Ranking the feeding habitats of Grey-headed flying foxes for conservation management

a report for
The Department of Environment and Climate Change (NSW)
&
The Department of Environment, Water, Heritage and the Arts
October 2008

Peggy Eby and Bradley Law

Acknowledgements

This project has benefited from the support and collaborative efforts of a large number of people. It was jointly funded by the Australian Department of the Environment, Water, Heritage and the Arts and by the Department of Environment and Climate Change (NSW). We are grateful for the support we received from Kylie McClelland, Linda Bell, Amelia Hurren, Kelly Waples and Graham Wilson of DECC (NSW); and Anna Lashko and Amanda Lawrence of DEWHA.

Michael Bedward of DECC (NSW) and John Woinarski of NRETA (NT) participated in several conversations, commented on draft material and gave valuable advice on design and methods. Sandy Wellington and Alison Towerton DPI (NSW) provided GIS support. Michael Bedward and Murray Ellis assisted with ARCVIEW scripts.

Numerous people assisted us in locating and acquiring vegetation classifications and maps, occasionally in draft form. Many more assisted with flower scores by providing us with unpublished reports, field records and their expert advice. We owe a debt of gratitude to them all. We believe the following list to be comprehensive and apologise to anyone we have inadvertently omitted.

Queensland

Patrina Birt, David Dique, Teresa Eyres, Greg Ford, Bruno Gemmel, Hamish Lamb, Jiaorong Li, Stacey Maclean, Clive McAlpine, Rosemary Neihus, Billie Roberts, Peter Warhurst, Bruce Wilson.

New South Wales

Mick Andren, Stephen Bell, Peter Bowen, Mark Cameron, Daniel Connolly, Mike Crowley, Bill Dowling, Peter Ewin, Felicity Faulkner, D. Frost, David Geering, Tim Hagan, Brian Hawkins, Ken Hill, Guy Hodgeson, Rod Kavanaugh, David Keith, Charlie Mackowski, Kylie Madden, Elizabeth Magarey, David Milledge, Kevin Mills, Hugh Nicholson, Bob Oelhman, Nancy Pallin, Travis Peake, John Rhodes, David Roots, Debbie Saunders, Martin Schulz, David Sharpe, Jim Shields, Judy Smith, Peter Smith, Doug Sommerville, Leonie Stanburgh, Andrew Steed, Chris Togher, Mark Tozer, John Turner, Bruce White, Katrina Yann

Victoria

David Cameron, Fiona Cross, Scott Leech, Bill Peel, Tony Mitchell, Alison Oates, David Swan, James Todd

Executive Summary

The Grey-headed flying fox is listed as a threatened species under state and Commonwealth legislation. The key threatening process for the species is loss of foraging habitat, and recovery actions aim to identify and protect key foraging areas. However, difficulties in defining foraging habitat have impeded these actions and prevented the needs of the animals from being incorporated into land use decisions.

This project defined foraging habitat for Grey-headed flying foxes, ranked native vegetation within the range of the species according to the quality of foraging habitat it provides and generated bi-monthly nectar maps to describe seasonal resource changes. Grey-headed flying foxes occupy a dynamic resource landscape in which the quality of forests and woodlands as foraging habitat vary substantially in space and time. Therefore, we developed an index of habitat quality that is primarily a function of the flowering and fruiting characteristics of diet plants and their patterns of distribution. Habitat quality is also moderated by whether vegetation provides resources during key phases of the life cycle of Grey-headed flying foxes and these considerations were taken into account.

Habitats in the study area were defined by the vegetation types described in 24 vegetation classifications. The accompanying digital maps provided nearly complete coverage of the species' range and included approximately 26.4 million hectares of land. Numeric assessments of the productivity, annual reliability and duration of flowering of each of 56 nectar-producing diet species were combined with estimates of plant densities in the vegetation data to score the quality of nectar-producing habitat. Data on the annual flowering phenologies of diet plants were used to produce bi-monthly maps that indicate spatial and temporal variations in food resources. To account for regional variations in flowering patterns, assessments were made independently in each of five geographically distinct regions. Fruit-producing habitats were assessed by a separate method based on the species richness of 50 diet plants.

Approximately 50% of land in the study area was mapped as being cleared of native vegetation. Forests and woodlands that produce nectar for Grey-headed flying foxes covered 33% of the study area, or 67% of remnant vegetation. Less than 2% of the study area contained forests that produce fruit for the species. Interactions between the distribution, density, flower scores and flowering phenologies of diet plants produced diverse patterns of habitat productivity for Grey-headed flying foxes. In general, extensive and wide-ranging areas are productive from late spring to early autumn. From late autumn to early spring the extent of habitat is reduced and restricted in distribution, largely occurring in areas east of the escarpment. Winter presents the greatest food resource bottleneck for the species. In winter, productive areas are concentrated in coastal floodplains, coastal dunes and inland slopes in SEQ and northern NSW. The majority of winter habitats are heavily cleared, poorly conserved and recognised as endangered vegetation communities.

Vegetation covering 16% of the study area was assigned the highest conservation and management priority (rank 1 of 4) and 11% was assigned the rank of 2. Lists of each vegetation type in the study area and its final rank are provided in the data files that accompany this report.

The output of this project is supplied in three formats: written reports, regional databases and regional maps (shape files) for use in ARCView Geographic Information System. We recommend that the work be exposed to an ongoing process of development and improvement in parallel with improvements in vegetation mapping.

Table of Contents

1. Introduction

The Grey-headed flying fox *Pteropus poliocephalus* is a large, endemic megachiropteran bat occurring in south-eastern Australia. It feeds on nectar and pollen from flowers of canopy trees and fleshy fruits from rainforest trees and vines (Ratcliffe 1931, McWilliam 1986, Parry-Jones and Augee 1991, Eby 1995 and 1998, Tidemann 1999, Hall and Richards 2000). Grey-headed flying foxes are exceptionally mobile, flying as far as 40 km to feeding areas and returning to their roost in one night (Eby 1991). They move freely through a range of vegetation communities, including highly disturbed and developed areas (Eby 1995). On a seasonal basis they may move over hundreds of kms (Eby 1991). The bats roost amongst foliage in large aggregations known as camps.

