

3 Results (N Kearnes, C Simpson, A Bryant, D Steller and S House)

The following sections detail the results of the four major components of this study:

- literature and data review
- vegetation—ecological communities
- species diversity—selected fauna species
- species diversity—selected flora species.

3.1 Literature and data review

Over 100 reports were reviewed during the data audit, resulting in an additional 3022 species sighting records, bringing the total number of records for the Georges River catchment to 6993. Of these, 233 related to priority species.

The most notable new records of priority species were:

- several records of Koalas from the Wedderburn colony
- a Yellow-bellied Glider in the Wedderburn area
- a Squirrel Glider in the St Helens Park area
- a Brown Treecreeper in the St Helens Park area.

Appendix I provides lists of typical flora for each of the fourteen councils of the catchment, based on the records of the NSW Atlas of Wildlife. These lists present typical flora lists only, and each council should carefully consider the entire species list for the Georges River catchment and pay specific attention to any species that occur in adjacent LGAs.

3.2 Vegetation—ecological communities

The classification of communities of vegetation has become a standard method for the broad-scale identification of different ecotypes and ecological communities. Throughout this report the term vegetation community is adopted as this better reflects the information being presented; however, in the discussion of results, the implications of the results of the vegetation classification and assessment for ecological communities are examined.

The following sections detail the results of the vegetation assessment. Throughout this report the term Map Units refers to the reference numbers used in relation to each vegetation community classification (see Table 13 for complete list).

3.2.1 Classification of vegetation communities

i) Cumberland Plain

Cluster analysis of 523 sample sites resolved a hierarchical classification of 22 communities occurring on or adjoining the Cumberland Plain. The principal dichotomy in the hierarchy resulted in the separation of sites located on sandy soils from those located on clay-loam soils derived from shale or alluvium. Six of the 22 communities

occurred mainly on soils derived from Wianamatta Shale (MU9, MU10, MU13, MU14, MU15 and MU152) and five were found only on soils derived from sandstone or aeolian sand deposits (MU8, MU31, MU32, MU33, and MU35). Four communities were found in association with deposits of Tertiary Alluvium (MU3, MU4, MU6 and MU103), although the presence of this substrate could not always be conclusively demonstrated. Three communities were restricted to soils of recent alluvial deposition (MU5, MU11 and MU12), while one was restricted to Estuarine Sediments (MU34). The remaining three communities were restricted to areas transitional between shale and sandstone soils. One community, Shale/Sandstone Transition forest—Low Sandstone Influence (MU1), was represented in the dendrogram by a cluster on each side of the shale/sandstone dichotomy, reflecting the transitional nature of soils at those sample sites. Repeated clustering using different association measures (Kulczynski vs Bray–Curtis) and various subsets of the data demonstrated that the location of the second cluster was unstable: it would often join with the first cluster in the top half of the dendrogram. Similar behaviour was observed for the cluster representing Shale/Gravel Transition Forest (MU103). This cluster joined alternately with Castlereagh Ironbark Forest (MU3) and Shale Plains Woodland (MU10), which was again a reflection of the transitional nature of the soils at the sample sites. Freshwater Wetlands was not sampled in this survey, but is recognised as a unique vegetation community and mapped using aerial photograph interpretation.

Full descriptions of the structure, physical habitat and species characteristics of each community are presented in Appendix C. Diagnostic species (listed for each community in Appendix C) are grouped according to growth form, and listed in decreasing order of frequency of occurrence.

ii) **Woronora Plateau**

The differentiation of clusters representing unique vegetation communities was more difficult on the Woronora Plateau because sites tended to cluster into groups according to observer. Sites sampled by different observers were spatially segregated, therefore there was no objective way of differentiating between observer effects and regional patterns in floristic composition. As a consequence, a dendrogram showing the relationship between vegetation communities on the Cumberland Plain and on the Woronora Plateau has not been included.

Clustering of the full data set of 853 sites was supplemented by clustering of pair-wise combinations of the five survey sets that made up the full data set. This process was guided by the classification given to sites in previous studies (Keith 1994, French *et al.* in press), and involved some subjective grouping of clusters based on an assessment of the raw data. Sample sites located on the Woronora Plateau were represented in ten clusters, four of which were identified in the first cluster analysis as communities adjoining the Cumberland Plain. Six additional clusters likely to represent unique floristic communities were identified. One hundred and sixteen sites could not be classified with confidence and were excluded from further analysis. The majority of sample sites were represented by five clusters that together represent variations of either Sandstone Gully Forest (two clusters) or Ridgetop Woodland/Heath Complex (three clusters). The remaining five clusters represented communities with restricted distribution on the Woronora Plateau. Full descriptions of the structure, physical habitat and the species characteristic of each assemblage are presented in Appendix C.

Because the sites sampled in other surveys did not cluster into cohesive groups the diagnostic species for communities on the Woronora Plateau were computed in a separate fidelity analysis. The first analysis included all sites sampled in the current survey in the calculation of fidelity scores. The results of these calculations form the basis for Appendix C, in which the diagnostic species lists differentiate Map Units 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 152, 103, 31, 32, 33, 34, 35, and 43.

The second analysis includes all sites representative of communities occurring on the Woronora Plateau, regardless of when they were surveyed. The results of these calculations form the basis for relevant profiles in Appendix C, in which the diagnostic species lists differentiate Map Units 31, 32, 33, 34, 35, 61, 62, 63, 64, and 65. Diagnostic species are grouped according to growth form, and listed in decreasing order of frequency of occurrence.

3.2.2 Comparison with previous classifications

i) Cumberland Plain

The classification of sites sampled in this survey corresponded well with existing, intuitively derived classifications for the Cumberland Plain (Table 13). Of the communities described in this report, eight are considered to be equivalent to those of the same name described by Benson (1992) and Benson & Howell (1990), and subsequently recognised by NPWS (1997b), those being:

- Castlereagh Ironbark Forest
- Castlereagh Scribbly Gum Woodland
- Agnes Banks Woodland
- Castlereagh Swamp Woodland
- Shale/Gravel Transition Forest
- Turpentine–Ironbark Forest
- Blue Gum High Forest
- Sandstone Ridgetop Woodland.

Cumberland Plain Woodlands was described as consisting of three communities: Grey Box Woodland, Grey Box–Ironbark Woodland and Spotted Gum Forest (Benson 1992). This subdivision was not supported by cluster analysis. Instead, Cumberland Plain Woodlands was divided into two separate communities (Shale Plains Woodland (MU10) and Shale Hills Woodland (MU9)). A third shale woodland community, Moist Shale Woodland (MU14), was identified occurring on steep, sheltered slopes in the Razorback Range. This community may not have been previously recognised.

River Flat Forest (Benson 1992) was divided into three separate communities: Alluvial Woodland (MU11), Riparian Forest (MU12) and Riparian Woodland (MU5). The first two of these communities correspond with a major dichotomy recognised by NPWS (1997) for alluvial areas draining shale-derived soils: Cumberland Plain Creek Systems, and Hawkesbury–Nepean River and major tributaries. Riparian Woodland describes the assemblage of species found within creeklines and poorly drained areas on alluvial soils, and was included within the more extensively distributed alluvial communities by both Benson (1992) and NPWS (1997b).

Western Shale/Sandstone Transition Forest (NPWS 1997a) was divided into two separate communities reflecting differences associated with variation in the level of sandstone influence: Shale/Sandstone Transition Forest—Low Sandstone Influence (MU1) and High Sandstone Influence (MU2). The Low Sandstone Influence (MU1) variant is possibly floristically similar to Benson and Howell's (1994) Bargo Brush. Eastern Shale/Sandstone Transition Forest (NPWS 1997) was not recognised as a unique assemblage. Areas included by NPWS (1997) under this name fell within Turpentine–Ironbark Margin Forest (MU43) or Castlereagh Ironbark Forest (MU3). Dry Rainforest (MU13) was equivalent to the community of the same name described by NPWS (1997) and referred to as Rainforest Scrub by Benson (1992).

ii) Woronora Plateau

Two communities, Western Sandstone Gully Forest (MU33) and Riparian Scrub (MU35), corresponded to communities of the same name described by Keith (1994). Communities recognised by Keith (1994) and French *et al.* (in press) were simplified for mapping at a regional scale (Table 13). Subtle floristic differences amongst six heath and woodland communities defined by Keith (1994) were insignificant compared to variation amongst samples from different surveys in adjacent, structurally analogous vegetation. These communities were therefore amalgamated under Sandstone Ridgetop Woodland (MU31).

Site data representative of Keith's (1994) Sedgeland Heath Mosaic, Ti-tree Thicket and Banksia Thicket were not available for analysis, and time constraints did not permit the use of aerial photography to map the complex mosaic of sedgeland and thicket over the whole study area. The three communities were included in the map as Sedgeland (MU64), and the distribution of this community was assumed to be represented by the extent of the Maddens Plains Soil Landscape (Hazelton *et al.* 1990). Refinements to the distribution of the Upland Swamps map layer were made using an independent API layer made available by Sydney Water Corporation. This layer has been added for completeness only, and has not been subject to field sampling or floristic description. The floristic relationship between this complex and the Sedgeland described by French *et al.* (in press) was not explored.

Two forest communities occurring on soils with a strong shale influence (French *et al.* in press) were united in a cluster representing MU32, Upper Georges River Sandstone Woodland, and were thus amalgamated. Melaleuca Thicket (French *et al.* in press) was recognised as a unique assemblage, although an outlying sample on the banks of the Georges River was represented by Riparian Forest (MU12).

Table 13 Vegetation community classifications—comparison with TSC Act 1995 and other authors

This survey (1999)				TSC Act (determination date)	Benson (1992)	Keith (1994)	French et al. (in press)
MU and Classification	Samp. ¹	Map ²	Diag. ³				
1. Shale/Sandstone Transition Forest (low sandstone influence)	Yes	Yes	Yes	Shale/Sandstone Transition Forest (1998)	–	–	–
2. Shale/Sandstone Transition Forest (high sandstone influence)	Yes	Yes	Yes	Shale/Sandstone Transition Forest (1998)	(9c) Ironbark Forest?	–	–
3. Castlereagh Ironbark Forest	Yes	Yes	Yes	–	(9e) Castlereagh Ironbark Forest	–	–
4. Castlereagh Swamp Woodland	Yes	Yes	Yes	Castlereagh Swamp Woodland (1999 prelim.)	(14c) Swamp Woodland	–	–
5. Riparian Woodland	Yes	No	Yes	Sydney Coastal River Flat Forest (1999)	(9f) River Flat Forest	–	–
6. Castlereagh Scribbly Gum Woodland	Yes	Yes	Yes	–	(14a) Castlereagh Scribbly Gum Woodland	–	–
8. Agnes Banks Woodland	Yes	Yes	Yes	–	(14b) Agnes Banks Woodland	–	–
9. Shale Hills Woodland	Yes	Yes	Yes	Cumberland Plain Woodland (1997)	(9b) Spotted Gum Forest (10c) Grey Box Woodland (10d) Grey Box—Ironbark Woodland	–	–
10. Shale Plains Woodland	Yes	Yes	Yes	Cumberland Plain Woodland (1997)	(9b) Spotted Gum Forest (10c) Grey Box Woodland (10d) Grey Box—Ironbark Woodland	–	–
11. Alluvial Woodland	Yes	Yes	Yes	Sydney Coastal River Flat Forest (1999)	(9f) River Flat Forest	–	–

This survey (1999)				TSC Act (determination date)	Benson (1992)	Keith (1994)	French et al. (in press)
MU and Classification	Samp. ¹	Map ²	Diag. ³				
12. Riparian Forest	Yes	Yes	Yes	Sydney Coastal River Flat Forest (1999)	(9f) River Flat Forest (6d) Camden White Gum Forest	–	–
13. Western Sydney Dry Rainforest	Yes	Yes	Yes	–	–	–	–
14. Moist Shale Woodland	Yes	Yes	Yes	–	–	–	–
15. Turpentine–Ironbark Forest	Yes	Yes	Yes	Turpentine–Ironbark Forest (1998)	(9o) Turpentine–Ironbark Forest	–	–
152. Blue Gum High Forest	Yes	Yes	Yes	Blue Gum High Forest (1997)	–	–	–
103. Shale/Gravel Transition Forest	Yes	Yes	Yes	–	(9e) Shale/Gravel Transition Forest	–	–
31. Sandstone Ridgetop Woodland	Yes	Yes	Yes	–	(10ar) Sydney Sandstone Ridgetop Woodland	Heath Woodland Ironstone Heath Ironstone Woodland Mallee Heath Sandstone Woodland	Woodland/Heath Complex
32. Upper Georges River Sandstone Woodland	Yes	Yes	Yes	–	–	–	Plateau Forest on Shale Plateau Forests (shale/sandstone transition)
33. Western Gully Forest	Yes	Yes	Yes	–	(10ag) Sydney Sandstone Gully Forest	Western Gully Forest	Gully Forest
34. Mangrove/Saltmarsh Complex	Yes	Yes	Yes	–	–	–	–
35. Riparian Scrub	Yes	Yes	Yes	–	–	Riparian Scrub	Riparian Scrub

This survey (1999)				TSC Act (determination date)	Benson (1992)	Keith (1994)	French et al. (in press)
MU and Classification	Samp. ¹	Map ²	Diag. ³				
36. Freshwater Wetlands	No	Yes	No	–	(28a) Freshwater Wetlands	–	–
43. Turpentine—Ironbark Margin Forest	Yes	Yes	Yes	Turpentine–Ironbark Forest (1998)	(9o) Turpentine–Ironbark Forest	–	
61. Eastern Gully Forest	No	Yes	Yes	–	–	Eastern Gully Forest	–
62. Woodland/Heath Complex (north east and central)	No	Yes	Yes	–	(10ar) Sydney Sandstone Ridgetop Woodland	–	Woodland/Heath Complex (north east and central)
63. Darkes Forest Shale Forest	No	Yes	Yes	O'Hares Creek Shale Forest (1998)	–	Shale Forest	–
64. Sedgeland	No	Yes	No	–	–	Banksia Thicket Sedgeland Heath Mosaic Ti-tree thicket	Sedgeland
65. Rock Pavement Heath	No	No	No	–	–	Rock Pavement Heath	–
66. Melaleuca Thicket	No	No	No	–	–	–	Melaleuca Thicket

1.Samp. indicates that community was sampled in this survey. 2.Map indicates that community was mapped in this survey. 3.Diag. indicates that diagnostic species for this community are listed in this report.

