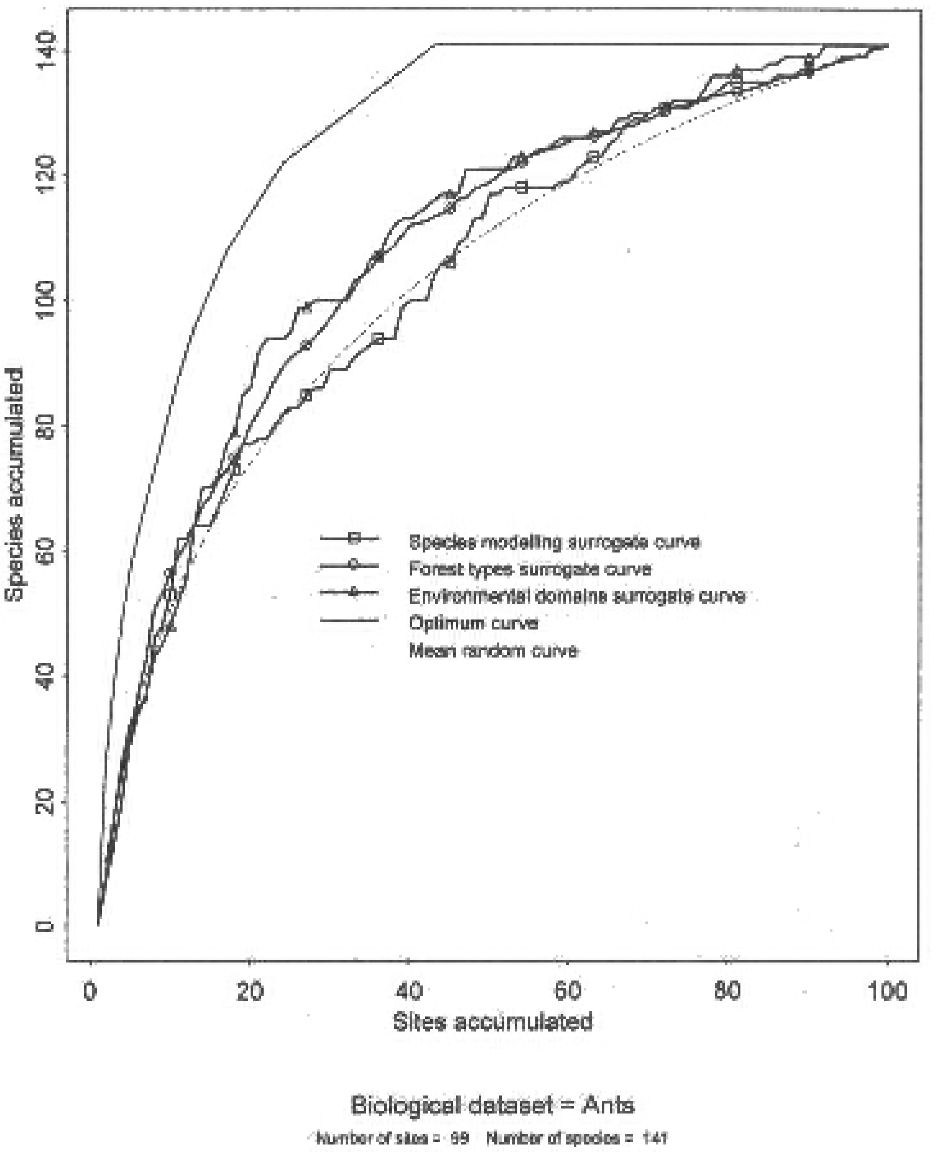