The conservation status of Grey-headed flying foxes is deteriorating (Eby and Lunney 2002). An ongoing decline in the population has been recognised with its listing as Vulnerable at the state (NSW *Threatened Species Act 1995;* Vic. *Flora and Fauna Guarantee Act 1988*), national (Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*) and international level (IUCN Red List 2008). A number of threats impact the species, such as shooting in commercial fruit crops, disturbance of roosting sites and electrocution on powerlines. However, the key threatening process for Grey-headed flying foxes is loss of foraging habitat (Dickman and Fleming 2002). Recovery actions for the species aim to identify and protect key foraging areas (Department of Environment and Climate Change (NSW) 2005; Eby 2006). However, difficulties in defining foraging habitat have impeded these actions and prevented the needs of the animals from being incorporated into land use decisions.

Grey-headed flying foxes occupy a dynamic resource landscape in which the quality of forests and woodlands as foraging habitat varies substantially in space and time. The distribution of the flower and fruit resources for Grey-headed flying foxes is a function of the productivity of the plant species in their diet and the distribution of those species in vegetation communities across its range. Variations in the patterns of productivity in flowering and fruiting diet plants in turn largely explain the extensive migration movements of Grey-headed flying foxes (Eby 1991 and 1996, Spencer *et al.* 1991, Eby *et al.* 1999).

Eucalypts (including *Eucalyptus* and *Corymbia*) are the most important contributors of nectar and pollen to the diet of Australian flying foxes. These trees are renowned for an irregular pattern of flower production (Law *et al*. 2000). A 15-year study of Spotted Gum *Corymbia maculata* on the south coast of NSW illustrates this well (Pook *et al*. 1997). While some flowers were produced every second year, sometimes at a level sufficient to provide food for flying foxes and other nectarivores, mass flowering occurred only once during the course of the study.

The relationship between flowering and nectar production in eucalypts is also considered unreliable (Wykes 1947, Porter 1978), although data from flowers measured in the canopy are scarce. Extensive nectar measurements were recently completed on the south coast of NSW in the canopy of two tree species: Spotted Gum *C. maculata* and Grey Ironbark *Eucalyptus paniculata* (Law and Chidel 2007). High nectar volumes and sugar concentration in flowers were most consistently related to recent climatic conditions. Yet these patterns are complex and not easy to predict. Nectar standing crops were not only influenced by nectar production, but also the feeding activity of flower visitors (eg insects) at the time, which itself was affected by prevailing temperatures and nectar attributes, such as sugar concentration and regional nectar availability. Variability in flowering and nectar production are thus two key criteria that need to be accounted for in describing the food resources for Grey-headed flying foxes.

Models of habitat quality can be presented in different ways, but maps are particularly useful tools for planners and managers because they can be incorporated with Geographic Information Systems and provide scientifically-based models of habitat quality delineated on maps. Examples of such maps have been produced for other fauna with well-defined habitat requirements (eg Koalas, Lunney *et al.* 2001), but "nectar" maps are still in their infancy and are lacking for most landscapes. Early attempts by Cocks and Dennis (1978) produced a simple map for a portion of the south coast NSW showing areas as having either an acceptable or unacceptable nectar index for European honeybees. The map was derived by valuing plants for honey bees on the basis of a simple nectar production index and weighting each plant species by its basal area in different plant communities.

Vertebrates require larger nectar rewards than insects and so a sub-set of nectar producing plants needs to be considered. Woinarski *et al.* (2000) pioneered nectar maps for honeyeaters in the Northern Territory which illustrate shifts in the nectar resource over large spatial scales and across the year. These maps were based on an assessment of the abundance of woody plant species within vegetation polygons, the flowering time of every woody plant species and an expert assessment of the nectar produced during a flowering event for every plant species considered. While vastly improving the spatial and temporal knowledge of nectar resources for wildlife in northern Australia, the final maps are limited as tools for planners by the large scale at which they were produced (1:1,000,000) and the fact that the variability and reliability of the resource were not incorporated.

More recently an approach similar to that of Woinarski *et al.* (2000) was used in Europe to produce descriptions of "flower landscapes" for entomophilous plant species (Frankl *et al.* 2005). Their model of flower resources was based on floral phenology and the cover of entomophilous plant species derived from vegetation maps, with an outcome of ranking different landscapes, including those experiencing different management, on the basis of their floral potential. Differential flower value for insects was not assessed in their study, nor was the variability or reliability of the resource, although the latter is probably less important for primarily annual, insect-pollinated species.

The aim of this study was to produce bi-monthly maps of the spatial and temporal variations in food resources for Grey-headed flying foxes across their range from Queensland to Victoria. We specifically included assessments of the productivity and reliability of each nectar-producing diet species and incorporated these into the best available vegetation maps. Fruit-producing habitats were assessed by a separate method based on plant species richness. To assist planners and managers in interpreting differences in habitat quality indicated by complexities of temporal variations and reliability in food supply across three Australian states, we developed an objective and systematic approach to ranking vegetation communities into simple categories. Our methods and assumptions are carefully documented so that the process can be revised and refined over time as new data on nectar availability and updated vegetation maps become available.