3.2.3 Species richness

A total of 1274 species (1051 native and 223 exotic) were recorded in 853 survey sites located on the Cumberland Plain and Woronora Plateau. In the current survey, 1086 species were recorded, of which 872 were native. The introduced flora is likely to be larger than the 214 species recorded in the sample sites because highly disturbed and weed-infested areas were avoided when selecting sites for survey. Of the 872 native species, 110 were restricted to sites located on sandstone soils. A total of 762 species were recorded in sample sites on the Cumberland Plain, which is approximately 95% of the estimated flora of 800 species (James *et al.* 1999). Half of the species recorded on the Cumberland Plain were recorded five times or less, with 23% of these species recorded in one sample only. Species richness varied considerably between communities (Table 14), from an average of 6.3 taxa per plot recorded for MU34 (Mangrove/Saltmarsh Complex) to 55.9 taxa per plot recorded on average in Sandstone Ridgetop Woodland. Species richness tended to increase along a continuum from the Cumberland Plain to the Sandstone Plateau in the east. Communities on shale-derived soils recorded fewer species per sample than those on sandstone-derived soils, while shale/sandstone transitional areas were intermediate in species richness. Species richness in communities on alluvial soils on the Cumberland Plain tended to be slightly lower than in the surrounding shale communities. Communities on Tertiary Alluvium were intermediate in species richness, with more species recorded on sandy soils than clay-loam soils.

The greatest number of species recorded in any community type was 359 in MU1, Shale/Sandstone Transition Forest (high sandstone influence). This community also contained a large number of species not recorded in other communities (24). An average (\pm sd) of 11 (\pm 8) unique species were recorded across all communities. Communities with very low numbers of unique species were Shale/Gravel Transition Forest (MU103), 1 species; Shale/Sandstone Transition Forest (High Rainfall) (MU43), 3 species; and Moist Shale Woodland (MU14), 4 species. The number of taxa recorded in each assemblage is likely to be related to sampling intensity. For example, Agnes Banks Woodland (MU8) was sampled at only 2 sites, and only 52 species were recorded. The actual number of taxa represented in this community is likely to be considerably higher (refer Benson 1992).

Table 14 Species richness of vegetation communities based on replicate samples of 0.04 ha area

Community	No. of taxa (total/unique ¹)	No. of taxa/plot (sd)	No. of samples
1. Shale/Sandstone Transition Forest (low sandstone influence)	265/9	41.3 (8.7)	40
2. Shale/Sandstone Transition Forest (high sandstone influence)	359/24	50.1 (+8.4)	59
3. Castlereagh Ironbark Forest	230/6	41.9 (+6.2)	23
4. Castlereagh Swamp Woodland	142/10	43.9 (+7.9)	7
5. Riparian Woodland	41/12	24.0 (+1.4)	2
6. Castlereagh Scribbly Gum Woodland	201/15	47.9 (8.0)	20
8. Agnes Banks Woodland	52/5	33.0 (+4.2)	2
9. Shale Hills Woodland	258/13	36.9 (7.2)	61
10. Shale Plains Woodland	277/10	43.8 (9.4)	72
11. Alluvial Woodland	255/11	37.1 (11.4)	37
12. Riparian Forest	112/5	28.7 (9.4)	9
13. Western Sydney Dry Rainforest	149/18	44.7 (9.5)	9
14. Moist Shale Woodland	117/4	36.3 (8.1)	9
15. Turpentine–Ironbark Forest	130/6	45.3 (7.3)	6
31. Sandstone Ridgetop Woodland	252/15	55.9 (6.7)	23
32. Upper Georges River Sandstone Woodland	269/5	53.8 (7.5)	45
33. Western Gully Forest	269/17	53.9 (9.6)	36
34. Mangrove/Saltmarsh Complex	15/8	6.3 (7.5)	3
35. Riparian Scrub	220/39	40.3 (12.0)	14
43. Shale/Sandstone Transition Forest (High Rainfall)	261/3	51.0 (6.7)	11
61. Eastern Gully Forest	337/21	52.2 (12.6)	51
62. Woodland/Heath Complex (north-east and central)	155/6	45.6 (9.5)	16
63. Darkes Forest Shale Forest	141/14	40.5 (6.2)	10
103. Shale/Gravel Transition Forest	216/1	45.1 (7.1)	25
152. Blue Gum High Forest	132/15	44.1 (8.6)	7

1. Unique species were those recorded in only one assemblage.

3.2.4 Correlation with environmental variables (spatial data)

Reducing the ratio/ordinal cut values from 0.9 to 0.2 resulted in a marked improvement in stress for ordination solutions in both five and six dimensions. No further improvement in stress resulted when the cut was reduced from 0.2 to 0.0, thus both solutions were equally acceptable. The six dimensional solution calculated with a ratio/ordinal cut of 0.0 was used for correlation with environmental variables.

Variables likely to influence floristic composition at a local scale were most strongly correlated with floristic patterns amongst sites on the Cumberland Plain (Table 15). These include ruggedness (all five neighbourhood types), slope and solar radiation, which are also expected to correlate strongly with each other given the influence of topography on exposure to solar radiation. Variables such as maximum temperature (January) and annual rainfall, which represent patterns in floristic composition at a regional scale, were also strongly correlated. Elevation was strongly correlated in the ordination space, but topographic position and terrain (all five neighbourhood types), which describe the relative position on localised elevation gradients, were less strongly correlated. This suggests that variation in elevation correlates most strongly with floristic patterns at a regional scale. Despite the strong correlation with solar radiation, aspect was not correlated in the ordination space. However, large discrepancies were observed between aspect measured in the field and aspect derived from the digital elevation model, which suggests that the elevation model may be insensitive to variation in aspect at a fine scale.

Floristic patterns on the Woronora Plateau were most highly correlated with regional gradients in rainfall and temperature, as well as with a suite of variables defining topographic variation at a local scale (Table 15). In contrast to the Cumberland Plain, terrain was highly correlated over neighbourhood windows of 900, 700 and 500 m, which suggests that the relative position of a site on an elevation gradient is an important determinant of species composition. Furthermore, the relatively poor correlation for topographic position shows that the magnitude of the elevation gradient is important, a result that is reinforced by the strong correlation of slope in the ordination space.

Table 15 Ranked correlation of variables using an ordination space of six dimensions

Cumberland Plain			Woronora Plateau		
Variable	Correlation	Scale of influence	Variable	Correlation	Scale of influence
Ruggedness (700 m)	0.708	Local	Annual rainfall	0.773	Regional
Ruggedness (500 m)	0.701	Local	Max. temp. (°C, Jan)	0.744	Regional
Ruggedness (900 m)	0.699	Local	Ruggedness (900 m)	0.652	Local
Ruggedness (300 m)	0.665	Local	Ruggedness (700 m)	0.646	Local
Ruggedness (100 m)	0.651	Local	Ruggedness (300 m)	0.644	Local
Slope	0.635	Local	Ruggedness (500 m)	0.636	Local
Elevation	0.619	Regional (Local?)	Ruggedness (100 m)	0.603	Local
Solar radiation (Jan)	0.580	Local	Solar radiation (Jan)	0.603	Local

Cumberland Plain		
Variable	Correlation	Scale of influence
Max. temp. (°C, Jan)	0.527	Regional
Annual rainfall	0.518	Regional
Distance to sandstone	0.516	Local (Regional?)
Wetness	0.469	Local
Min. temp. (°C, July)	0.421	Regional
Distance to stream	0.401	Local
Topographic position	0.380	Local
Terrain (900 m)	0.355	Local
Terrain (700 m)	0.351	Local
Terrain (500 m)	0.342	Local
Solar radiation (July)	0.329	Local
Terrain (300 m)	0.306	Local
Distance to coast	0.260	Regional
Aspect	0.167	Local
Terrain (100 m)	0.150	Local

Woronora Plateau		
Variable	Correlation	Scale of influence
Slope	0.589	Local
Terrain (900 m)	0.580	Local
Terrain (700 m)	0.570	Local
Elevation	0.558	Regional (Local?)
Terrain (500 m)	0.550	Local
Distance to sandstone	0.526	Local (Regional?)
Distance to stream	0.504	Local
Distance to coast	0.499	Regional
Terrain (300 m)	0.474	Local
Wetness	0.442	Local
Min. temp. (°C, July)	0.435	Regional
Topographic position	0.278	Local
Solar radiation (July)	0.251	Local
Terrain (100 m)	0.202	Local
Aspect	0.185	Local

3.2.5 Modelling of community distributions and mapping extant vegetation

A total of 145 decision rules were applied to 22 variables to produce a pre-1750 map of the distribution of vegetation communities on the Cumberland Plain and Woronora Plateau (Figure 3). The most frequently used variables in the rule set were slope, soil landscape, elevation and rainfall (Table 16).

The primary node of the tree split samples into six geological classes: Wianamatta Shale, Holocene Alluvium, Tertiary Alluvium, Estuarine Sediments, Aeolian Deposits and Hawkesbury Sandstone combined with Mittagong Formation. Higher order splits within shale sites were predominantly based on rainfall, distance to sandstone and elevation, with soil landscape, slope and solar radiation (January) used frequently in lower order splits. Distance to streams was frequently used to expand the distribution of riparian communities beyond the boundaries of alluvium as mapped at 1:100 000 scale.

Communities on Tertiary Alluvium were split using a combination of distance to shale, elevation and ruggedness in a 700 m or 900 m locality. MU3 (Castlereagh Ironbark Forest) and MU6 (Castlereagh Scribbly Gum Woodland) in the elevation range 34 to 44 m could not be differentiated based on any of these variables. MU6 was accepted as the majority class and was hand edited to include an area of MU3 within Castlereagh Nature Reserve, using Benson's (1992) vegetation map. Rainfall and

terrain (900 m) were used extensively in higher order decision rules to differentiate communities on sandstone soils. Frequently used variables in lower order rules included distance to shale, parent geology and soil landscape. The final rule set was a product of 10 iterations, with earlier versions exploring alternative tree structures and later versions refining the split points within the chosen structure.

Modifications to successive rule sets were prompted by discrepancies in the distribution of sample sites compared to the modelled distribution of communities.

Four communities were difficult to model and were therefore not represented in the decision tree. Melaleuca Thicket, Rock Pavement Heath, and Riparian Woodland were represented by too few samples for modelling and none are represented in the distribution map. It can safely be assumed however that Riparian Woodland occurs along at least high-order streams. In addition, no variables were found to reliably isolate occurrences of MU4 (Castlereagh Swamp Woodland). Aerial photography was used to map the distribution of this MU in areas with soils derived from Tertiary Alluvium. The presence of dense melaleuca sp. understorey was used as a diagnostic feature in the photographs. The extent of Freshwater Wetlands (MU36) was represented by the mapped occurrence of the Bakers Lagoon soil landscape (Banneman & Hazelton 1990), which was consistent with the interpretation of Benson (1992). Additional wetlands were added using API. The distribution of Castlereagh Ironbark Forest in the vicinity of Bankstown was modelled on the extent of the Villawood Soil Association mapped by Walker (1960).