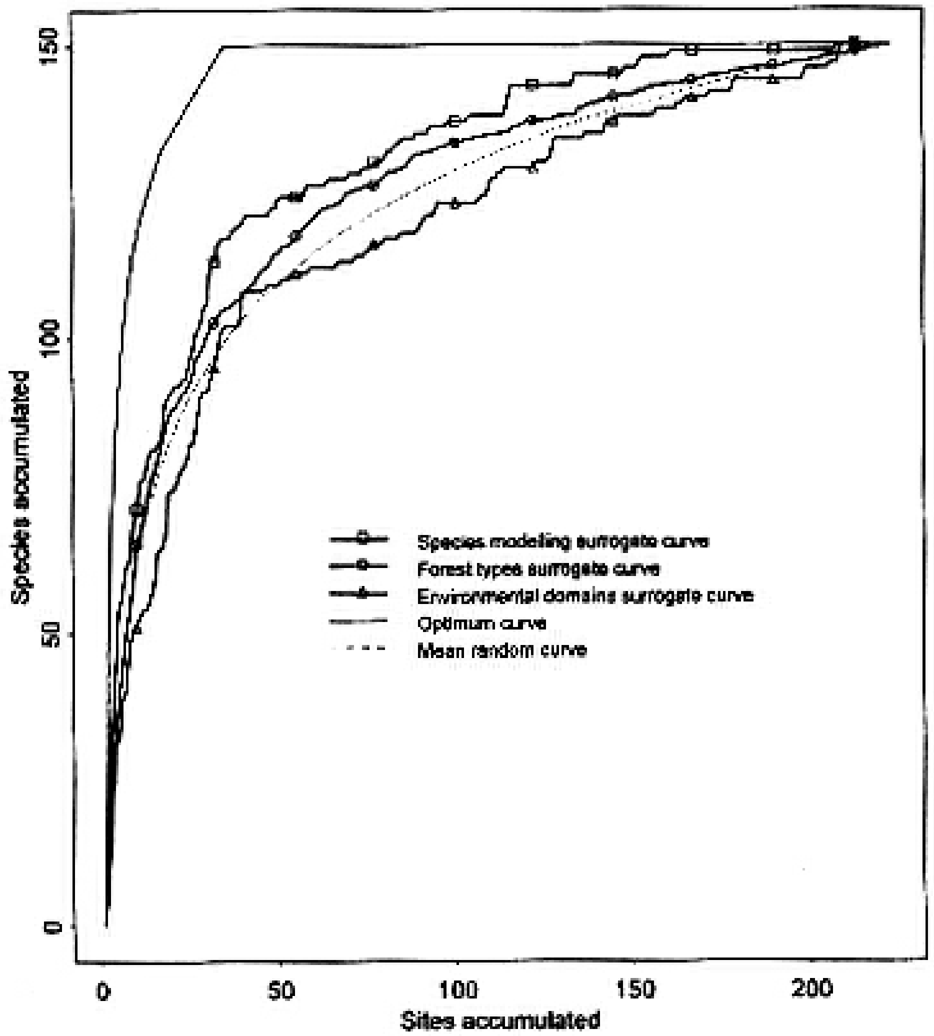