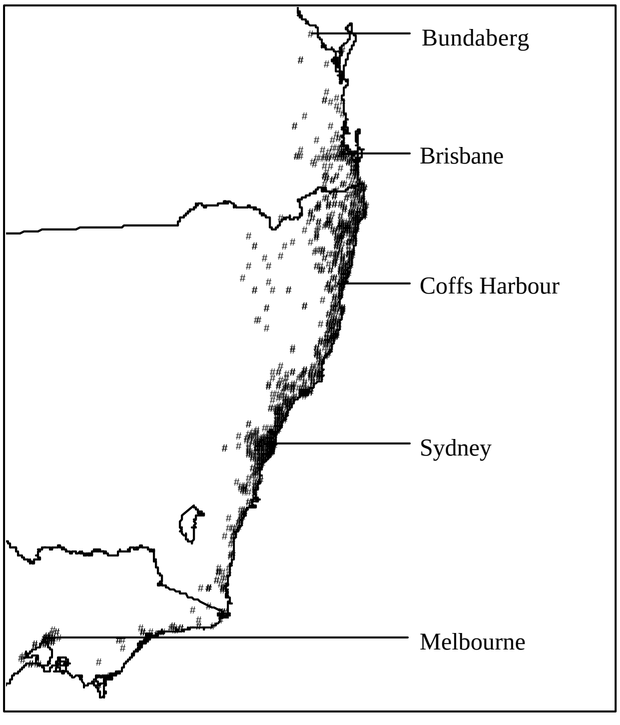
2. Study area

The study encompassed the range of Grey-headed flying foxes. Grey-headed flying foxes are highly mobile animals that migrate in response to irregular resources. Occupancy at the edges of their range is ephemeral in most areas, and vagrants are occasionally sighted several hundred kilometres beyond expected bounds (Eby 2006). For example, individuals or small groups have been recorded west to Adelaide, north to Gladstone and south to Flinders Island. For this work, we defined the range of Grey-headed flying foxes by the area of repeated occupation described in the draft national recovery plan for the species (Figure 2.1.; Eby 2006). This recognised the localities where >1 sighting had been recorded within an area of 40 km radius during the 20 years from 1984 to 2004 (black circles in Figure 2.1.).

The range of Grey-headed flying foxes described by this method extends from approximately $24^{o}30'$ in the north to 39^{o} in the south, and from the coast inland to the tablelands in southern Queensland and to the tablelands and western slopes in northern NSW. Sightings inland from the escarpment are uncommon in southern NSW and Victoria.

Details of landforms, topography, climate, etc within the study area are provided in regional profiles (Chapters 7-11).

Figure 2.1. The distribution of Grey-headed Flying-foxes from recorded sightings. Dots represent areas of repeated occupation (>1 record in 40 km radius) from 1984-2004. There are few data from inland regions, and blank localities on the map cannot be interpreted as areas unoccupied by the species. The extent of these records define the study area for this work.



Sources of data: NSW Wildlife Atlas, NSW DECC; Atlas of Victorian Wildlife, Victoria DSE; WildNet, QPWS; Eby 2004; Tidemann and Nelson 2004; G. O'Brien University of New England)

3. Methods

This project ranks native vegetation within the study area according to the quality of foraging habitat it provides for Grey-headed flying foxes. We developed an index of habitat quality that is primarily a function of the flowering and fruiting characteristics of diet plants and their patterns of distribution. Habitat quality is also moderated by the capacity of vegetation to provide resources during key phases of the life cycle of Grey-headed flying foxes (reproduction, migration, etc). These considerations were taken into account. The procedure for ranking habitat quality involved five steps:

1. compile a comprehensive list of plant species in the diet of Grey-headed flying foxes;
2. assess and score the flowering or fruiting characteristics of diet plants, including seasonal patterns of phenology;
3. score habitat quality on the basis of the presence and relative densities of scored plants in mapped vegetation types;
4. incorporate key biological considerations for Grey-headed flying foxes into habitat scores;
5. classify habitat scores into ranks.

No attempt was made to find an objective method for comparing the relative importance to Grey-headed flying foxes of fruit and blossom. These two dietary types were assessed independently and the results were integrated in the final ranking.

3.1. Diet list

The diet of Grey-headed flying foxes comprises primarily nectar and pollen from blossom in the canopy of various vegetation types and pulp from the fleshy fruits of rainforest trees and lianas (Parry-Jones and Augee 1991, Eby 1995). When feeding on blossom, nectar provides the primary source of carbohydrates whereas pollen provides the protein source (Law 1992). There is evidence that flying foxes sometimes eat leaves (Parry-Jones and Augee 1991) and exudates from leaf-mining insects, such as psyllids (Law and Lean 1992). Insect remains are also occasionally found in faecal material (Parry-Jones and Augee 1991). This assessment was restricted to the primary dietary items, fruit and blossom. Subsidiary items were not considered.

The blossom and fruit diet of Grey-headed flying foxes has been a topic of study over several years and at various locations within the range of the species (e.g. Ratcliffe 1931, McWilliam 1986, Parry-Jones and Augee 1991, Eby 1995 and 1998, Hall and Richards 2000). A preliminary list of diet plants was compiled from published documents, unpublished reports and theses, the field records of the authors and observations of others as reported to the authors.

Plant taxonomy generally followed Harden (2000 and 2002) and taxonomic revisions as reported by state herbaria were incorporated (Council of Heads of Australasian Herbaria. 2008). All taxa were checked for synonyms and consistency. Some differences in nomenclature occur between Queensland and New South Wales/Victoria, particularly in the *Corymbia* (Jessup 2002 and 2003, Qld Environmental Protection Agency 2005). Those differences are discussed in regional lists (see Regional Profiles Chapters 7-11).

Entries on the diet list were then scrutinised to verify use by the animals. Plant species whose use was confirmed by direct field observations or by analyses of faecal and spat material were entered onto a final diet list. Species whose use had not been confirmed were highlighted and the complete list was circulated to four people with field expertise in Australian flying foxes, particularly Grey-headed flying foxes. They were asked to 1) verify use of unconfirmed species, and 2) make additions to the list on the basis of direct observations or analyses. Their comments were incorporated into a working diet list, which was updated during the study as additional information became available.

3.2. Flower scores

Temporal and spatial flowering patterns and productivity of diet species are significant components of the assessment of the relative importance of feeding habitat. We consider that a high quality diet species is one that:

1. has the potential to be highly productive,
2. is annually reliable in its productivity (reducing searching behaviour and the likelihood of food shortages), and
3. is productive for lengthy periods (reducing the likelihood of food shortages).

These three broad characteristics are referred to as: productivity, reliability and duration, and five attributes are used to describe them (modified from Law *et al.* 2000). Those attributes that vary spatially were assessed at a scale relevant to the feeding behaviour of Grey-headed flying foxes as defined by typical nightly commuting distances from roosts of 20 km. The characteristics and their attributes are not considered substitutable. For example, a reliable species is of little use to flying foxes if it is not productive as well. The attributes are therefore linked by multiplicative functions (Burgman *et al.* 2001).

3.2.1. Productivity

Productivity is a function of the maximum abundance of resource available to Grey-headed flying foxes from an individual tree, and the spatial synchrony of flowering of the tree species in the local area.