Table 16 Number of times variables were used in a total set of 94 decision rules

Variable	No. of occurrences	Variable	No. of occurrences
Slope	14	Distance to Tertiary Alluvium	1
Soil landscape	14	Ruggedness (100 m)	1
Annual rainfall	13	Ruggedness (300 m)	1
Elevation	13	Ruggedness (700 m)	1
Terrain (900 m)	12	Solar radiation (July)	1
Northing	11	Topographic position	1
Distance to stream (any order)	9	Aspect	0
Distance to stream (order 4, 5 or 6)	9	Distance to coast	0
Geology	9	Min. temp. (°C, July)	0
Distance to sandstone (2)	6	Ruggedness (500 m)	0
Distance to shale	6	Terrain (100 m)	0
Max. temp. (°C, Jan)	6	Terrain (300 m)	0
Easting	6	Terrain (500 m)	0
Solar radiation (Jan)	5	Terrain (700 m)	0
Distance to sandstone (1)	4	Wetness	0
Ruggedness (900 m)	2		

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FIGURE 3**

Figure 3 Pre-1750 modelled vegetation for the Georges River catchment

3.2.6 Distribution and extent of depletion

The original extent of native vegetation and the extent of depletion up to November 1997 are shown in Table 17. The area of communities on the Woronora Plateau has not been calculated since only a small proportion of the distribution of these communities was represented in this survey (see Figures 3 and 4).

3.2.7 Comments on methodology

i) Uncertainties in modelling vegetation communities

The number of sample sites representing each MU may be used as a coarse index of how reliably present and pre-1750 distributions have been estimated. The distribution of communities modelled on relatively few sample sites is likely to be less accurate than those modelled using large numbers of samples. For example, the distributions of Western Sydney Dry Rainforest (MU13) and Moist Shale Woodland (MU14) were modelled using only nine sample sites each. Although the decision tree analysis was successful in identifying environmental features which separated these communities from other communities (and each other), further field sampling is required to assess the accuracy of the model's prediction. It was more difficult to identify environmental features that separated Castlereagh Ironbark Forest (MU3) and Shale/Gravel Transition Forest (MU103), and areas mapped as MU3 may occasionally be more accurately assigned to MU103 and vice versa. A large proportion of the pre-1750 distribution of MU3 (69%) is based on the distribution of the Villawood Soil Series in the Auburn area (Walker 1960). This MU has not previously been mapped so extensively in this area and further sampling to confirm the association between MU3 and this soil series is not possible due to the lack of surviving native vegetation. The correlation between the distribution of this MU and particular features represented by the Villawood Soil Series (lateritic gravel) is plausible, however the Villawood Soil Series has not been represented in subsequent publications (Bannerman & Hazelton 1990) and it is possible that the distribution of laterite is somewhat variable. Therefore, the distribution of MU3 may be overestimated in this area, at the expense of Shale/Gravel Transition Forest (MU103), Shale Plains Woodland (MU10) or Turpentine–Ironbark Forest (MU15). Agnes Banks Forest (MU8) was modelled using only two sample sites, however this community is restricted to a particular geological substrate and may be considered to be modelled with reasonable accuracy.

ii) Use of diagnostic species

A list of diagnostic species has been provided for each community to assist in differentiating communities in the field. Species are classified into one of four categories that characterise the frequency with which they are recorded in a target community relative to other communities. Positive diagnostic species are more likely to be recorded in the target community than in other communities, although they may not always be present in high abundance. In particular, where the transition from one community to another is gradual, the abundance of diagnostic species may decline steadily across the transition. Occasionally, positive diagnostic species record high cover/abundance scores in non-target communities. This can occur because tree species tend to record high cover/abundance scores when present in a survey quadrat, even if that species is relatively uncommon throughout the community. Negative diagnostic species are less likely to be recorded in the target community than in other communities, although similar anomalies can be expected. Species that are frequently recorded in the target community, but are also common in other communities are less useful in differentiating communities. Such species have been classified as constant in the list of diagnostic species. Species recorded with low frequency across all communities are uninformative. These species have been omitted from the lists, with the exception of tree species, which were included to show the range of variation in overstorey species that may be expected in the field.

The reliability with which a particular stand can be classified will increase with the number of diagnostic species recorded, however it is emphasised that the probability of encountering a species is a function of its abundance and the area sampled. Diagnostic species have been identified on the basis of frequency of occurrence estimated using replicate quadrats 0.04 ha in area. The probability of encountering species present at low abundance is likely to increase with increasing area sampled, which could result in misleading results. Where possible, observations of structural and habitat characteristics can provide further evidence of the identity of the community. Nevertheless, sampling conducted in this survey is unlikely to have represented the full range of environmental variables influencing the composition of floristic communities. Inevitably stands of vegetation will be identified which can not be reliably ascribed to communities described in this report.

Table 17 Vegetation communities in the Georges River catchment in 1997 compared to their pre-1750 extent and areas protected within the existing reserve system (NPWS and SCA lands)¹

MU and classification	Area (ha)		% Extant 1997	Protected lands		
	Extant ² 1997	Modelled pre-1750		Area (ha)	% of Extant	% of pre-1750
1. Shale/Sandstone Transition Forest (low sandstone influence)	182.9	1595.3	11.5	0.0	0.0	0.0
2. Shale/Sandstone Transition Forest (high sandstone influence)	544.5	2267.1	24.0	0.0	0.0	0.0
3. Castlereagh Ironbark Forest (incl. 3a)	129.8	5915.1	2.2	0.0	0.0	0.0
3a. Cooks River Clay Plain Scrub Forest	21.1	–	–	0.0	0.0	–
4. Castlereagh Swamp Woodland	32.7	–	–	0.0	0.0	–
6. Castlereagh Scribbly Gum Woodland	213.7	–	–	0.0	0.0	–
8. Agnes Banks Woodland	8.0	375.0	2.1	0.0	0.0	0.0
9. Shale Hills Woodland	538.4	6853.4	7.9	23.3	4.3	0.3
10. Shale Plains Woodland	878.9	15 651.5	5.6	20.8	2.4	0.1
11. Alluvial Woodland	461.0	5080.0	9.1	0.0	0.0	0.0
12. Riparian Forest	93.5	453.1	20.6	0.0	0.0	0.0
13. Western Sydney Dry Rainforest	2.1	48.4	4.3	2.1	99.9	4.3
14. Moist Shale Woodland	43.9	126.0	34.8	27.5	62.5	21.8
15. Turpentine–Ironbark Forest	1.2	928.9	0.1	0.0	0.0	0.0
31. Sandstone Ridgetop Woodland	15 633.6	20 537.3	76.1	4111.2	26.3	20.0
32. Upper Georges River Sandstone Woodland	5152.5	6250.3	82.4	80.4	1.6	1.3
33. Western Gully Forest	7252.9	8565.3	84.7	538.6	7.4	6.3
34. Mangrove/Saltmarsh Complex	322.5	492.1	65.5	90.2	28.0	18.3
35. Riparian Scrub	791.4	1111.9	71.2	171.6	21.7	15.4
36. Freshwater Wetlands	18.2	17.1	106.4	6.3	34.8	37.1
43. Turpentine–Ironbark Margin Forest	257.4	1230.2	20.9	5.5	2.1	0.4
61. Eastern Gully Forest	10 004.7	11 445.8	87.4	2857.4	28.6	25.0
62. Woodland/Heath Complex (northeast and central)	1957.9	2821.3	69.4	5.0	0.3	0.2
63. O'Hares Creek Shale Forest	156.2	158.8	98.3	12.5	8.0	7.9
64. Sedgeland	1612.5	–	–	829.2	51.4	–
67. Vegetation of Volcanic Substrates	0.0	16.2	0.0	0.0	–	0.0

MU and classification	Area (ha)		% Extant 1997	Protected lands		
	Extant ² 1997	Modelled pre-1750		Area (ha)	% of Extant	% of pre-1750
103. Shale/Gravel Transition Forest	484.0	481.4	100.5	0.0	0.0	0.0
152. Blue Gum High Forest	9.3	30.8	30.2	0.0	0.0	0.0
9999.Unclassified Vegetation	189.7	–	–	7.4	3.9	–
Total	10 532.9	41 720.4	1015.2	1820.4	383.2	158.4

1. See Figures 3 and 4. 2. Area extant is for vegetation classes A, B, C and S only. – indicates communities for which a comparison with the pre-1750 native vegetation model was not possible.

iii) Limitations of the mapping

Figure 4 illustrates the predicted distribution of vegetation communities in the Georges River catchment in 1997. This map should be interpreted with regard to the limitations inherent in the methods used in its compilation:

- The representation of discrete patches of each vegetation community belies the fact that floristic composition varies continuously across the landscape. Although some community boundaries are distinct, a gradual transition between communities is more often apparent.
- Modelling community distributions is subject to limitations imposed by a highly fragmented native vegetation coverage.
- Large areas of the Cumberland Plain are completely free of native vegetation and were not sampled. The extent to which relationships between floristic patterns and environmental variables used in the modelling process are representative of such areas is unknown.
- In cases where additional information was available to support the mapping of vegetation remnants as Map Units other than those assigned by the model, the pre-1750 distribution for those Map Units was not corrected. However, discrepancies in the area calculated for each MU are likely to be small. Further work is planned to examine this question.

Further inaccuracies relate to limitations of the spatial data layers used. For example, each soil landscape coverage was produced for use at a scale of 1:100 000 and is inadequate for application at much finer scales. The use of aerial photograph interpretation enabled these inaccuracies to be overcome to some extent. Nevertheless, the estimation of overstorey composition from photographs is also subject to limitations, as described in a separate report (Roberts 1999). In addition, many communities are not reliably discriminated by the composition of the overstorey. For some areas of scattered tree cover (Polygon classes Tx, Txu and Txr), the composition of the overstorey was not estimated. Whilst the condition of these polygons is unknown, the understorey is generally expected to be moderately to highly degraded. In such cases, the application of a vegetation community classification reflects the presumed status prior to disturbance.

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Figure 4

Extant vegetation of the Georges River catchment

3.3 Species diversity—fauna

During the 1998–1999 fauna survey season 308 sites were surveyed. The sites were selected to adequately sample the range of environmental variables and vegetation remnants within the Georges River catchment.

As a result of this study an additional 3971 fauna records were added to the survey database through the field studies, producing a final total 10 686 individual records for the Georges River catchment. Appendix D provides lists of fauna for each of the fourteen councils of the catchment, based on the records of the NSW Atlas of Wildlife. These lists present typical fauna lists only, and it is noted that the records in some LGAs are extremely limited, and probably reflect fewer reports in those areas rather than fewer occurrences of the species on the list. Each council should carefully consider the entire species list for the Georges River catchment, and pay specific attention to any species that occur in adjacent LGAs.

3.3.1 Guide to interpreting fauna habitat models

Species habitat models are a means to describe a relationship between patterns in the location of species and local and regional environmental data. If strong relationships exist between the location of a species and a single or combined data layer then the reliability of the model will be greater. As a coarse guide to the fit of the model, the pattern of existing locations displayed on the derived model will indicate the degree of accuracy. In some cases the habitat model has been further refined to highlight areas of high-quality habitat. Some records of species will exist outside of areas considered to be high-quality habitat. This should be expected because the strength of the relationship between the location of the species and the environmental data is rarely perfect, and so extrapolations (maps) based from derived models will reflect such inaccuracies. Such problems are also apparent with expert and qualitative models.

Table 18 lists the selected fauna species and refers to the types of model that have been developed to describe and map their habitats. The maps produced illustrate the potential distribution of habitat of each species, not whether the species occupies the mapped habitat at any given point in time.

For ease of reference, Table 5 lists the codes that were used in the API process described in Section 2.2.2. These codes are referred to in some of the fauna models.

Each model has been developed based on presence/absence records for each species, and on the distribution of key habitat requirements in the Georges River catchment. Potential habitat for each species is then further classified according to the suitability of that area based on the quality of that habitat. These classifications are listed in Table 19. The only species for which these classifications have not been used is the Koala, for which more detailed habitat classifications are used (See Section 3.3.2—Koala).

Table 18 Modelling for selected fauna species for the Georges River catchment

Group	No. ¹	Common name	Scientific name	Model	
				Type	Figure
Amphibians	i	Giant Burrowing Frog	<i>Heleioporus australiacus</i>	expert	5
	ii	Red-crowned Toadlet	<i>Pseudophryne australis</i>	expert	6
	iii	Brown Toadlet	<i>Pseudophryne bibronii</i>	no	–
	iv	Green and Golden Bell Frog	<i>Litoria aurea</i>	no	–
	v	Green Tree Frog	<i>Litoria caerulea</i>	no	–
Reptiles	vi	Heath Monitor	<i>Varanus rosenbergi</i>	no	–
	vii	Broad-headed Snake	<i>Hoplocephalus bungaroides</i>	GAM-expert	7
Birds	viii	Bush-stone Curlew	<i>Burhinus grallarius</i>	expert	8
	ix	Glossy Black-Cockatoo	<i>Calyptorhynchus lathami</i>	no	–
	x	Swift Parrot	<i>Lathamus discolor</i>	no	–
	xi	Turquoise Parrot	<i>Neophema pulchella</i>	no	–
	xii	Barn Owl	<i>Tyto alba</i>	expert	9
	xiii	Powerful Owl	<i>Ninox strenua</i>	expert	10
	xiv	Rock Warbler	<i>Origma solitaria</i>	expert	11
	xv	Brown Treecreeper	<i>Climacteris picumnus</i>	no	–
	xvi	Regent Honeyeater	<i>Xanthomyza phrygia</i>	expert	13
Mammals	xvii	Koala	<i>Phascolarctos cinereus</i>	GLM-expert	14
	xviii	Squirrel Glider	<i>Petaurus norfolcensis</i>	no	–
	xix	Eastern Horseshoe-bat	<i>Rhinolophus megaphyllus</i>	GAM	15
	xx	Eastern Freetail-bat	<i>Mormopterus norfolkensis</i>	expert	16
	xxi	undescribed Freetail-bat	<i>Mormopterus species 1</i>	expert	17
	xxii	Common Bentwing-bat	<i>Miniopterus schreibersii</i>	no	–
	xxiii	Eastern False Pipistrelle	<i>Falsistrellus tasmaniensis</i>	expert	18
	xxiv	Large-footed Myotis	<i>Myotis adversus</i>	GLM	20

1. These numbers will be used in reference to the associated species throughout this report.

The modelling process has recognisable limitations, nevertheless they do form an important layer of information for NSW, regional and local planning and decision-making processes, and also for informing recovery planning processes for these species.