Figure 4.32 Species accumulation curves for ants using three different surrogates: species modelling, forest types and environmental domains. Note that the symbols which idetitfy each curve are plotted for only a subset of points.



Biological dataset = Diurnal birds

Number of sites = 222 Number of species = 150

Figure 4.33 Species accumulation curves for diurnal birds using three different surrogates: species modelling, forest types and environmental domains. Note that the symbols which identify each curve are plotted for only a subset of points.

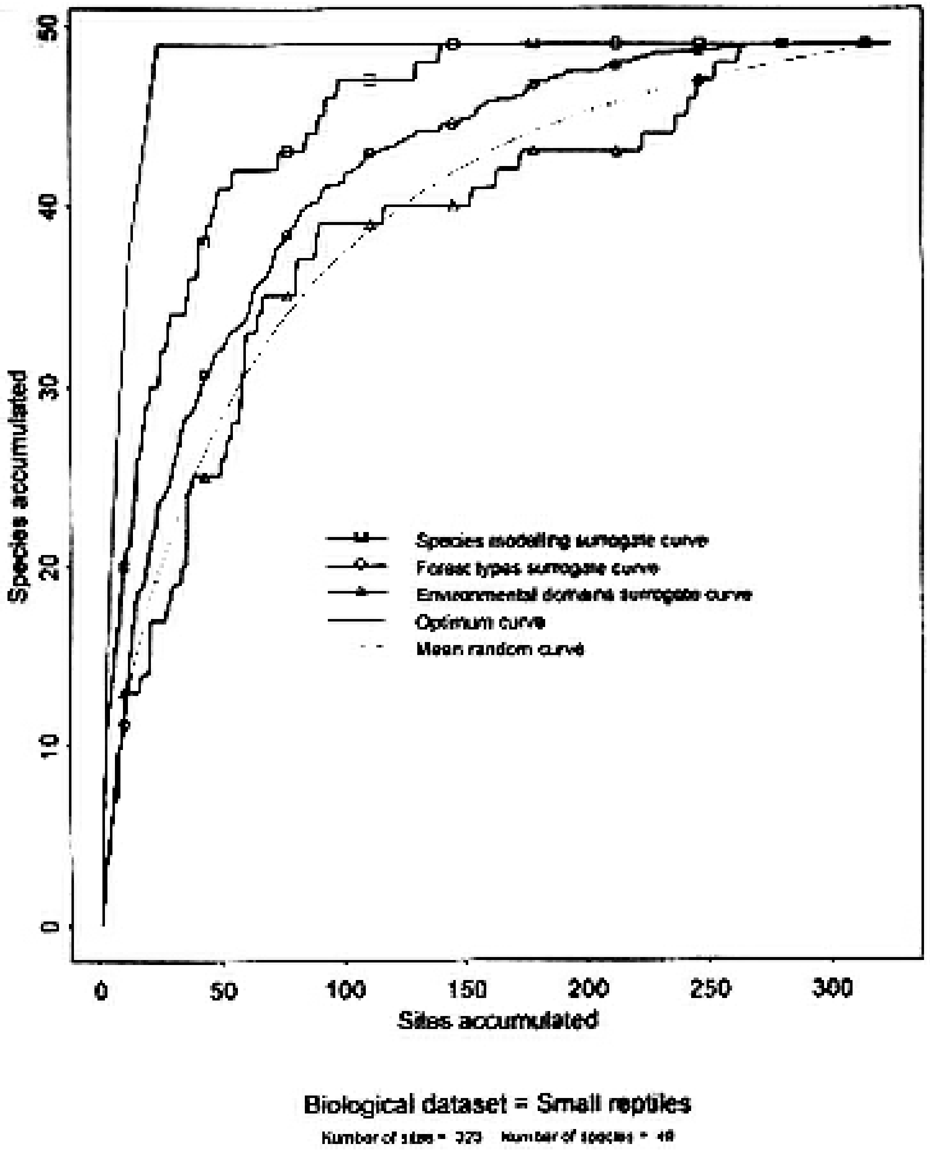


Figure 4.34 Species accumulation curves for small reptiles using three different surrogates: species modelling, forest types and environmental domains. Note that the symbols which identify each curve are plotted for only a subset of points.