<u>Abundance</u> is an assessment of the productive potential of a diet species, or the maximum resource that an individual tree produces when assessed during peak flowering. Various studies have proposed that the diet of vertebrate nectar feeders is primarily associated with rates of nectar secretion, sugar concentrations and the number of flowers per tree, but these are highly variable between and within tree species (Paton 1985, Pyke 1985, Kavenaugh 1987, Goldingay 1990, Law 1994, Goldingay 2005, Law and Chidel 2007). Other characteristics that may impact dietary preferences include diel patterns of nectar secretion, palatability, patterns of pollen production, nutritional quality of pollen and floral morphology (Law 1993, 1994, Birt 2005, Goldingay 2005). Data on these variables are either missing or rare in Australian canopy trees due largely to the logistical problems associated with field studies (but see Law and Chidel 2007). For this project we used visitation rates by flying foxes and other nocturnal mammals (particularly arboreal marsupials) to assess the relative abundance of food. These assessments were guided by a collation of nectar abundance measurements where they exist (Table 3.1).

Table 3.1. Nectar abundance per tree calculated from measurements of nectar secretion and flower abundance available in the literature. Also included is the abundance score recorded in this study for the different species. Nectar abundance is provided for one non-diet species, *E. obliqua*. Note that the numbers of flowers per tree are only indicative, because estimating flower numbers is difficult and strongly influenced by tree size and stage of flowering. Values reported here are considered typical or average values for large trees, but are not maximum values reported (see Law and Chidel 2007). * = estimated dawn standing crop from measurement of 24 h nectar production; na = data not available.

Species	**J per flower/ inflorescence**	**Flowers/ inflorescences per tree**	**KJ per tree**	**Source**	**Abundance score (this study)**
E. paniculata (good flowering)	85	12500	1063	Law & Chidel 2007	0.7
C. maculata	74	3600	266	Goldingay 1990; Law & Chidel 2007	1
E. robusta	72	3500	252	Law unpubl. data	1
C. gummifera	18	5500	99	Pyke 1985; Goldingay 1990; Goldingay 2005	1
B. integrifolia	1200	50	60	Law 1992; Law 1996	0.7
B. serrata *	3000	15	45	Armstrong 1991	0.5
E. obliqua	na	na	38	Paton 1985	-
E. paniculata (poor flowering)	16	12500	20	Law & Chidel 2007	0.7
Grevillea robusta	96	Na	na	Nicolson 1995	1
E. tricarpa	50	Na	na	Timewell & MacNally 2004	0.5
E. melliodora	13	Na	na	Nunez 1977	0.7

This table indicates that there is good correspondence between the estimated nectar produced per tree (kJ/tree) and abundance scores. It also highlights some anomalies that deserve further comment. The first is the extremely high variability in nectar productivity for *Eucalyptus paniculata*, which has been calculated to produce 1063 kJ/tree under optimal conditions, but at other times just 20 kJ/tree (Table 3.1., Law and Chidel 2007). Flying foxes were not observed by Law and Chidel during nocturnal observations at any of the sites where nectar was measured for *E. paniculata*, even when nectar-rich flowers were measured. In addition, no other vertebrates were observed feeding on nectar when flowers were nectar-rich. The reason for this is not known, but sugar concentrations were exceptionally high (>60%). Given that *E. paniculata* is a known diet species for Grey-headed flying foxes, a high score (0.7), but not the maximum (1), was allocated. The nectar measure data (13 J/flower) and abundance score (0.7) for *Eucalyptus melliodora* on Table 3.1. also appear anomalous. However, the low nectar yield per flower is perhaps not surprising because of the small flower size (~4-5 mm diameter) in this species (Nunez 1977), and it is likely that low nectar yields per flower are compensated for by high flower densities in the canopy of the tree in this species.

Because few direct measurements are available, our rating of abundance was primarily a comparative measure scored in relation to other trees in the diet of Grey-headed flying foxes. Non-diet plants were assigned a score of zero and were not considered in the relative appraisal. We considered abundance to be the most significant variable in the assessment of flowering characteristics. The other variables serve to moderate this productive potential.

Eight Grey-headed flying foxes feeding in a *Grevillea robusta* in full flower. The abundance score for *G. robusta* in this project is 1.0.

Abundance was scored in four categories which were assigned the following values: 0.3, 0.5, 0.7, 1.0. Broad classification intervals were chosen to minimise error when allocating species.

Examples from north east NSW:

Score	Species
1.0	*Corymbia maculata* ; *Eucalyptus robusta*
0.7	*Banksia integrifolia* ; *E. saligna*
0.5	*E. grandis*; *E. resinifera*
0.3	*Angophora costata*; *E. acmenoides*

Spatial synchrony is an index of how uniformly the species flowers across a local area defined by the nightly foraging range of Grey-headed flying foxes (25km). It is measured as the percentage of local sites (stands of trees) that experience peak flowering concurrently and is scored at three levels.

Examples from north east NSW:

Score	Range (% stands)	Species
1.0	>70%	*B. integrifolia*; *Grevillea robusta*
0.7	40 – 70%	*E. siderophloia*; *E. albens*
0.4	<40%	*E. propinqua*

Productivity Score

Abundance and spatial synchrony were combined to produce the productivity score. Abundance was weighted more heavily than the spatial synchrony of flowering, because species that produce little nectar, but flower synchronously (e.g. *A. costata*) are considered to be less important for mobile flying foxes than species that produce a patchy, but rich resource. This process produced 12 possible scores for productivity.

Productivity = abundance$^{0.75}$ $*$ synchrony$^{0.25}$

3.2.2. Reliability

Australian trees vary substantially in the consistency with which they flower from year to year, and the reliability of a plant moderates its productivity through time (over many years). Reliability is a measure of the frequency of substantial flowering events. It is a function of annual frequency and the proportion of flowering events that produce significant resources for Grey-headed flying foxes. Diet species that flower reliably are likely to be of particular importance at times when many other species fail to flower for environmental reasons.

Annual reliability is the percentage of years in which a flowering event occurs. Species that flower regularly receive a higher score. Very sparse flowering events (flowers present in <10% of canopy area) do not attract migratory Grey-headed flying foxes (Eby 1991). Very sparse flowering events were therefore not considered.