Table 19 Categories of potential habitat used in developing habitat models for selected fauna species¹

Habitat category	Description ²
Potential habitat	Identified habitat that shows relatively little disturbance compared to other vegetated areas. These areas have been selected from the API Classes A, C and S.
Disturbed potential habitat	Identified habitat that has experienced a higher level of disturbance and has been classified as B by API.
Severely disturbed potential habitat	Identified habitat that has been subject to severe disturbance and has been classified as Tx, Txu or Txr by API.

1. Except for the Koala (see Section 3.2.2—Koala)

2. See Table 5 for API codes

It is envisaged that the robustness of these models will be tested by future more detailed surveys at the local and site levels. As comprehensive model validation was beyond the scope of this project, review of the habitat maps was made against expert knowledge of species habitat requirements. Where statistical models were used, the pre-1750 distribution of environmental variables was used in relation to the presence of species records.

3.3.2 Habitat models—selected fauna species

Table 20 Information for habitat modelling for the Giant Burrowing Frog (*Heleioporus australiacus*) (Shaw & Nodder 1795)

Ecology	Both sexes burrow into sandy soil to wait out non-breeding periods (winter–spring) before moving into pools in the upper reaches of 1st and 2nd order streams during breeding periods (summer–autumn). Once a male establishes a breeding site (apparently in burrows in the banks of small creeks) it calls in order to attract females.
Distribution in the GRC	This large species of frog is largely restricted to watercourses of the Woronora Plateau, where there have been several records of the species, most of which are records of tadpoles indicating the presence of breeding populations. Potential habitat for this species in the Georges River catchment is restricted to the ridges and upper valleys of the Woronora Plateau, much of which is already within the reserve system. There are also areas of habitat in the relatively inaccessible Holsworthy Military Area.
Adjacent to the GRC	The species is known from a number of records: <ul style="list-style-type: none"> • Royal National Park • further south in the Metropolitan Water catchments.
Model for the GRC	Despite the number of known locations for this species a robust statistical model is not available. Consequently an expert model (Figure 5) was derived incorporating those areas deemed not to be deep gullies but confined to sandstone geologies. It should be noted that this model overestimates the amount of potential habitat as the GIS data is not sensitive enough to distinguish subtle topographical variations.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • increasing the conservation status of the remaining areas of the Woronora Plateau • establishing development controls that limit habitat loss and impacts on water quality on the Woronora Plateau.

Table 21 Information for habitat modelling for the Red-crowned Toadlet (*Pseudophryne australis*) (Gray 1835)

Ecology	This small species of frog typically inhabits depressions and creeklines at the heads of sandstone gullies, and can generally be found below the first bench on 2nd and 3rd order streams. Leaf litter and small rocks are important microhabitat.
Distribution in the GRC	Given its preference for the sandstone areas of the Woronora Plateau much of its habitat is still in a natural state. It is known from numerous records within the Georges River catchment.
Adjacent to the GRC	It is known from numerous records in Royal National Park.
Model for the GRC	The statistical models were found to be insensitive to subtle habitat variations and were overpredicting the likely extent of the species. An expert model (Figure 6) has been developed to describe the habitat of this species by combining wetness and slope indices and confining the likely distribution to sandstone geologies.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • increasing the conservation status of the remaining areas of the Woronora Plateau • development controls that limit habitat loss and impacts on water quality on the Woronora Plateau.

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FIGURE 5**

Figure 5

Predicted habitat map for the Giant Burrowing Frog

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Figure 6

Predicted habitat map for the Red-crowned Toadlet

Table 22 Information for habitat modelling for the Brown Toadlet (*Pseudophryne bibronii*) (Gunther 1858)

Ecology	This small frog lives in moist and boggy areas under forest or woodland canopies both on the coast and in the mountains. It occurs on a variety of substrates including shale and sandstone but prefers areas that generally are not too steep.
Distribution in the GRC	In the Georges River catchment a few small populations are known, including populations at: <ul style="list-style-type: none"> • Fairfield Farm • Prospect Reservoir. There is also a potential recording along Peter Meadows Creek in the Campbelltown LGA.
Adjacent to the GRC	Whilst being abundant in some areas of its distribution, this species is under extreme threat in the Sydney area.
Model for the GRC	The lack of records and information relating to habitat requirements for this species in the Georges River catchment prevented the derivation of either statistical or expert models.
Conservation strategies	Appropriate conservation strategies are difficult to define for this species due to the variability of its habitat and general lack of knowledge about its ecology. However, broad strategies for the conservation of this species in areas where they are known to occur in the Georges River catchment might include: <ul style="list-style-type: none"> • maintaining the shrub understorey and leaf-litter • managing weeds • encouraging a natural forest structure to develop.

Table 23 Information for habitat modelling for the Green and Golden Bell Frog (*Litoria aurea*)

Ecology	<p>This species formerly occupied ephemeral areas such as the overflow areas of major rivers, but throughout its range it now occurs only in marginal habitat areas.</p> <p>Despite being the most prolific breeder amongst Australian frogs; this species has experienced an alarming decrease in numbers in recent years, largely due to:</p> <ul style="list-style-type: none"> • predation by Mosquito Fish (<i>Gambusia holbrooki</i>) and the Black Rat (<i>Rattus rattus</i>) • loss of remaining (including artificial) habitat areas • infection by the chytrid fungus.
Distribution in the GRC	<p>It has been recorded in several areas within the Georges River catchment in the past, most within close proximity to the Georges River itself. Populations are currently known at:</p> <ul style="list-style-type: none"> • Lt Cantello Reserve • Sandmine at Chipping Norton • East Hills Golf Course • Maddens Crossing • Old mine, Darkes Forest. <p>Populations were also previously known at the following sites, each of which now appears to have disappeared:</p> <ul style="list-style-type: none"> • Sandy Point • Williams Creek • Voyager Point.
Adjacent to the GRC	<p>Interestingly, this species appears to be confined to highly disturbed sites in the Sydney area, such as brick pits and golf courses.</p>
Model for the GRC	<p>No model is available for this species. However, apart from the previous and known populations identified above there are further sites that are suitable habitat areas, including:</p> <ul style="list-style-type: none"> • Moorebank brickworks • Deepwater Park • any golf course (particularly close to the Georges River).
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • protection of existing populations through cooperative area management agreements (as has been done elsewhere in Sydney) • funding for ongoing research to identify all current populations within the Georges River catchment • developing the significant potential for this flagship species to be readily conserved in urban backyards.

Table 24 Information for habitat modelling for the Green Tree Frog (*Litoria caerulea*) (White 1790)

Ecology	This forest dwelling species is often found in areas that experience periodic inundation, such as floodplains, however the species is known from a wide variety of habitats and is frequently found in human dwellings, lavatories, water tanks and troughs, windmills, downpipes etc.
Distribution in the GRC	In the Georges River catchment the species was recorded in a single significant population at the Moorebank brickworks, where six individuals were found on a single night.
Adjacent to the GRC	It has a wide national distribution, and in some areas it is abundant. However, it has experienced a significant decline in many coastal areas, particularly around Sydney.
Model for the GRC	The lack of records and information relating to this species' habitat preference in the Georges River catchment prevented the derivation of statistical and expert models. Further study of the alluvial woodlands, particularly those with a melaleuca spp. understorey within the Holsworthy Military Area, would paint a more precise picture of the habitat requirements of this species within the Georges River catchment.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • protecting existing communities through either formal reservation or voluntary conservation agreements • regenerating areas of Castlereagh Scrub with particular emphasis on the understorey.

Table 25 Information for habitat modelling for the Heath Monitor (*Varanus rosenbergi*) (Mertens 1957)

Ecology	This is a mostly terrestrial species which shelters in burrows (which it digs itself), hollow logs and rock crevices of coastal heath, humid woodlands, and both wet and dry sclerophyll forests.
Distribution in the GRC	Within the Georges River catchment the Heath Monitor is restricted to the heath and open forests of the Woronora Plateau. This species was not recorded during the course of surveys. However, several records for this species have been made available through the data review project. These records are dispersed across the Woronora Plateau.
Adjacent to the GRC	Potential habitat occurs to the east and south of the Georges River catchment, particularly along the Illawarra Escarpment.
Model for the GRC	The lack of records and appropriate GIS layers prevented the development of an accurate habitat model for this species.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • protecting remaining unprotected areas of the Woronora Plateau.

Table 26 Information for habitat modelling for the Broad-headed Snake (*Hoplocephalus bungaroides*) (Schlegel 1837)

Ecology	<p>This species spends the winter months on the edges of sandstone scarps sheltered beneath exfoliating sandstone. In the hotter summer months it moves into the valleys where it shelters within tree hollows. It is an aggressive, nocturnal snake largely confined to the Hawkesbury sandstone formation.</p> <p>It has experienced a major decline due to the combined impact of:</p> <ul style="list-style-type: none"> • destruction of habitat through urban development • accidental killings due to fear of snakes • removal of bushrock • removal by snake collectors.
Distribution in the GRC	<p>It is confined to the dissected sandstone areas of the Woronora Plateau, and is known from several records in the Georges River catchment, both current and historic.</p>
Adjacent to the GRC	<p>The Broad-headed Snake is considered threatened both within New South Wales and at the national level, as shown by the species being listed as threatened under the relevant legislation for each jurisdiction. The species distribution is largely restricted to the sandstone geologies of the Sydney Basin. Habitat modelling undertaken by the NPWS for the Sydney Basin indicates that the Woronora Plateau, the Illawarra Escarpment and plateaux of the Metropolitan Water Catchments contain a significant portion of the predicted high-quality habitat for this species.</p>
Model for the GRC	<p>A generalised additive model (GAM) was confined to sandstone geologies (Figure 7) This model was produced across the entire species range as part of the Broad-headed Snake Recovery Plan. The model was then clipped to the catchment boundary. Consistent with the known ecology of this species, the model identified the scarps and upper valleys of the Woronora Plateau as areas of significant potential habitat.</p> <p>Note that the model appears to have overpredicted slightly into the sedgeland and upland swamps within Dharawal State Recreation Area.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • protecting remaining unprotected areas of the Woronora Plateau • preventing habitat destruction through bushrock collection • preventing removal by snake collectors.

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Figure 7

Predicted habitat map for the Broad-headed Snake

Table 27 Information for habitat modelling for the Bush-stone Curlew (*Burhinus grallarius*)

Ecology	<p>This large ground-dwelling insectivore is usually associated with Woodland habitats, and like most predators requires a large foraging area, which is manifest in the large home ranges these birds usually have.</p> <p>The requirement for large home ranges and the likelihood that the prey of this species would benefit from older vegetation containing hollows mean that this species is particularly vulnerable to the impacts of habitat fragmentation and understorey degradation.</p>
Distribution in the GRC	<p>The relatively small and immature remnants in the Georges River catchment offer only limited habitat potential for this species. Not surprisingly therefore there are only three known records of this species in the catchment:</p> <ul style="list-style-type: none"> • two in the western section of the Georges River catchment in the Liverpool LGA • a single record from the St Helens Park area.
Adjacent to the GRC	<p>There are few current records of this species in the Sydney region.</p>
Model for the GRC	<p>The model (Figure 8) was derived using expert knowledge of the species habitat requirements. Consistent with known habitat requirements and records of this species, potential habitat in the Georges River catchment includes those areas mapped as:</p> <ul style="list-style-type: none"> • Cumberland Plains Woodland • Hills Woodland. <p>As a result all habitat is confined to the Cumberland Plain, much of which is fragmented and highly disturbed.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • regeneratiin areas identified as corridors, consolidating small fragments into larger contiguous remnants • using artificial nesting hollows while natural areas are regenerating.