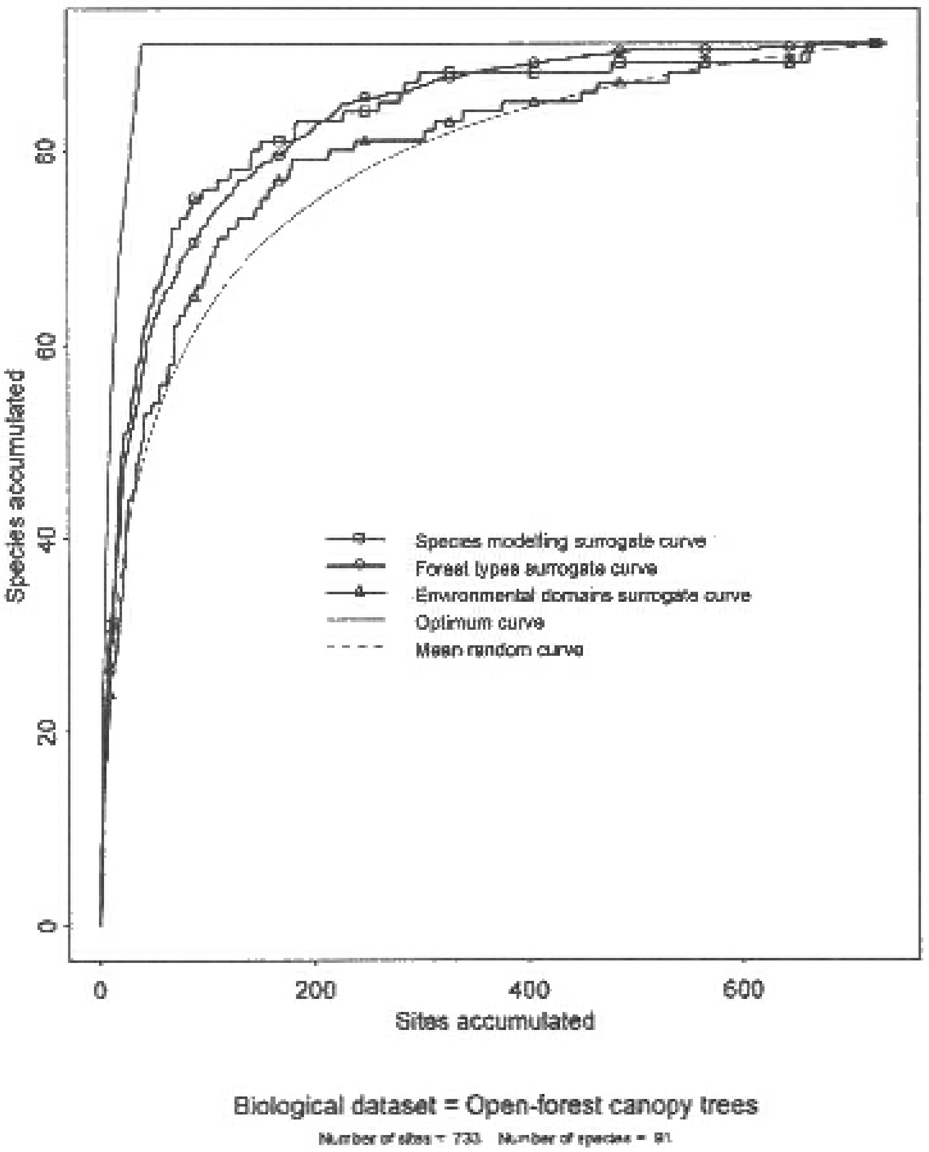


Figure 4.35 Species accumulation curves for open-forest canopy trees using three different surrogates: species modelling, forest types and environmental domains. Note that the symbols which identify each curve are plotted for only a subset of points.