Examples from north east NSW:

Score	Range (% years)	Species
1.0	>70%	*Melaleuca quinquenervia*; *E. robusta*
0.7	40 – 70%	*E. siderophloia*; *E. saligna*
0.4	<40%	*C. henryi*; *E. albens*

Variation scores the frequency of significant flowering events and thus recognizes the variability in flowering intensity from one event to another. It is the percentage of events in which >50% of the canopy area is in flower. High scores reflect species that usually flower prolifically.

Examples from north east NSW:

Score	Range (% events)	Species
1.0	>70%	*E. pilularis*; *E. robusta*
0.7	40 – 70%	*E. siderophloia*; *E. saligna*
0.4	<40%	*C. henryi*; *E. albens*

Reliability score

Annual reliability and variation are evenly weighted in calculating the reliability score. There are six possible scores for reliability.

Reliability = annual reliability*variation.

Weighted productivity x reliability

Productivity and reliability describe different aspects of flowering in a tree species. The two scores were combined to create a single value which could be used to score the overall characteristics of individual species within vegetation types. Productivity was weighted more highly than reliability in the calculation because Grey-headed flying foxes are mobile over large areas enabling them to access rich, but unreliable resources.

Wt p*r = (productivity)$^{0.7}$ * (reliability)$^{0.3}$

3.2.3. Duration

Duration is the length in months of a single flowering event. This variable is assessed excluding months of very sparse flowering (<10% of foliage), which are unlikely to attract Grey-headed flying foxes. Three scores were used:

Examples from north east NSW:

Duration (mths)	Species
>3	*B. integrifolia*; *M. quinquenervia*
2	*E. siderophloia*; *E.tereticornis*
1	*A. costata*; *G. robusta*

3.2.4. Bi-monthly flowering schedules

Although most plants in the diet of Grey-headed flying foxes do not flower or fruit every year, the majority have clear seasonal phenologies. Long-term studies of flowering patterns have found that some eucalypts are able to produce flowers in most months of the year, but that discernible monthly peaks occur in the probability of flowering (Kavenaugh 1987, Law *et al.* 2000, Keatley and Hudson 2006). The annual flowering schedules of diet plants were collated as presence/absence data at bi-monthly intervals. Periods of sparse (<10% canopy cover) or infrequent (<20% of years) flowering were excluded from assessments.

3.2.5. Data acquisition

Data for this project were acquired from a combination of quantitative field data and expert opinion (Burgman and Lindenmeyer 1998). Spatial variations in flowering attributes are likely to exist, particularly in widespread species (Keatley and Hudson 2006). Therefore, the range of Grey-headed flying foxes was divided into five regional areas (Figure 3.1.) and flowering characteristics were assessed independently in each region.

Initially, systematically collected field data were compiled. These data were sourced from published manuscripts, unpublished reports, theses, the diaries of apiarists, unpublished data from concurrent research projects and the unpublished field records of the authors (see Section 6.1. for references). Field data were sourced on a subset of diet species. Inherent disparity in the data set was expected due to differences between sources in methods of collection and levels of precision.

Data were classified into three or four scores per attribute, with scores scaled from 0 (score assigned to non-diet plants) to 1 (score assigned to optimum condition). In general, the bounds of the scores for each attribute were set at even intervals. Very low values (sparse or very infrequent flowering) have a low probability of being captured by visual assessments (Sykes *et al.* 1983). Indeed no field studies recorded values <0.1 for any variable. We assumed scores <0.1 were unlikely to be recorded and adjusted the bounds of lowest scores accordingly (bound elevated by 0.1). Systems of scoring simplify data and reduce sensitivity to real differences (Regan *et al.* 2002). However, considerable variation between species was captured and described in this study by the combined scores.

Field workers with expertise in particular regions were then asked to score attributes of diet plants that occur in the region using data from their records and observations. They were asked to limit their input to species which they were confident they had sufficient direct experience to score.

No expert was able to score all diet plants in a region. Additional information was sought as needed until data on each of the five attributes had been compiled from at least four sources. We were not successful in sourcing a complete set of data for a small number of species including *E. deanei*, *E. rummeryi*, *E. maidenii* and the Grey Ironbarks *E. tetrapleura*, *E. placita* and *E. fusiformis.* No data were acquired for the last two species. However, neither they nor *E. tetrapleura* were identified by the vegetation classifications used to define habitats within their range. Thus the absence of flowering data for these species did not influence the outcome of the work. We also did not acquire complete data sets for some diet plants in Victoria and species scores from the SE NSW region were substituted where needed (see Chapter 11).

In some cases, the experts advised of intra-specific differences within regional areas – such as differences in productivity and reliability associated with soil fertility or topography; and differences in flowering phenologies associated with latitude or altitude. Where the disparity was confirmed by more than one field worker, the species in question was scored separately for each condition.

Data sets for each region were scrutinised for consistency in the scores assigned by the various experts. Levels of agreement were high. In 89.6% of cases (n = 693 species x variable combinations) there was agreement in scores. Where the scores assigned from different sources differed by one level (9.5% of cases), the majority view was taken. Where scores differed by two levels (<1% of cases), further information was sought and a final decision was taken by the authors. Final consensus scores from experts were compared to field data in a set of diet species in the Upper north east New South Wales region to check for anomalies.

3.3. Nectar habitat scores

3.3.1. Definitions of feeding habitats

Feeding habitats of Grey-headed flying foxes were identified by the plant assemblages (vegetation types) described in various vegetation classifications and maps that have been produced within the range of the species. The productivity and reliability of different habitats were defined by the species richness, basal area (density), and flower scores of the diet species they contain. Uniform vegetation classifications that encompass large areas have been developed to assist with land use planning and to aid with conservation and management of native vegetation (e.g. Woodgate *et al.* 1994, NSW National Parks and Wildlife Service 1998, NSW National Parks and Wildlife Service 2003a, Tozer *et al.* 2004, Qld Environmental Protection Agency 2005). They describe patterns of distribution and composition of native vegetation. The classifications uniformly focus on the presence and abundance of overstorey species, making them relevant for defining habitat for canopy feeding fauna such as Grey-headed flying foxes. The scale of mapping varies. A scale of 1:100,000 is considered appropriate for most land use management applications, while a scale of 1:25,000 is considered appropriate for areas of intensive land use (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997, Nelder *et al.* 2005). The maximum scale of maps included in this project is 1:100 000, substantial areas are mapped at 1: 25,000 and the finest resolution is 1: 5,000 (Eastern Suburbs Banksia Scrub, NSW Department of Environment and Conservation 2004).