Table 28 Information for habitat modelling for the Glossy Black-Cockatoo (*Calyptorhynchus latham*)

Ecology	<p>This species has a well-understood foraging association with <i>Allocasuarina litoralis</i> and <i>A. torulosa</i>. It is most commonly sighted in forests that support these species, which generally occur on alluvial soils.</p>
Distribution in the GRC	<p>Whilst not recorded during the course of this survey, this species has been recorded in the area previously. Riparian forests of <i>Allocasuarina</i> spp. most often occur in the middle reaches of a river system and on flood plains. In the Georges River catchment these areas have been largely cleared.</p>
Adjacent to the GRC	<p>There are records of this species throughout the Sydney region, however these records are scattered and decreasingly common.</p>
Model for the GRC	<p><i>Allocasuarina</i> has not been mapped within the Georges River catchment, consequently an expert model with the required level of reliability could not be produced. The small number of records of this species and the course-scale of vegetation mapping prevented a statistical model from being produced. Currently there is very little <i>Allocasuarina</i> forest within the catchment, the last fragments being along the banks of the Georges River itself.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • regenerating riparian areas and other alluvial areas with appropriate species of <i>Allocasuarina</i>.

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Figure 8

Predicted habitat map for the Bush-stone Curlew

Table 29 Information for habitat modelling for the Swift Parrot (*Lathamus discolor*)

Ecology	This species migrates north from Tasmania during the winter months and is a nomadic visitor to the sclerophyll forests and woodlands of the south-east mainland, the pattern of migration following the blossom of trees between March and November.
Distribution in the GRC	It is known from several sightings across the Georges River catchment, all recorded during the winter months.
Adjacent to the GRC	Records of this species are decreasingly common throughout the Sydney region, however it was once a regular visitor to the region.
Model for the GRC	The lack of records and definitive habitat information prevented the production of any habitat models. The habitat preferences of this species in the Georges River catchment are largely unknown, although winter-flowering species including the Mugga Ironbark (<i>Eucalyptus sideroxylon</i>) would provide a valuable food source for this species.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • maintaining and, where possible, increasing winter-flowering eucalypts.

Table 30 Information for habitat modelling for the Turquoise Parrot (*Neophema pulchella*)

Ecology	This is a migratory species present in the Sydney region during the winter months and relies on winter-flowering eucalypts as a food source. It is known to prefer woodland remnants.
Distribution in the GRC	This species is known from five records within the Georges River catchment, the most recent being in 1991, all in close proximity to the Georges River itself.
Adjacent to the GRC	There are irregular and sporadic records in the Sydney region, however it is still known from recent records to use habitat within the region.
Model for the GRC	The small number of records and lack of definitive habitat information prevented the production of a habitat model for this species.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • maintaining and, where possible, increasing the number of winter-flowering eucalypts, such as <i>E. sideroxylon</i> • maintaining the Georges River riparian corridor.

Table 31 Information for habitat modelling for the Barn Owl (*Tyto alba*)

Ecology	This nocturnal predator occurs in woodland communities throughout mainland Australia, foraging primarily along the open fringes where the woodland gives way to adjacent grasslands or cleared land. As with other top predators this species requires a relatively large foraging area. Mature, hollow-bearing trees are used as nesting sites by this species and many of its prey species.
Distribution in the GRC	There are few records of this species in the Georges River catchment. The lack of sufficiently large areas in which to forage is likely to have largely driven this species out of the Georges River catchment.
Adjacent to the GRC	There are few records of this species in the broader region, which may also be attributed to the modified landscapes of the Cumberland Plain.
Model for the GRC	<p>The small number of records prevented the production of a statistical model for this species, however an expert model (Figure 9) was developed to define the vegetation communities considered to provide suitable habitat for this species. These included:</p> <ul style="list-style-type: none"> • Castlereagh Scribbly Gum Woodland • Agnes Banks Woodland • Shale Hills Woodland • Shale Plains Woodland. <p>As with many other species also confined to the Cumberland Plain the remaining habitat of the Barn Owl is highly disturbed and fragmented. Some larger remnants do exist, particularly:</p> <ul style="list-style-type: none"> • Prospect Reservoir • Fairfield Farm • Varroville area.
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • consolidating the smaller remnants into a larger linked habitat system • providing buffer areas of pasture surrounding habitat areas • maintaining mature and old-growth trees • providing appropriate fire management of open woodlands and fringe areas.

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FIGURE 9**

Figure 9

Predicted habitat map for the Barn Owl

Table 32 Information for habitat modelling for the Powerful Owl (*Ninox strenua*)

Ecology	This large nocturnal predator nests in large tree hollows in tall open forests, where it forages for small- to medium-sized arboreal and terrestrial mammals, including gliders, possums, rats and rabbits. It is an uncommon resident of sclerophyll forest in south-eastern Australia. It breeds during winter and incubates eggs for about 40 days.
Distribution in the GRC	Several records of this species exist from the deeper gullies of the upper Georges River catchment, including parts of the Woronora River that support tall open forest.
Adjacent to the GRC	There have been several records of this species in Royal National Park, all in gullies.
Model for the GRC	An expert model (Figure 10) identified potential habitat for this species as those vegetation types that correlate with Tall Open Forest in the Georges River catchment, including: <ul style="list-style-type: none"> • Alluvial Woodland • Upper Georges River Sandstone Woodland • Western Gully Forest • Eastern Gully Forest. <p>The predicted habitat correlates well with both the known habitat requirements and the known locations of this species. Much of the modelled habitat is within the confines of the Woronora Plateau and as a result is relatively undisturbed.</p>
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • increasing the conservation status of areas of potential habitat currently outside the reserve system.

Table 33 Information for habitat modelling for the Rock Warbler (*Origma solitaria*)

Ecology	This species occurs in areas dominated by rugged sandstone benches, often in steep, deeply dissected areas immediately adjacent to large watercourses. Unique amongst warblers for nesting in darkened positions.
Distribution in the GRC	Several individuals were recorded along the upper reaches of the Georges and Woronora Rivers. The bulk of the habitat for this species is within the protected areas of the Woronora Plateau, however much of its habitat has been lost to urban development, particularly lower in the Georges River catchment.
Adjacent to the GRC	It is thought to be largely confined to the Hawkesbury sandstone formation of the Sydney region, with some records in adjacent limestone areas. It is common in less disturbed parts of its range, including parts of the Blue Mountains.
Model for the GRC	A statistical model was not available for this species, however an expert model (Figure 11) was developed combining areas of sandstone displaying high ruggedness values. This is consistent with both the known habitat requirements of this species and the recorded locations.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • maintaining and in some areas enhancing of protection of the upper Georges River, Woronora River and tributaries.

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FIGURE 10**

Figure 10

Predicted habitat map for the Powerful Owl

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Figure 11

Predicted habitat map for the Rock Warbler

Table 34 Information for habitat modelling for the Brown Treecreeper (*Climacteris picumnus*)

Ecology	This species is known to prefer drier, tall woodlands. In the Georges River catchment the tree species that it would most likely be associated with are <i>Eucalyptus tereticornis</i> and <i>E. molucana</i> . Consequently, its main habitat is likely to be on the Cumberland Plain. Survey work suggests that this species prefers large areas of relatively undisturbed vegetation within close proximity to larger woodland remnants. It is often observed in groups of three.
Distribution in the GRC	During bird surveys the species was identified at only one site—St Helens Park—in tall open forest on the transition area between the Cumberland Plain and the Woronora Plateau. It was not recorded in any of the woodland remnants.
Adjacent to the GRC	Records of this species are known throughout the Cumberland Plain, however records have been decreasingly common over the past 50 years.
Model for the GRC	Due to the lack of records of this species a statistical model is not available. Uncertainty regarding the usage of tall open forest by this species prevented the development of an expert model.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • protecting remnant woodland • restoring links between remnants and the Woronora Plateau • protecting habitat in St Helens Park areas and encouraging fringing Cumberland Plains Woodland to spread.

Table 35 Information for habitat modelling for the Regent Honeyeater (*Xanthomyza phrygia*)

Ecology	Within the Georges River catchment the species has a definite preference for foraging in Mugga Ironbark (<i>Eucalyptus sideroxylon</i>), one of the major winter-flowering species in the area. They have also been observed foraging in suburban gardens (Dick Turner pers. comm).
Distribution in the GRC	<p>Whilst not being recorded during this study, the Regent Honeyeater is known from a number of records within the Georges River catchment, all in close proximity to the alluvial soils of the Georges River in the Liverpool and Bankstown LGAs.</p> <p>There are however some large relatively undisturbed areas remaining, including:</p> <ul style="list-style-type: none"> • Moorebank brickworks • Holsworthy Sewerage Treatment Plant • Holsworthy Military Area.
Adjacent to the GRC	It is known from a number of records immediately adjacent to the Georges River catchment.
Model for the GRC	<p>The small number of records within the Georges River catchment prevented the development of a statistical habitat model, therefore expert knowledge has been used to develop a model (Figure 12) for this species. Those communities most likely to constitute potential habitat for this species are those supporting <i>E. sideroxylon</i>. In the Georges River catchment potential habitat therefore is represented by:</p> <ul style="list-style-type: none"> • Castlereagh Ironbark Forest • Castlereagh Swamp Woodland • Castlereagh Woodland. <p>All recorded sightings of this species in the Georges River catchment are close to one or more of the remaining stands of these communities. The distribution of these communities in the Georges River catchment has been greatly reduced from pre-1970 distributions, most having been cleared. Remaining patches are usually small, isolated and disturbed fragments.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • maintaining remaining habitat of this species • linking fragments • encouraging residents to plant Mugga Ironbark and using it where appropriate for landscaping purposes. (Note that it is an excellent habitat tree for many species of bird and is also aesthetically appealing.)

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Figure 12 **Predicted habitat map for the Regent Honeyeater**

Table 36 Information for habitat modelling for the Koala (*Phascolarctos cinereus*) (Goldfluss 1917)

Ecology	This large arboreal mammal is an obligate-folivore (feeds only on foliage) that occurs in a range of habitats along the eastern seaboard of Australia. It has been closely linked to the presence of high-nutrient soils and specific eucalypt species, though other tree species are also known as both habitat and feed trees. Preferred habitat and feed trees vary between geographic areas.
Distribution in the GRC	<p>The Koala population of the Georges River catchment is one of the few populations surviving on the coast and ranges south of Sydney and is probably one of the larger populations. Estimates of the size of this population range between 90 and 200 individuals but it is thought this is an underestimate as the large area contained in the Holsworthy Army Firing Range has not been thoroughly surveyed (Ward 2001).</p> <p>Recent studies by Steven Ward (Ward 2001) and by Dr Rob Close (University of Western Sydney) have identified breeding colonies of Koalas in the Wedderburn and Kentlyn areas on the western side of the GRC. The studies showed that Koalas ranged widely throughout the Georges River catchment—including to Sandy and Alford's Points in the north, east to Heathcote and Royal National Parks and south to Douglas Park. Recent investigations have shown this population to be genetically distinct from Koalas in the nearby Avon River catchment to the south (Dr Rob Close pers.comm).</p> <p>In 1998 the Australian Koala Foundation published the Koala Habitat Atlas identifying areas of potential Koala habitat for the Campbelltown LGA. This species was recorded at two locations during the surveys:</p> <ul style="list-style-type: none"> • four individuals were sighted on the Wedderburn Plateau • a single individual was identified in the St Helens Park area. <p>The majority (449, 88%) of records of Koala sightings were provided by Steven Ward and Dr Rob Close, with an additional 61 (12%) records obtained from the Atlas of NSW Wildlife. This total of 510 records was then correlated with the vegetation communities in which they occurred in order to assist in deriving the expert-based model.</p>
Adjacent to the GRC	<p>Today in New South Wales the Koala occurs principally on the central and north coast ranges and adjacent slopes with a sparse and scattered distribution on the north-west plains and south coast (Reed <i>et al.</i> 1990). Small populations are also known from the Metropolitan Water Catchments, Morton NP and the far south coast forests in the Bega/Eden area.</p> <p>The species is likely to have once been more common across the Cumberland Plain. Gould (1863, in Reed <i>et al.</i> 1990) remarked that 'Although no where very abundant ... it is the brushes which skirt the sea side of the mountain ranges between the district of the Illawarra and the river Clarence that it is most numerous; here amongst the branches of the great trees, the Koala remains sleeping during the daytime'. Govatt (1836) remarked that Koalas were 'numerous on the ranges leading to the Cox's River, below the mountain precipices, and also in the ravines which open into the Hawkesbury River.' (in Reed <i>et al.</i> 1990).</p>
Model for the GRC	The expert model identifies Koala habitat as either high-quality or medium-quality, as set out below.