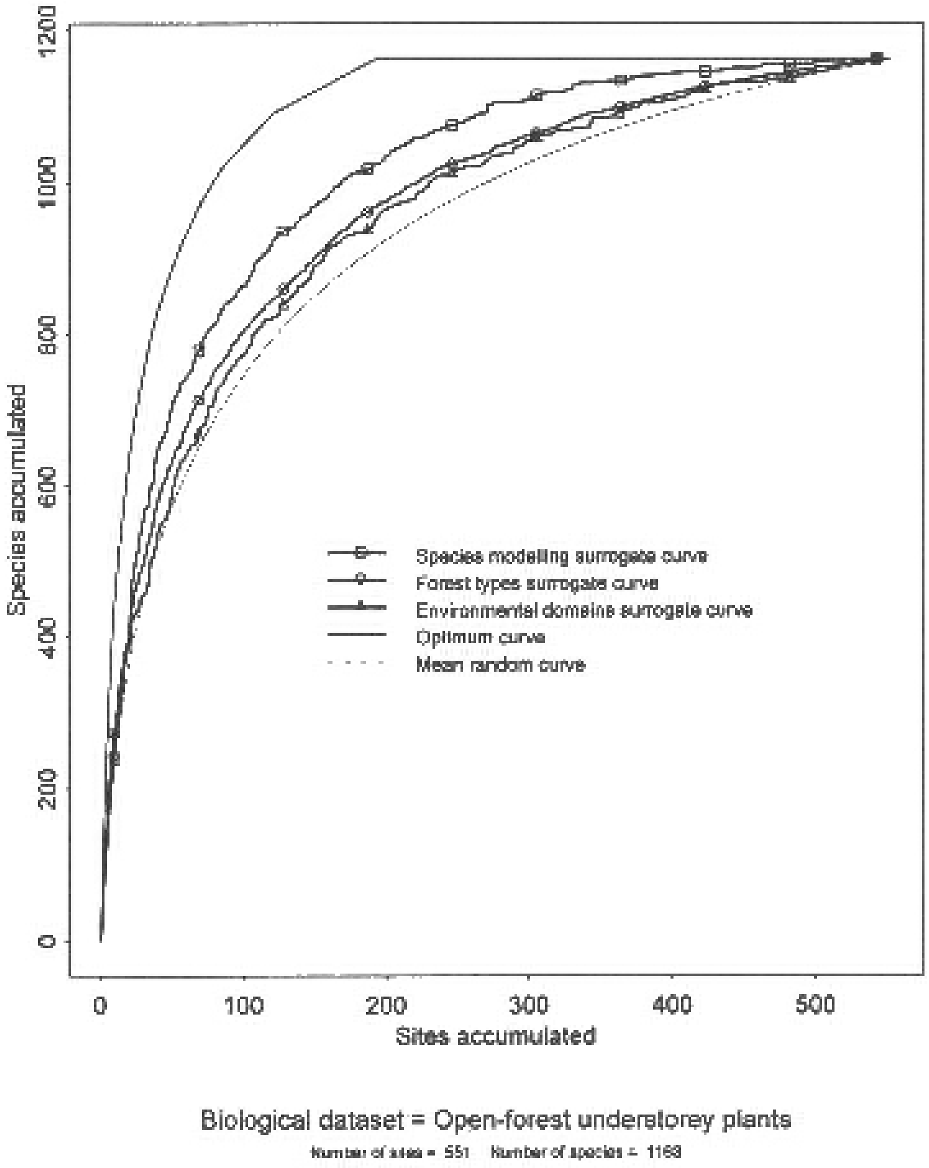


Figure 4.36 Species accumulation curves for open-forest canopy trees using three different surrogates: species modelling, forest types and environmental domains. Note that the symbols which identify each curve are plotted for only a subset of points.

classification. The biological groups used in the examples (ants, birds, reptiles, open forest trees, open forest understorey plants) were selected to represent a range of differentiation in performance of the three surrogates.

4.5 Discussion

The evaluation of surrogates in forested north east NSW revealed clear differences in performance, both between different types of surrogates and between different biological groups.

Little differentiation in surrogate performance was apparent within the invertebrate groups. All broad types of surrogates performed poorly when evaluated using invertebrates. Clear trends in performance across different types of surrogates were evident only within the vertebrate and vascular plant groups. The poor performance of surrogates in relation to invertebrates might be due to a number of factors. The ground dwelling invertebrates used in the evaluation could be responding to environmental factors quite different to those regulating the distributions of vascular plants and vertebrate fauna. These factors may not be well correlated with either the vegetation classes used in forest type mapping, or the abiotic environmental variables used to derive environmental classifications, environmental ordinations and species models. The environmental factors controlling distributions of ground dwelling invertebrates are also likely to operate at a finer spatial scale than that at which surrogates are usually mapped.

Another scale related problem may account for the poor correlation between invertebrates and environmental surrogates in this study. Most of the surrogates evaluated address variation within environmental space but not geographical space. In applying these surrogates it is assumed that two sites with the same value for a surrogate will be similar biologically, regardless of the geographical distance between the sites. In the region evaluated in the study, sites close together in environmental (or surrogate) space can be separated by up to 400km in geographical space. A critical issue relating to the performance of surrogates is the relative influence that environmental distance and geographical distance have on the biological similarity between sites. While, in a region of the size of north east NSW, it might be reasonable to assume that environmental separation of sites has a much greater effect than geographical separation on biological similarity in terms of vertebrate fauna and (probably to a lesser extent) vascular flora, this may be an unreasonable assumption in the case of ground dwelling invertebrates. It could be that sites close together in surrogate environmental space (e.g. in the same forest type or environmental domain) but widely separated in geographical space are less similar in terms of ground dwelling invertebrates than sites in very different environments but close together geographically.