The relative densities of diet plants were estimated from information provided in the descriptions of vegetation types in the classifications. Habitat scores were calculated as the sum of the products of estimates of relative densities and flower scores of each diet plant. Habitat scores for weighted productivity x reliability, productivity and reliability were calculated separately for each vegetation type. Vegetation classifications were sourced from state government agencies, local government and catchment management authorities.

This approach conferred a number of benefits to the study:

1. It provided a method for compiling data on the flowering characteristics of species into a spatial format explicitly designed to describe plant distributions and relative densities.
2. It produced a map-based output, convenient for use by land managers.
3. It provided the opportunity to interrogate and summarise data over different areas of interest and at a range of scales.
4. It allowed the data to be analysed in relation to an increasing range of digital layers describing biotic and abiotic variables, political boundaries, tenure, etc.

<u>Background to vegetation classification and mapping</u>

Several major regional and local vegetation surveys and maps have been produced in south eastern Australia since the early 1990s (see Keith 2002 for NSW review). All maps that were developed prior to 1999 and several developed after that time were based on intuitive vegetation classifications derived from the authors' field experiences and interpretations of changing patterns across the landscape of interest. These products focus on dominant species and can be considered effective in representing major vegetation patterns (Keith 2002).

Methods for classifying and mapping vegetation have developed rapidly since the late 1990s when regional vegetation maps were produced to assist with developing a Comprehensive, Adequate and Representative reserve system within the Australian Regional Forest Agreements (JANIS 1997). Vegetation classifications are increasingly based on analyses of quantitative floristic data; and maps increasingly incorporate both spatial environmental data and remote image interpretation. The precision of the classifications and maps vary and none are perfect representations of extant vegetation. Uniform methods for classifying and mapping vegetation have not been agreed, although standards and guidelines have been published in NSW and Qld (Sivertsen & Smith 2001, Nelder *et al.* 1999).

Recent methods typically involve five components:

1. acquire field samples of floristic and spatial data within the study area;
2. generate a vegetation classification usually based on numerical analyses of field data, but also incorporating more intuitive, expert field knowledge;
3. model the spatial distribution of floristic assemblages using abiotic environmental variables;
4. generate line work from stereoscopic interpretation of aerial photographs;
5. map floristic assemblages.

Estimates of the pre-clearing extent of vegetation types are sometimes produced.

Biases can be introduced at several levels in this process.

Field sampling - The intensity and design of field sampling affects the reliability of the models. Remote areas are often poorly sampled, and vegetation types that occur in remote areas and have restricted distributions are particularly affected.

Predictive layers – Digital layers of variables such as elevation, substrates, climate, and drainage are integral to modeling procedures. The accuracy and precision of these layers vary and are often unknown.

API interpretation – Aerial photograph interpreters create linework (boundaries) for vegetation maps by delineating changes in the patterns they perceive across aerial photographs. The patterns are generally related to vegetation (canopy type), geology and topography. The skills and experience of aerial photo interpreters and the extent of ground truthing influence the quality of the line work they create.

Boundaries - Although boundaries between vegetation types appear as one dimensional lines on the maps, actual boundaries are usually diffuse. They commonly occur as areas of transition along a continuum of changing vegetation, and vary in width. Boundaries are particularly diffuse in eucalypt-dominated vegetation on gentle gradients. Distortions occur in steep and rugged terrain.

Scale – The scale of mapping (1:100,000; 1:25,000, etc) determines the minimum size of polygons that are identified. This effectively governs the minimum scale at which vegetation types are defined, and the level of classification is generally commensurate with the mapping scale. Vegetation can be classified in greater detail in fine scale maps, while closely-related types are grouped in larger scale maps.

Choice of model – The maps are models and the numerical techniques and algorithms that they use assign different degrees of importance to different types of attributes (floristic, ecological, etc).

3.3.2. Calculating habitat scores

The relative densities of diet plants in each vegetation type were estimated from the type description presented in reports on the classification projects. Habitat scores were calculated by summing the products of estimates of relative densities and nectar scores of each diet plant in the vegetation type.

The procedures used to delineate dominant canopy species vary between vegetation classifications and can be grouped as descriptive and quantitative accounts. Each approach uses standard methods and we therefore developed two procedures for estimating species densities within habitats: an averaging method for use in descriptive accounts and a frequency-cover abundance method for use in quantitative accounts. The frequency-cover abundance method is the more objective and has been applied preferentially over the averaging method where the data are available.

<u>Averaging method</u>

This method is used for vegetation classifications where the species composition of the canopy is described by lists of dominant and subdominant or associated species (eg. Qld Regional Ecosystems (Qld Environment Protection Agency 2005) and NSW Forest Types (Forestry Commission of NSW 1989)). The relative dominance and frequency of species are indicated in the text of reports or in species lists punctuated with standard symbols. Species in each category are listed in order of abundance.

Habitat scores were calculated by averaging the scores of canopy trees and weighting for dominance or sub-dominance. Equal weight was given to the scores of all dominant species and the weight of a single dominant was given to the average score of subdominants. Where only one sub-dominant species was listed, its score was halved. In species rich habitats, all dominant species and the three most abundant sub-dominant species were considered. Species nectar scores were incorporated into the formulae to generate habitat nectar scores. Species not in the diet of Grey-headed flying foxes were assigned scores of 0.