<p>High-quality habitat (Figure 13) has been defined as:</p>	
<p>Land vegetated with Upper Georges River Sandstone Woodland, Shale/Sandstone Transition Forest (both high and low sandstone influence) and Western Gully Forest, where this vegetation is of Condition Classes A, B or S</p>	<p>Based on existing Koala records, these three communities support the greatest densities of Koala records per unit area of that vegetation type (Appendix G). These communities occur on both shale and shale-influenced geologies. Favoured Koala feed trees for this region, <i>Eucalyptus punctata</i> (Grey Gum) and <i>E. agglomerata</i> (Blue-leaved Stringybark), occur in abundance in these communities, as well as less frequented trees, such as <i>E. pilularis</i>, <i>E. capitellata</i>, <i>E. piperita</i>, <i>E. sieberi</i> and <i>E. sclerophylla</i> (all favoured food trees in the Campbelltown area) (Phillips & Callaghan 2000). Shale-influenced vegetation in the GRC has been shown to support greater densities of Koalas and also higher numbers of breeding females (Ward 2001; Ward & Close in prep.). Where the above communities adjoin other vegetation communities such as Sandstone Ridgetop Woodland, Eastern Gully Forest or Woodland Heath Complex, then the latter communities are also included as High-quality Koala Habitat if they occur within 1 km of the three favoured communities indicated above.</p>
<p>Land vegetated with Sandstone Ridgetop Woodland, Woodland Heath Complex or Eastern Gully Forest, where this vegetation is of Condition Class A, B, or S and is adjacent to and within 1 km of land identified in (I) above.</p>	<p>Large contiguous areas of forest and woodland are very important for the survival of a wide-ranging species such as the Koala and while some communities contain more favoured feed trees it is the mosaic of largely undisturbed forest communities which is important for their survival. Ridgetops supporting Sandstone Ridgetop Woodland between gullies in the Wedderburn area also support a large number of Koala records and are undoubtedly contributing to Koala habitat, providing linking habitats and some less frequented feed tree species e.g. <i>E. capitellata</i> and <i>E. sieberi</i> (Phillips & Callaghan 2000). The extensive areas of Sandstone Ridgetop Woodland and Eastern Gully Forest in the Holsworthy Army Firing Range have not been thoroughly surveyed due to restricted access and so the true value of these habitat types to Koalas in the GRC is yet to be determined.</p>
<p>Medium-quality habitat (Figure 13) has been defined by two criteria:</p>	
<p>Land containing vegetation communities Eastern Gully Forest and Sandstone Ridgetop Woodland and of Condition Classes A, B or S where these lands are contiguous with vegetation of the Woronora Plateau.</p>	<p>The vegetation communities Eastern Gully Forest and Sandstone Ridgetop Woodland also support numbers of Koala records from areas which are accessible to the public, although not as abundantly as the vegetation communities listed as high-quality. These communities include low abundances of favoured Koala feed trees such as <i>E. punctata</i> and <i>E. agglomerata</i> as well as occurrences of less favoured but utilized species such as <i>E. pilularis</i>, <i>E. sclerophylla</i>, <i>E. piperita</i> and <i>E. sieberi</i> (NPWS 2001 Phillips & Callaghan 2000).</p> <p>As mentioned previously, large areas of these communities occur in the Holsworthy Army Firing</p>

		<p>Range and the restricted public access has meant a true assessment of the value of these habitats to Koalas has not been possible.</p> <p>Koalas have been recorded in these habitats around the perimeter of the Holsworthy Range at Wedderburn, Heathcote, Waterfall, Mill Creek and the Woronora Valley, and the movement of ear-tagged individuals across the Range from Wedderburn in the west to Heathcote and Waterfall in the east does indicate Koalas are using these areas (Close 1993).</p>
	<p>Areas of vegetation communities Upper Georges River Sandstone Woodland, Shale/Sandstone Transition Forest (High Sandstone) and Western Gully Forest that are of Condition Classes Tx, Txr and Txu and where this vegetation adjoins high-quality habitat.</p>	<p>These areas contain the vegetation communities containing the highest density of Koala records however in a deteriorated condition. Tx, Txr and Txu represent scattered trees in an area of greater than 0.5 ha and in a rural, rural residential and urban environment respectively. This habitat, while degraded, is utilised by Koalas as demonstrated by the records. Breeding females are known to regularly occupy some low-density urban areas (Dr Rob Close pers. comm.) While not as significant as the high-quality habitat, this disturbed habitat is considered important for the maintenance of the Georges River Koala population and warrants protection within a Biodiversity Support Area management class.</p>
<p>Conservation strategies</p>	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • increasing the area of high-quality Koala habitat within the reserve system • avoiding additional urban development in the Wedderburn area. Koalas are particularly susceptible to indirect urban impacts such as increased fire frequency, harassment by dogs, habitat fragmentation, road kill and stress-related diseases • maintaining natural fire management regimes and incorporating fire refuges and fire shadows in the landscape (D. Andrew pers. comm) • monitoring vegetation communities to ensure that fire management and other management practices are maintaining key processes and species • managing feral and domestic animals, and traffic impacts. 	

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Figure 13

Predicted habitat map for the Koala

Table 37 Information for habitat modelling for the Squirrel Glider (*Petaurus norfolcensis*) (Kerr 1792)

Ecology	This small arboreal mammal occupies a range of habitats throughout the temperate zones along the east coast of Australia, however it is considered to prefer mixed eucalypt forests. It is a cryptic species, unidentifiable by call and rarely seen, particularly in the Sydney area.
Distribution in the GRC	This species was recorded at St Helens Park during these surveys.
Adjacent to the GRC	It is known from only a few records in the Sydney region.
Model for the GRC	The lack of records of this species in the Georges River catchment limits the production of a robust statistical or expert model for this species. Further study into the status of this species within the greater Sydney Basin would provide a better context in which to make informed decisions.
Conservation strategies	Methods for conserving this species are difficult to define with the current lack of information about its true status and distribution, however some strategies for the conservation of this species in the Georges River catchment might include: <ul style="list-style-type: none"> • making a formal reservation of the St Helens Park area • maintaining and restoring the links between the St Helens Park area and the Woronora Plateau.

Table 38 Information for habitat modelling for the Eastern Horseshoe-bat (*Rhinolophus megaphyllus*) (Gray 1834)

Ecology	This below-canopy species forages amongst dense vegetation along major drainage lines, roadways and gullies in rainforest and within open forest and woodland. It is thought to rarely move through open areas such as pastures, and does not forage in such areas. It prefers to roost in caves but is also known to use large tree hollows and man-made structures, including disused tunnels and mines, and occasionally houses.
Distribution in the GRC	The only record for this species within the Georges River catchment is adjacent to Dingo Tunnel along the Woronora River, suggesting that it is using this or a nearby tunnel as a roosting site. Potential habitat is restricted to deep gullies of the Woronora Plateau and the upper Georges River.
Adjacent to the GRC	There are several records of this species from Royal National Park, all of which are within moist forest along the Hacking River.
Model for the GRC	A generalised additive model (GAM) was produced (Figure 14) for this species using the single record from within the Georges River catchment and those immediately adjacent in Royal National Park. Consistent with records and the known habitat requirements of this species, the model identified moist forest along major drainage lines as being suitable habitat. The majority of potential habitat within the Georges River catchment remains in a good condition.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • maintaining areas of existing artificial habitat • making a formal reservation of moist forest areas • designing future bridges and culverts in such a way that they provide bat habitat.

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Figure 14

Predicted habitat map for the Eastern Horseshoe-bat

Table 39 Information for habitat modelling for the Eastern Freetail-bat (*Mormopterus norfolkensis*) (Gray 1839)

Ecology	<p>This above-canopy species occurs in open woodland, using tall, mature, often emergent trees as roosting sites, possibly because these trees are easily accessible above the canopy.</p> <p>It is known to forage above farm dams and woodlands, particularly larger, less disturbed remnants.</p>
Distribution in the GRC	In the Geogres River catchment all records for this species are from parts of the Cumberland Plain.
Adjacent to the GRC	In the locality of the Georges River catchment this species has been recorded in parts of the Cumberland Plain.
Model for the GRC	<p>The model (Figure 15) was derived using expert knowledge of the species habitat requirements. Consistent with known habitat requirements and records of this species, only those areas mapped as Woodland have been identified as potential habitat for this species. As a result all potential habitat for this species is confined to the Cumberland Plain, much of which is highly disturbed.</p> <p>The clustered pattern of records for this species in the Georges River catchment suggests that preferred habitat areas are the larger, less disturbed remnants such as:</p> <ul style="list-style-type: none"> • Prospect Reservoir • Fairfield Farm • Varroville.
Conservation strategies	<p>Strategies for the conservation of this species in the Geogres River catchment include:</p> <ul style="list-style-type: none"> • retaining large trees, no matter how isolated • maintaining areas of existing artificial habitat • improving the condition and size of remnant habitat • designing future bridges and culverts in such a way that they provide bat habitat.

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Figure 15 **Predicted habitat map for the Eastern Freetail-bat**

Table 40 Information for habitat modelling for undescribed Freetail-bat (*Mormopterus species 1*)

Ecology	<p>This above-canopy, fast-flying species occurs in open woodland, using tall, mature, often emergent trees as roosting sites, possibly because these trees are easily accessible above the canopy.</p> <p>This species is known to forage above farm dams and woodlands (particularly larger, less disturbed remnants).</p>
Distribution in the GRC	<p>Several individuals were recorded using echolocation along the middle section of the Georges River (Moorebank area) and in the larger upstream sections of the Georges and Woronora Rivers.</p> <p>All potential habitat for this species in the Georges River catchment is confined to the Cumberland Plain. It chooses to roost in old-growth trees and to forage in larger remnants and around farm dams.</p>
Adjacent to the GRC	<p>In the locality of the Georges River catchment this species has been recorded in parts of the Cumberland Plain.</p>
Model for the GRC	<p>The model (Figure 16) was derived using expert knowledge of the species habitat requirements. Consistent with known habitat requirements and records of this species, only those areas mapped as Woodland have been identified as potential habitat for this species. As a result all potential habitat for this species is confined to the Cumberland Plain, much of which is highly disturbed.</p> <p>The clustered pattern of records for this species in the Georges River catchment suggests that preferred habitat areas are the larger, less disturbed remnants such as:</p> <ul style="list-style-type: none"> • Prospect Reservoir • Fairfield Farm • Varroville.
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • retaining large trees, no matter how isolated • improving the condition and size of remnant habitat.

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Figure 16

Predicted habitat map for undescribed Freetail-bat

Table 41 Information for habitat modelling for the Common Bentwing-bat (*Miniopterus schreibersi*) (Kuhl 1817)

Ecology	<p>This bat prefers deep caves for roosting sites, however it is known to use man-made structures to roost and has been found in tunnels and under bridges.</p> <p>Evidence suggests that this species will forage in urban areas, often targeting insects that have been attracted to streetlights.</p>
Distribution in the GRC	<p>There are no known roosting sites for this species (i.e. caves) in the Georges River catchment. As the nearest known natural roosting sites are within the Blue Mountains, it is likely that individuals recorded using echolocation in the Georges River catchment are utilising artificial structures as roosting sites.</p>
Adjacent to the GRC	<p>The species has been recorded along the eastern escarpment of the Blue Mountains.</p>
Model for the GRC	<p>No statistical model was available for this species and the uncertainty surrounding its habitat preferences within the Georges River catchment prevented the derivation of an expert model.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • maintaining areas of existing artificial habitat • improving the condition and size of remnant habitat • designing future bridges and culverts in such a way that they provide bat habitat.

Table 42 Information for habitat modelling for the Eastern False Pipistrelle (*Falsistrellus tasmaniensis*) (Gould 1858)

Ecology	This predominantly above-canopy species roosts in open woodland, using tall, mature, often emergent trees to roost in, as these trees are easily accessible above the canopy. Its potentially large home range could enable it to roost in isolated mature trees during the day, then fly to larger remnants to forage by night (Ray Williams pers. comm).
Distribution in the GRC	In the Georges River catchment the majority of records for this species are from the Cumberland Plain, with a further three individuals identified in the Cumberland Plain–Woronora Plateau transition area.
Adjacent to the GRC	It is known from several records on the Cumberland Plain.
Model for the GRC	<p>The model (Figure 17) was derived using expert knowledge of the species habitat requirements. Consistent with known habitat requirements and records of this species, only those areas mapped as Woodland have been identified as potential habitat for this species. As a result all potential habitat is confined to the Cumberland Plain, much of which is highly disturbed.</p> <p>The clustered pattern of records for this species in the Georges River catchment suggests that preferred habitat areas are the larger, less disturbed remnants such as:</p> <ul style="list-style-type: none"> • Prospect Reservoir • Fairfield Farm • Northern Holsworthy • Varroville • Appin Road.
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • retaining large trees, no matter how isolated • maintaining areas of existing artificial habitat • improving the condition and size of remnant habitat • designing future bridges and culverts in such a way that they provide bat habitat.