The problem of geographical scale adds an unavoidable level of complexity to the use and evaluation of environmental surrogates. The performance of surrogates is likely to vary across spatial scales. A surrogate that performs well within a small study area will not necessarily perform well across a much larger region, and *vice versa*. The exact nature of this interaction between surrogate performance and geographical scale will in turn be dependent on the biological group under consideration. The current study did not attempt to address this problem All surrogates were evaluated for a region of fixed extent, i.e. north east NSW. Findings regarding the relative performance of surrogates are therefore applicable only at the scale of this region. Quite different results might be obtained if a similar study were to be conducted within a subset of the region (e.g. a single river catchment) or a superset of the region (e.g. all of NSW or the entire continent). Further research is needed to clarify the relationship between spatial scale and surrogate performance, and in particular the relative effects of geographical and environmental distance on biological similarity between sites, measured in terms of different biological groups. Research projects currently being conducted by Bob Pressey (NSW NPWS) and Ian Oliver (Macquarie University) are starting to address these problems.

The north east NSW evaluation revealed relatively consistent differences in performance of surrogates within all vertebrate and vascular plant groups. The poorest performing surrogates were those derived purely from abiotic environmental data, i.e. environmental domain classifications and environmental ordinations. Surprisingly, however, the environmental unit classification derived through simple combination of four key environmental variables performed marginally better than the numerically based classifications and ordinations. Canonical ordination (CCA) also performed marginally better than abiotic environmental domain classification and ordination, especially for canopy trees (less so for vertebrates). Forest type mapping performed relatively well as a surrogate for all vertebrate and vascular plant groups. The best performance of all was achieved by modelling of species distributions, especially when modelling was applied to species within the biological group under evaluation. The use of models for one biological group as a surrogate for other biological groups also appeared to have potential. In particular, modelled canopy trees performed better than forest type mapping as a surrogate for both canopy and understorey flora, and for vertebrates.

The performance of abiotic environmental classifications and ordinations is disappointing given the obvious benefits of this approach in terms of cost efficient application to large geographical areas. The poor performance of these techniques relative to modelling of species distributions may seem surprising given that the same abiotic environmental variables are employed in all cases. The problem with the environmental classifications and ordinations does not appear to be attributable to the type or quality of environmental variables on which they are based. These same variables have been shown to function well as predictors in the modelling of species distributions. The problem instead appears to relate to the way in which the environmental variables are integrated within the numerical classifications and ordinations and, in particular, the weights assigned to these variables.

The weighting of variables in most environmental classifications or ordinations is essentially arbitrary. Even though we endeavoured to match, as closely as possible, weighting schemes used in previous domain analyses, the combination of weights employed in this study was just one of an almost infinite number of alternatives. Each of these alternatives would generate a different classification or ordination. The resultant classification or ordination is also dependent on the type of dissimilarity measure used to estimate environmental distance between sites. The Gower metric employed in this study is just one of a number of alternatives (e.g. Euclidean distance), each with different properties. It could be argued that a different combination of dissimilarity measure and variable weights would have generated better performing classifications and ordinations for north east NSW. The problem, however, lies in choosing the right mix of dissimilarity measure and variable weights in the absence of biological data. If abiotic classifications or ordinations are to be used as surrogates in regions lacking adequate biological data then selection of dissimilarity measures and variable weights must be based on either ‘gut feeling’ or previous experience in other regions.