For example:
SEQ Region
RE 12.3.4. *Melaleuca quinquenervia, Eucalyptus robusta* open forest on or near coastal alluvial plains.
Both species are diet plants, both are dominants.
Species density formula for RE 12.3.4. =AVERAGE(MEQUI,EUROB)
The species wt p*r score for MEQUI = 0.88; and EUROB = 1.0;
Then the habitat wt p*r score = (0.88 + 1.0)/2 = 0.94

RE 12.5.12. *Eucalyptus racemosa, E. latisinensis* ± *Corymbia gummifera, C. intermedia, E. bancroftii* woodland with heathy understorey on remnant Tertiary surfaces
E. racemosa and *E. latisinensis* are dominant species, neither is a diet plant.
C. gummifera, C. intermedia and *E. bancroftii* are sub-dominant species, all are diet plants.
Species density formula = AVERAGE(0,0,AVERAGE(COGUM,COINT, EUBAN))
Species wt p*r scores - COGUM= 0.65; COINT = 0.81; EUBAN = 0.54
Habitat wt p*r score = 0.22

<u>Frequency – cover abundance method</u>

This method was used where the occurrence of species in vegetation types was described numerically in tables of standard data from field samples (e.g. SCIVI map units (Tozer *et al.* 2006) and Yengo-Parr map units (NSW Department of Environment and Climate Change 2008a). For each vegetation class, the frequencies (f) of canopy species were calculated as the proportion of field samples in which the species was recorded. Cover abundance scores (C/A) were taken as median scores from the field samples, scored on a 6 class modified Braun-Blanquet scale (Poore 1955). Tree species with frequencies <0.3 or C/A scores <2 were excluded from calculations of habitat scores due to their infrequent or sparse occurrence in the vegetation class.

Then:

1. the density estimate of each canopy species in a vegetation type was calculated as: $d = f * C/A$;
2. the relative density of each diet species was calculated as the density estimate of that species divided by the sum of densities of all species: $Rd = d_i/\Sigma(d_{1\text{-}k})$;
3. the density-weighted nectar score for each diet species was calculated as: NS = Rd * species nectar score;
4. finally, the total nectar score for the habitat is the sum of density-weighted nectar scores: $Ts = \Sigma(NS_{1\text{-}k})$

For example:
SE NSW Region
SCIVI Map Unit p90 Batemans Bay Cycad Forest
Contains three canopy trees with C/A scores $\geq$2 and frequencies $\geq$0.3. Two are in the diet of Grey-headed flying foxes

Species	f	C/A	Species wt p*r score
C. maculata	0.71	2	0.65
E. globoidea	0.62	2	-
E. paniculata	0.52	2	0.49

Species density formula =
(COMAC*2*0.71)/(2*0.71+2*0.52+2*0.62)+(EUPAN*2*0.52)/(2*0.71+2*0.52+2*0.62)
Habitat wt p*r score = 0.39

3.3.3. Generating bi-monthly habitat scores

Bi-monthly habitat scores were generated by including in calculations of habitat scores only those species that are productive in each bi-month. Diet species that were not productive in a given bi-month were assigned scores of zero in that calculation. For each habitat in each region bi-monthly habitat scores were produced for productivity, reliability and wt p*r.

3.3.4. Area-weighted index

Area-weighted indices were calculated to summarise overall levels of habitat quality across regions, and to allow comparisons to be drawn between regions of different land area. They are the sum of products of habitat scores for individual vegetation types and the area of types found within the region of interest, divided by the total land area of the region, $(\Sigma_{1-j}(\text{habitat score}_{(j)} * \text{area}_{(j)}))/\text{total land area}$. Area-weighted indices for weighted productivity x reliability were calculated in each region, at each bi-monthly interval.

3.4. Fruit habitat scores

Insufficient data were available on the productivity and reliability of plants in the fruit diet of Grey-headed flying foxes to allow comparisons to be drawn between species. Fruit bearing (usually rainforest) vegetation types were therefore scored on the species richness of diet plants. Types that contained ≥10 species were assigned the highest score, habitats with 5-9 species were assigned an intermediate score, habitats with <5 species were assigned a low score. The range of Grey-headed flying foxes runs from the species-rich subtropical zone in the north to a species-poor temperate zone in the south. Over 90% of plants in the fruit diet reach their southern extent within the range of the animals. Where vegetation classifications were defined over local areas, shifts in species distributions were taken into account in the descriptions of vegetation types (e.g. Bell 2006). Where vegetation classifications covered extensive areas over which a number of diet plants reached their range limit, changes in species richness were not always reflected in habitat descriptions. In these circumstances, separate data on species distributions were acquired and incorporated into the assessments of vegetation types (Floyd 1989, CHAH 2007).

3.5. Habitat ranks

A primary aim of this project was to identify habitat necessary to secure continuous forage for Grey-headed flying foxes and support key biological requirements of the species. These conditions introduce spatial and temporal elements to the ranking process which we accommodated by conducting separate assessments of habitat quality in each of the five regional areas and in each bi-monthly period; that is, 30 region x bi-month assessments. Final habitat ranks were assigned to the vegetation types within each region using the highest rank achieved in any bi-monthly interval.

This procedure ensured that the critical, short-term role of highly seasonal habitats was captured in the ranking process; that differences between regions in the relative importance of widespread vegetation types were captured; and that high ranking habitat was dispersed through space and time; i.e. across the distribution of Grey-headed flying foxes and throughout the year. By sampling each region separately we also built into the ranking process a degree of resilience to impacts on flowering and fruiting patterns from unfavourable climatic conditions that occur at local or regional scales.

3.5.1. Biological considerations

Four key areas in the biology and ecology of Grey-headed flying foxes were identified as requiring attention. We considered it important to allocate high ranks to feeding habitats that support animals under each condition. They included: periods of recurring food bottlenecks; periods in the annual reproductive cycle associated with elevated energetic requirements; periods of high rates of visitation to commercial fruit crops (which expose animals to lethal crop protection methods) and migration pathways. The first three considerations have strong temporal elements, being associated with specific months or seasons. The fourth introduces a further imperative for sampling vegetation through combinations of space and time. We consider that the method of ranking habitats in 30 bi-month x region assessments provides for these conditions. The rationale for each is as follows.

Food bottlenecks

Recurrent, widespread food shortages for Grey-headed flying foxes have been recorded in winter and spring (Eby 1999 and unpublished data, Collins 2000, Parry-Jones and Augee 2001). These incidents are consistently associated with rapid weight loss in adults and substantial reductions in pre-weaning reproductive output. Evidence of repeated food shortages during winter and spring suggest inadequate productive foraging habitat currently exists in these seasons to sustain the current population. Supplementary plantings of food trees have been proposed as a method for ameliorating the impact of food bottlenecks as has targeted conservation of winter/spring feeding habitat (Law *et al.* 2002).