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Figure 17

Predicted habitat map for the Eastern False Pipistrelle

Table 43 Information for habitat modelling for the Large-footed Myotis (*Myotis adversus*) (Morsfield 1824)

Ecology	<p><i>Myotis adversus</i> is understood to be an under-canopy, water-foraging bat and as such the presence of water bodies (lotic and/or lentic) is a determining habitat requirement.</p> <p>Although the species prefers to roost in caves or large tree hollows, it is known to make use of man-made structures, including tunnels, bridges and culverts.</p>
Distribution in the GRC	<p>Watercourses, as well as dams and other water storage facilities, present possible foraging areas in the Georges River catchment.</p> <p>The species has been recorded in several locations within the Georges River catchment. These records have been:</p> <ul style="list-style-type: none"> • Prospect Reservoir • Woronora plateau—along the streams and rivers • Cumberland Plain—along the streams and rivers.
Adjacent to the GRC	<p>In the locality of the Georges River catchment this species has been recorded in:</p> <ul style="list-style-type: none"> • Royal National Park • parts of the Cumberland Plain • the Cordeaux River Catchment.
Model for the GRC	<p>The model (Figure 18) indicates that proximity to streams is a determining habitat requirement for this species within the Georges River catchment, consistent with the known ecology of the species. Extensive areas of undisturbed habitat occur adjacent to watercourses of the Woronora Plateau. The model also indicates that narrow fragments of potential remnant habitat occur along creeks of the Cumberland Plain, although much of this is disturbed. Prospect Reservoir provides the most extensive area of modelled habitat on the Cumberland Plain and two individuals have been recorded at this location.</p> <p>Roosting habitat is harder to identify during the modelling process as individuals are recorded during foraging activity, not roosting. However in the Georges River catchment it is known to use both caves and tree hollows as roost sites (Ray Williams pers comm).</p>
Conservation Strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • maintaining mature and old-growth trees • maintaining rocky outcrops • maintaining areas of existing artificial habitat • improving the condition and size of remnant habitat • designing future bridges and culverts in such a way that they provide bat habitat.

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Figure 18

Predicted habitat map for the Large-footed Myotis

Habitat models—additional fauna species

The species profiles included in tables 44 through 46 have been listed as threatened since the completion of field work. No additional field assessment has been carried out to target these three species: Heath Frog (*Litoria littlejohni*), Grey-headed Flying-fox (*Pteropus poliocephalus*) and Eastern Pygmy Possum (*Cercartetus nanus*).

Table 44 Information for habitat modelling for the Heath Frog (*Litoria littlejohni*) (White, Whitford & Mahoney 1994)

Ecology	The Heath Frog (<i>Litoria littlejohni</i>) is a recent addition to the TSC Act, Schedule 2. Very little is known about the distribution and ecology of the species. It was formally described in 1994, having previously been grouped with the Jervis Bay Tree Frog (<i>Litoria jervisiensis</i>).
Distribution in the GRC	From within the study area, this species has been found at Darkes Forest and in Dharawal SRA.
Adjacent to the GRC	Heath Frog is a misnomer, as this species can be found in a variety of habitats on the coast and ranges from the Victorian border to Newcastle, NSW.
Model for the GRC	This species was listed on Schedule 2 of the NSW NPWS Threatened Species Act after the model creation process was completed. Nevertheless, at this stage the lack of knowledge about the Heath Frog, and the lack of records from within the study area would preclude the production of a habitat model.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • conserving existing populations through cooperative area management agreements • conducting ongoing research to identify all current populations and habitat requirements of this species within the Georges River catchment.

Table 45 Information for habitat modelling for the Grey-headed Flying-fox (*Pteropus poliocephalus*) (Temminck 1825)

Ecology	The Grey-headed Flying-fox is a new addition to Schedule 2 of the TSC Act. It is distributed from Rockhampton, Queensland, to Victoria, generally restricted to the coastal belt but occasionally being found inland of the Great Dividing Range (Strahan 1998). This species lives in colonies, travelling large distances at night to take advantage of fruiting or flowering events of favoured tree species. Some of its preferred feed tree species are rainforest trees such as figs and cabbage tree palms and flowering angophora spp., banksia spp. and melaleuca spp.
Distribution in the GRC	Within the Georges River catchment there is a roost site at Cabramatta Creek in Fairfield LGA. This colony is not a breeding site, and it is not occupied at all times of the year. This species probably opportunistically exploits flowering and fruiting events within the Georges River catchment.
Adjacent to the GRC	The nearest breeding colony is at Gordon, in the northern suburbs of Sydney.
Model for the GRC	This species was added to the TSC Act after the completion of the habitat modelling process. Therefore no model has been produced for the species. Aside from highlighting the roosting colony at Cabramatta Creek, it is unlikely that a satisfactory model could be made for this species due to the temporally sporadic nature of its habitation of the study area.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • retaining vegetation within the known roosting areas along Cabramatta Creek • protecting roosting areas from potential predators such as cats, foxes and dogs.

Table 46 Information for habitat modelling for the Eastern Pygmy Possum (*Cercartetus nanus*) (Desmarest 1818)

Ecology	The Eastern Pygmy Possum feeds primarily on nectar and pollen of banksia spp., eucalyptus spp. and callistemon spp., although it will eat soft fruits and insects. The species is a solitary animal found in a range of sclerophyllous habitats, but in the Sydney region appears only to be common in areas with heathland, such as Royal National Park and Ku-ring-gai Chase National Park.
Distribution in the GRC	There are 37 records of this species from within the Georges River catchment. Most of these are from Sandstone Ridgetop Woodland, although a number are from vegetation types that adjoin this community type.
Adjacent to the GRC	There are records of this species from sandstone communities to the west, south and east of the Georges River catchment. It is distributed in a coastal band from the Queensland border to South Australia and Tasmania (Strahan 1998).
Model for the GRC	There was no model created for this species, as its listing on Schedule 2 of the TSC Act came after the habitat model creation had been completed. It is likely that high-quality habitat for this species is restricted to the Sandstone Ridgetop Woodlands of the Woronora Plateau, with some usage of the adjacent Eastern Gully Forest and Upper Georges River Sandstone Woodland.
Conservation Strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • protecting patches of sclerophyllous vegetation and links between them throughout the region • monitoring vegetation communities to ensure that fire management and other management practices are maintaining key processes • managing feral and domestic animals, and traffic impacts.

3.4 Species diversity—flora

No new locations were recorded for any of the selected flora species, however investigation of previously recorded sites provided valuable information for use in the modelling process.

As a result, habitat models were developed for six of the seven species, however the available data was sufficient for statistical modelling for only three of those six species (see Table 47). There was insufficient data in relation to *Pterostylis gibbosa* to formulate any model.

3.4.1 Guide to interpreting flora habitat models

The models are a means to describe a relationship between patterns in the location of species and local and regional environmental data. If strong relationships exist between the location of a species and a single or combined data layer, then the reliability of the model will be greater. As a coarse guide to the fit of the model, the pattern of existing locations displayed on the derived model will indicate the degree of accuracy. In some cases the habitat model has been further refined to highlight areas of high-quality habitat. Some records of species will exist outside of areas considered to be high-quality habitat. This should be expected because the strength of the relationship between the location of the species and the environmental data is rarely perfect, and so extrapolations (maps) based from derived models will reflect such inaccuracies. Such problems are also apparent with expert or qualitative models.

Table 47 Selected flora species for the Georges River catchment

Number ¹	Scientific name	Family	Model	
			Type	Figure
I	<i>Pimelea spicata</i> R. Br.	Thymelaeaceae	GAM	19
II	<i>Persoonia nutans</i> R. Br.	Proteaceae	Distance to alluvium	20
III	<i>Pultenaea parviflora</i> Sieber ex DC.	Fabaceae	Expert	21
IV	<i>Pterostylis saxicola</i> D.L. Jones & M.A. Clem.	Orchidaceae	Expert	22
V	<i>Pterostylis gibbosa</i> R. Br.	Orchidaceae	–	–
VI	<i>Cynanchum elegans</i> (Benth.)	Asclepiadaceae	Habitat	23
VII	<i>Gyrostemon thesioides</i> (Hook.f.) A.S. George	Gyrostemonaceae	Expert	24

1. Number used for reference to the associated species throughout this report.

The species maps illustrate the potential distribution of habitat for each species. They do not indicate whether the species occupies the mapped habitat at any given point in time. Future field surveys can be used to validate the reliability of the habitat models. The success of the model can be judged through empirical validation. As this was beyond the scope of this project, review of the habitat maps was made against expert knowledge of species habitat requirements.

The models should be used acknowledging the limitations of the modelling process. Nevertheless they can and should be used to trigger the need for the types of surveys required for environmental impact assessment purposes. Furthermore, the models should also initiate and provide information for the preparation of species impact statements in land acquisitions or development applications. Results from such fieldwork can then be fed back into the model to evaluate model reliability. It can also be used to guide broader conservation objectives seeking to address the vulnerability or conservation status of biodiversity attributes in the Georges River catchment. For specific land allocation decisions users may wish to refine mapped habitats by ensuring that habitat which includes known records of the target species be identified preferentially.

3.4.2 Habitat models—selected flora species

Table 48 Information for habitat modelling for *Pimelea spicata* R. Br. (Thymelaeaceae)

Ecology	<p><i>Pimelea spicata</i> (Thymelaeaceae) is a small shrub growing erect up to 50 cm. It has glabrous stems and opposite narrow-elliptic leaves, 5 to 20 mm long. Flowers are predominantly white to sometimes pinkish. Flowers occur from December to February (Harden 1990; Fairley & Moore 1989).</p> <p>It is often found occurring in association with common Cumberland Plain Woodland species such as <i>Eucalyptus moluccana</i>, <i>Bursaria spinosa</i> and <i>Themeda australis</i>.</p>
Distribution	There are 67 known locations of <i>Pimelea spicata</i> , predominantly in Western Sydney, though some records are known in the Illawarra region.
Distribution in the GRC	<p>Of the 67 known locations of <i>Pimelea spicata</i>, 25 are records within the Georges River catchment, where it occurs on undulating topography of substrates derived from shale and Holocene Alluvium.</p> <p>The two main populations of <i>Pimelea spicata</i> in the Georges River catchment are:</p> <ul style="list-style-type: none"> • Lansdowne Park (Bankstown) • the northern side of Prospect Reservoir.
Model for the GRC	<p>A generalised additive model was generated for this species (Figure 19). A significant association was found between distance to sandstone and distance to coastline and the recorded <i>Pimelea spicata</i> localities.</p> <p>Field experience of the habitat of this species habitat garnered during the Western Sydney Vegetation Mapping Project and Urban Bushland Biodiversity Survey (UBBS) (1997a) suggested that the generated model was likely to overestimate the extent of preferred habitat. In order to refine the habitat, close revision of site data was completed to extract potential local environmental influences on species distribution. The model was refined by accepting only those areas that:</p> <ul style="list-style-type: none"> • contained at least a 75% likelihood of occurrence • were characterised by undulating topography. <p>These areas were delineated using the ruggedness 900 m variable. This model explained 68.94% of the deviance in the data, which can be considered as a relatively accurate fit when values of less than 50% are commonly encountered (NPWS 1997).</p> <p>In examination of this predicted habitat model, 65% of the recorded locations have been mapped with a high probability of occurrence. The remaining locations are situated within 1.5 km of this mapped area, giving further confidence to the modelling procedure. The mapped area corresponds to the landscape area that contains optimum data values for the two variables chosen.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • assessing potential habitat for the occurrence of the species, • protecting populations if found.

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FIGURE 19**

Figure 19

Predicted habitat model for *Pimelea spicata*

Table 49 Information for habitat modelling for *Persoonia nutans* R.Br. (Proteaceae)

Ecology	<i>Persoonia nutans</i> (Proteaceae) is an erect to spreading shrub up to 1 m high. It is often relatively inconspicuous except when flowering with drooping yellow flowers from December to March. Leaves are typically 15 to 30 cm long, glabrous, smooth, and often flat with recurved margins (Harden 1990; Fairley & Moore 1989).
Distribution	<i>Persoonia nutans</i> is confined to the Cumberland Plain where there are 34 known locations. The two main populations of <i>Persoonia nutans</i> occur in Castlereagh and Liverpool. The population of <i>Persoonia nutans</i> in the Castlereagh area is the largest and occurs on flat, dry areas of sclerophyll forest and shrubland. The substrates underlying the species in this area are predominantly Tertiary Alluvium, however <i>Persoonia nutans</i> has also been recorded on shale and soils with a strong sand influence.
Distribution in the GRC	Ten of the 34 records of this species occur within the Georges River catchment. Within the Georges River catchment <i>Persoonia nutans</i> is found on similar substrates as well as on soil types derived from Mittagong Formation and Holocene Alluvium. As in the Castlereagh area, <i>Persoonia nutans</i> in the GRC area is known to inhabit dry sandy locations in association with <i>Eucalyptus sclerophylla</i> .
Model for the GRC	<i>Persoonia nutans</i> was modelled using only the distance to alluvium variable (Figure 20). The model states that high species occurrence probability surrounds the areas closest to alluvium-derived geology. This initially appears to be an anomaly since the species have been recorded on geologies of Tertiary and Holocene Alluvium, shale and Aeolian deposits, as well as Mittagong Formation. However, given this seemingly strange distribution across a range of differing geologies, all recorded locations are within 2.5 km of Tertiary Alluvium (apart from two unconfirmed records in the Appin area). This highlights possible limitations with the fine-scale resolution of the soil landscape/geological variables. As there is limited application for the variables to match all habitat variation within the species distributions, the modelling procedure has been modified accordingly. The model analysed the data to explain 62.3% of the variation. Furthermore, 85% of recorded locations are modelled as high probability areas using this method. Thus, the predicted areas of highest species occurrence probability are the areas of Tertiary Alluvium geology and surrounds. These areas include Chipping Norton, Prospect Creek and Holsworthy Military Area (Figure 20). The latter is the only area with a sizeable proportion of its remnant vegetation remaining intact. Any future searches for <i>Persoonia nutans</i> in the GRC should consider this area with the highest priority.
Conservation strategies	Strategies for the conservation of this species in the Georges River catchment include: <ul style="list-style-type: none"> • assessing potential habitat for the occurrence of the species • protecting known populations where feasible.