If good biological survey data are available for a region then these can be integrated with abiotic environmental data to first analyse and model the relationship between biological and environmental patterns and then to extrapolate biological patterns across unsurveyed parts of the landscape using the environmental data alone. Canonical ordination (CCA) and modelling of individual species distributions represent two different means of achieving this integration. CCA essentially models all species in a group simultaneously by finding linear combinations of abiotic environmental variables that best ‘explain’ variation in the biological survey data. In this study the technique performed moderately well as a surrogate for canopy trees but provided little improvement over abiotic classification and ordination for vertebrates (CCA was not applied to understorey flora due to constraints imposed by software). It is beyond the scope of this report to examine, in any detail, reasons for the mediocre performance of CCA as a surrogate in north east NSW. Any such examination should, however, focus on the reasonableness of assumptions underlying the technique (symmetrical bell-shaped species response curves, even packing of species along environmental gradients etc). The concept of canonical ordination is an appealing one, with considerable scope for further development and refinement.

Modelling of individual species distributions performed much better as a surrogate than CCA, and in fact outperformed all other surrogates evaluated in north east NSW. It could be argued that the good performance of species modelling is hardly surprising given that models are tailored to provide the best possible prediction of species distribution within each biological group, whereas other surrogates are intended to serve as general purpose surrogates for all biological groups. While this point has some validity it should be noted that the performance of species models within each biological group was evaluated against data for all species in that group, not just those for which models were fitted (a sizable proportion of species had insufficient data for modelling). Furthermore, models derived for one biological group were evaluated as surrogates for other biological groups. Canopy tree models performed particularly well as surrogates for both canopy and understorey flora, and vertebrates. In other words, there appears to be considerable potential for using modelled species distributions from one or more selected biological groups as a general purpose surrogate for all biological groups.

Caution should be exercised in generalising the above results to other regions or surrogates. The results are specific to forested north east NSW and to the particular versions of surrogates evaluated. Performance of surrogates in other regions may differ greatly, for the following reasons:

- Some surrogates may perform better in particular environments than in others.

- Performance of surrogates may vary across spatial scales. A surrogate that performs well for a region the size of north east NSW might perform poorly for a substantially smaller or larger region, and *vice versa*.

- Performance of vegetation mapping as a surrogate may vary between regions depending on the type of mapping employed. Forest type mapping is specific to NSW and is primarily designed to fulfill the needs of timber production rather than conservation planning. Vegetation mapping schemes employed elsewhere may be better designed to map vegetation communities for the purposes of conservation planning, thereby providing better surrogate performance.

- The quality and spatial resolution of available abiotic environmental data varies greatly between regions. This variation is likely to affect the relative performance of environmental classifications and ordinations, and modelling of species distributions.

- The quality and quantity of biological survey data also varies greatly between regions. Surrogates employing biological data (species modelling and canonical ordination) will not perform as effectively in regions with less extensive survey data than that available for north east NSW.

The discussion so far has dealt only with the performance of surrogates and not with the cost of their implementation. It is extremely difficult to make generalisations about the cost of implementing surrogates. This cost is dependent on the availability of data within a region and will therefore vary substantially between regions. In north east NSW, data were already available for all of the surrogates evaluated (although the geographical coverage of forest type mapping is not complete). Assuming this availability of data, there would be very little difference in the cost of employing any of the evaluated surrogates as a basis for reserve planning. In other regions cost of implementation may differ greatly between surrogates depending on the availability of data. If we limit this discussion to the types of surrogates evaluated in north east NSW then three types of data are of relevance:

- vegetation mapping;

- abiotic environmental data (terrain, climate and substrate); and

- systematic biological survey data.

Vegetation mapping is a surrogate in its own right. Environmental classifications and ordinations require only abiotic environmental data. Species modelling and canonical ordination require both abiotic environmental data and systematic biological survey data. If the data required by a surrogate are already available then the cost of implementing that surrogate is minor. Cost of implementation will, however, be major if one or more of the required datasets is not already available. All three of the datasets listed above are expensive to establish. Selection of an appropriate surrogate in any given region should consider not only the relative performance of potential surrogates but also the availability of data required by those surrogates and the cost of obtaining such data if they are not already available.