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FIGURE 20**

Figure 20 **Predicted habitat model for *Persoonia nutans***

Table 50 Information for habitat modelling for *Pultenaea parviflora* Sieber ex DC. (Fabaceae)

Ecology	<p><i>Pultenaea parviflora</i> (Fabaceae) is a small erect shrub with small, recurved leaves 2 to 6 mm long, narrow to broad obovate in shape and densely packed on the stems. Individual plants produce small, yellow, pea-shaped flowers between September and December (Harden 1990; Fairley & Moore 1989).</p> <p>The species is found in association with Ironbark Forest (<i>Eucalyptus fibrosa</i>) as well as Scribbly Gum Woodland (<i>Eucalyptus sclerophylla</i>).</p>
Distribution	<p><i>Pultenaea parviflora</i> is confined to 60 locations throughout the greater Western Sydney area. The typical <i>Pultenaea parviflora</i> habitat is open forest on heavier clay soils arising from shale or alluvium-based geology. However, all known locations appear to be influenced by the presence of Tertiary Alluvium. The Shale/Gravel Transition areas of the Castlereagh Woodlands are prime habitat examples with this area of Western Sydney containing the majority of recorded species locations.</p>
Distribution in the GRC	<p>As mentioned previously there are no confirmed records of <i>Pultenaea parviflora</i> occurring in the Georges River catchment, however there are a number of areas that are considered to be potential habitat for this species. The species has been recorded less than 3 km west of the Georges River catchment in the Kemps Creek area.</p>
Model for the GRC	<p>An expert model (Figure 21) was undertaken for the species of <i>Pultenaea parviflora</i>. In this procedure, the values of all environmental variables are obtained at known species locations. The significance for each individual variable is determined through the presence of a clear data range for recorded species locations. From this process it was discovered that distance to Tertiary Alluvium and ruggedness index provided a sound match for current species locations.</p> <p>The relationship of distance to Tertiary Alluvium (<3km) and ruggedness index (<6) was then extrapolated across the landscape to provide a potential habitat map. Map 3 displays the portions of the Georges River catchment covered by this relationship. The model encompasses 93% of sites.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • assessing potential habitat for the occurrence of the species • protecting known populations where feasible.

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FIGURE 21**

Figure 21

Predicted habitat model for *Pultenaea parviflora*

Table 51 Information for habitat modelling for *Pterostylis saxicola* D.L. Jones & M.A. Clem (Orchidaceae)

Ecology	<p><i>Pterostylis saxicola</i> (Orchidaceae) is a small terrestrial herb with leaves forming a rosette and flowering with 2 to 10 terminal flowers. The 5 to 8 basal leaves are typically 1 to 2.5 cm in length. The inflorescence is dark red-brown on a scape of up to 25 cm and produces flowers from September to November (Harden1990).</p> <p>According to the Preliminary Determination of the NSW Scientific Committee, <i>Pterostylis saxicola</i> grows in shallow sandy soils found on sandstone ledges commonly above cliff lines. The vegetation found in these areas is either Shale/Sandstone Transition or Shale Communities. This includes species such as <i>Eucalyptus punctata</i> and a sparse covering of ground level grasses and herbs.</p>
Distribution	<i>Pterostylis saxicola</i> (formerly known as <i>Pterostylis sp E</i>) is known at only nine locations around the fringe of the Cumberland Plain, all areas of Shale/Sandstone Transition.
Distribution in the GRC	Five species records have been found within the Georges River catchment, from a total of nine records overall. Within the Georges River catchment boundary the <i>Pterostylis saxicola</i> records are mostly on shale geology, however they are also in close proximity to streams and/or sandstone valleys.
Model for the GRC	Due to the lack of species records, the Species Modelling Package could not be utilised for <i>Pterostylis saxicola</i> . An expert model (Figure 22) was therefore used for the potential habitat mapping of this species. As noted above, this species appears to inhabit areas of Shale/Sandstone Transition Forest. This basic habitat characteristic can now be further refined by extracting areas of high slope and areas distant from shale geologies. The variables used for this analysis were the modelled vegetation classes 2 and 32 (two variations of Shale/Sandstone Transition Forest), terrain index 100 m (0–1) and distance to shale (<2km). This type of modelling is obviously restricted by the small number of site locations with only 56% of these locations matching the modelled landscape area. The model does however match the hypothesised habitat, thus highlighting the area bordering the main Georges River, and particularly the areas upstream of its tidal influence.
Conservation strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • assessing potential habitat for the occurrence of the species • protecting known populations where feasible.

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FIGURE 22**

Figure 22 **Predicted habitat model for *Pterostylus saxicola***

Table 52 Information for habitat modelling for *Pterostylis gibbosa* R. Br. (Orchidaceae)

Ecology	<p><i>Pterostylis gibbosa</i> (Orchidaceae) is similar in appearance to <i>Pterostylis saxicola</i>. <i>Pterostylis gibbosa</i> has 4 to 7 elliptic to ovate leaves from 1.5 to 3.5 cm long. It has a taller scape than <i>P. saxicola</i>, developing to 45 cm, and more sheathing stem leaves (3–6). Unlike <i>P. saxicola</i>, the flowering portion of this species is bright green (only slightly brownish) with transparent patches in its petals. The typical flowering period is from August to November (Harden1990).</p> <p><i>Pterostylis gibbosa</i> grows amongst grass in sclerophyll forest and open woodlands. In the Illawarra region it occurs on loamy soils with heavy clay subsoils. It is commonly found in association with <i>Eucalyptus tereticornis</i>, <i>E. longiflora</i> and <i>Melaleuca decora</i>.</p>
Distribution	<p>There are six recorded populations of the species in the Wollongong/Lake Illawarra area. As noted below, there was an unconfirmed report of the species from the Woronora River and it has been previously recorded on the Cumberland Plain proper in Woodland and River Flat Forest communities. Another population in the Hunter Valley is awaiting taxonomic confirmation.</p> <p><i>Pterostylis gibbosa</i> was first collected in the Cumberland Plain by George Caley in 1803. The species has not been found in Western Sydney since this date despite recent searches. Little is known about the actual site and the location of the collection is not known with any accuracy (i.e. within 10km). Furthermore, confusion surrounding the taxonomy of the genus has further hindered the identification of this species.</p> <p>Many of these potential areas were searched with no success in 1993 (NPWS 1994):</p> <ul style="list-style-type: none"> • St Andrews Boys Home; St Andrews Road; Kemps Creek; Water Supply Canal; Christian School; Liverpool and Fairfield Showgrounds; Prospect Reservoir; State Brickworks; Nurragingy Reserve; Plumpton Park; Schofields Aerodrome; Fulton Road; Shanes Park; Rouse Hill; Scheyville; Long Neck Lagoon; Old Stockyard Route; Marsden Park Australian Defence Industries; St Marys; Kingswood Armaments Depot. <p>Within the Cumberland Plain, the habitat requirements of this species are thought to be heavy clay soil or drier areas of the Cumberland Plain on gently undulating topography (NPWS 1994b). Various areas of suitable habitat exist within the Cumberland Plain (determined from speculative textual information and extrapolation of site characteristics from Illawarra populations). However, the lack of accurate locality data results in very little being known of the original distribution or potential site characteristics for the occurrence of this species within Western Sydney. There are habitat types present similar to those on which the Illawarra populations are found, however so little is known about its occurrence on the Cumberland Plain that it has now been presumed extinct in this area (NPWS 1994b).</p>
Distribution in the GRC	<p>The species was recorded (unconfirmed) from the Woronora River and has been previously recorded on the Cumberland Plain proper in Woodland and River Flat Forest communities. Several of the sites listed above are within the Georges River catchment.</p> <p>There are habitat types present similar to those on which the Illawarra populations are found, however so little is known about its occurrence on the Cumberland Plain that it has now been presumed extinct in this area (NPWS1994a).</p>
Model for the GRC	<p>Due to a lack of records and uncertainty about its habitat requirements potential habitat modelling was not carried out for this species.</p>
Conservation strategies	<p>Strategies for the conservation of this species in the Geogres River catchment include:</p> <ul style="list-style-type: none"> • assessing potential habitat for the occurrence of the species • protecting known populations if feasible.

Table 53 Information for habitat modelling for *Cynanchum elegans* Benth. (Asclepiadaceae)

Ecology	<p><i>Cynanchum elegans</i> (Asclepiadaceae) is a climber species with stems to 1 m long. It has broad to ovate leaves that are mostly hairless and 1.5 to 5.5 cm in length. It flowers over summer with a few clustered white flowers (Harden 1990).</p> <p>This plant is typically found in dry and littoral rainforest on clay or clay-loam soils with the preferred habitat having fertile soils and intermittent moisture (Matthes & Nash 1993). It is often found in association with <i>Pittosporum revolutum</i> and <i>Notelaea microcarpa</i>, in vine thickets on the east and south facing slopes.</p>
Distribution	The distribution of this species extends from Wollongong to the Mid-North Coast. The habitat requirements described above are consistent throughout this distribution.
Distribution in the GRC	There is one recorded location within the Georges River catchment out of the 67 other known populations. The habitat requirements described above are consistent with the recorded population in the Georges River catchment.
Model for the GRC	<p>This species has a naturally restricted habitat, growing as a climber species principally within dry rainforest. The areas modelled (Figure 23) as dry rainforest by the Western Sydney Vegetation Mapping Project (1997b) were therefore utilised to predict areas of potential habitat for this species. Due to the limited amount of suitable landscape types, only a small portion of the Georges River catchment was modelled as potential habitat for this species.</p> <p>The justification for using the vegetation modelling for this species rather than a more ad hoc expert modelling procedure is due to the lack of species locations in the Cumberland Plain area as well as the association this species has with dry rainforest vegetation communities. Furthermore, the vegetation modelling was undertaken using actual field survey sites and involved modelling vegetation communities rather than individual species. The modelling process for the dry rainforest remnants involved selecting areas of high elevation, high slope and low solar radiation. Other variables such as rainfall, wetness index or topographic position might also have provided a useful relationship. It should however be noted that this species and associated vegetation community occupies a restricted niche habitat often occurring in small isolated gullies (at a resolution difficult to model). Any subsequent species search should be aware of the limitations of the modelling procedure in highlighting such small pockets of the landscape.</p>
Conservation Strategies	<p>The one known location for this species is within Western Sydney Regional Park. Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • managing the population within the reserve appropriately • assessing potential habitat for the occurrence of the species • protecting known populations if feasible.

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Figure 23

Predicted habitat model for *Cynanchum elegans*

Table 54 Information for habitat modelling for *Gyrostemon thesoides* (Hook.f.) A.S. George (Gyrostemonaceae)

Ecology	<p><i>Gyrostemon thesoides</i> (Gyrostemonaceae) grows to 70 cm tall with numerous angular stems. Its narrow-linear leaves (5–20 mm long) often fall when mature and can reach 35 mm in length. The species has solitary flowers in leaf axils on pedicels to 1 mm long, developing into small red-brown fruit. The species is noted as being a fire-opportunist (Harden 1990).</p> <p>Habitat for this species would include alluvial soils derived from sandstone. It is also hypothesised that this species requires the wetter, eastern and southern facing slopes of sandstone valleys and/or proximity to shale colluvium. Typical vegetation communities would include species such as <i>Calotis dentex</i> and a mix of sandstone gully <i>Eucalyptus</i> species.</p>
Distribution	It has been recorded twice, initially in 1910 near the Nepean River at Douglas Park, and on the bank or valley side of the Georges River at Ingleburn in 1964.
Distribution in the GRC	It was recorded at the Georges River Nature Reserve site (Picnic Grove Rd) for a number of years (Final Determination, NSW Scientific Committee) however was not found in a comprehensive search of this area in August 1999.
Model for the GRC	<p>An expert model (Figure 24) was developed for this species. Only two accurate locations of this species exist, so the mapped habitat is a rather crude estimation. A likely habitat suitable for this species is proposed as being valley sides of sandstone in close proximity to shale. This conclusion was arrived at through a review of relevant literature as well as site inspections of the two previously recorded locations. The modelling procedure was undertaken using distance to shale (<250), distance to sandstone (<50), distance to streams (<350), and maximum rainfall (<990). The justification for the usage of these variables was to highlight the landscape areas of damp sandstone valleys in close proximity to streams and those areas that are influenced by shale substrates. Figure 24 displays the result of the modelling process, illustrating the distribution of potential habitat for this species.</p> <p>Searches for the plant at recorded locations have not provided confirmation of its persistence within the Georges River catchment.</p>
Conservation Strategies	<p>Strategies for the conservation of this species in the Georges River catchment include:</p> <ul style="list-style-type: none"> • assessing potential habitat for the occurrence of the species • protecting known populations where feasible.

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Figure 24

Predicted habitat model for *Gyrostemon thesioides*