Reproductive cycle

The reproductive cycle of Grey-headed flying foxes is seasonal and largely synchronous (Nelson 1964, Martin *et al.* 1996). Conception occurs in April/May, gestation lasts approximately six months, births commence as early as late September and continue into November in some years, and lactation continues through March/April. Females spontaneously abort if exposed to physiological stress during the final trimester of pregnancy, and lactation can be interrupted during food shortages (Martin *et al.* 1996). Therefore, elevated energy demands associated with reproduction last from late winter through autumn.

Migration paths

The migrations of Grey-headed flying foxes are complex, variable and occur throughout the year (Eby 1991 and 1996, Tidemann and Nelson 2004, van der Ree *et al.* 2006). Broad regional patterns are apparent (Eby 2003, 2006). However, complexity is introduced by highly productive diet species that sometimes flower in unusual areas (Eby 1991), by the increasing use of urban landscapes (Tidemann and Nelson 2004), and by the apparent searching behaviour of individuals whose movements run contrary to general trends (Tidemann and Nelson 2004; B. Roberts, Griffith University unpublished data). The habitats that support long-distance migrations also include stopover sites (Fleming and Eby 2003). This complex system is best conserved by targeting high quality feeding habitats distributed through space and time.

Use of commercial fruit crops

Grey-headed flying foxes have caused damage to cultivated fruit crops since the time of European settlement (Ratcliffe 1931, Tidemann *et al.* 1997). Levels of damage vary considerably between localities and years, and there is consistent evidence that the animals increase their use of commercial crops when native food is scarce (Ratcliffe 1931, McWilliam 1986, Teagle 2002). In these circumstances greater numbers of animals are exposed to mortality from crop management practices. We considered that mortality in crops will be ameliorated by conserving habitat that is productive during periods of fruit maturation.

Table 3.2. The timing of biological considerations for Grey-headed flying foxes, scored at bi-monthly intervals.

Issue	**D-J**	**F-M**	**A-M**	**J-J**	**A-S**	**O-N**
Food shortages				X	X	
Pregnancy (final trimester) & birth				x	X	X
Lactation	X	X				X
Mating and conception	x	X	X			
Migration paths	X	X	X	X	X	X
Fruit industries	X	X			X	X

3.5.2. Bi-monthly habitat ranks (nectar)

The weighted productivity * reliability scores of habitats were used to assign ranks to vegetation in each bi-monthly period. Each region was assessed separately. Scores were classified into four ranks of equal land area, with 1 being the highest rank. Each rank then comprised one quarter of the foraging habitat.

The procedure for each bi-month was to:

1. sort wt p*r habitat scores in descending order,
2. calculate the total productive habitat area in the region and the bi-month being considered (the total area of each habitat in a region was derived from ARCView map layers),
3. using the total productive area as the base, calculate quartiles of productive area;
4. allocate habitats to ranks in descending order of wt p*r scores until bounds for each category as defined by the equal area value were reached.

Extra value was placed on retaining habitats that are productive during months associated with food shortages. In the June-July and August-September bi-months, 50% of the productive area was assigned rank 1 and the residual 50% was allocated evenly between the remaining ranks (ie 16.7% each to ranks 2 to 4).

3.5.3. Final habitat ranks

The final nectar rank of a vegetation type was taken as the highest bi-monthly rank assigned to it. This ensured that the maximum productive value of a vegetation type was ranked and mapped. Using this method the most productive vegetation was identified in each region, thus fulfilling the objective to identify key habitat across the range of the species.

Examples from two vegetation types referred to in 3.3.2:

SEQ region

RE 12.3.4. *Melaleuca quinquenervia*, *Eucalyptus robusta* open forest on or near coastal alluvial plains.

	Bi-monthly phenology					
Diet species	D-J	F-M	A-M	J-J	A-S	O-N
E. robusta			X	X		
M. quinquenervia			X	X		
Bi-monthly habitat scores	0	0	0.94	0.94	0	0
Bi-monthly ranks			1	1		
Final rank	**1**					

SE NSW region

SCIVI Map Unit p90: Batemans Bay Cycad Forest

	Bi-monthly phenology					
Diet species	D-J	F-M	A-M	J-J	A-S	O-N
C. maculata		X	X	X	X	
E. paniculata	X				X	X
Bi-monthly habitat scores	0.14	0.14	0.25	0.25	0.39	0.14
Bi-monthly ranks	4	4	2	2	1	3*
Final rank	**1**					

* the same score can achieve different ranks in different bi-months depending on the total area of productive habitat in the bi-month, and relationships between the habitat scores and the areas of individual habitats.

We considered that the reliable nature of fruiting phenologies in diet plants was of particular benefit to Grey-headed flying foxes, providing relatively predictable feeding habitat. A rank of one was subjectively assigned to rainforest habitats containing ≥5 diet plants, a rank of two was assigned to habitats with <5 diet plants.

4. Results

This chapter presents summaries of range-wide results. More detailed descriptions of regional data are provided in the Regional Profiles (Chapters 7-11).

4.1. Diet lists

The final diet lists for Grey-headed flying foxes comprised 59 species in the blossom diet and 46 species in the fruit diet. It was unlikely that the lists were comprehensive. Use by the animals was less likely to be observed in diet species with restricted distributions or distributions in remote or unpopulated areas. Newly recognised plant species were also less likely to be identified as diet species. Taxonomy and systematics of the Australian flora are active areas of research, particularly in the *Eucalyptus* where new species continue to be recognised. Field work targeted to clarify use of newly identified species by flying foxes is seldom conducted and it was generally not possible to confirm their use from previous field work.

4.1.1. Blossom diet

Flowering trees in the diet list were primarily of the Myrtaceae and Proteaceae, although single species of Arecaceae, Fabaceae and Pittosporacea were also used. The majority of species were eucalypts (genus *Eucalyptus, Corymbia* or *Angophora*) (80%; n=47).

Four species on the blossom list were not identified as dominants or subdominants in any of the vegetation classifications used to rank habitats and were not considered further. They were *E. fusiformes, E. tetrapleura, Callistemon salignus* and *Stenocarpus sinuatus.* The flowering characteristics of 55 species were scored and used to rank feeding habitat for Grey-headed flying foxes (Table 4.1.)

In New South Wales, the blossom diet list comprises approximately 23% of the eucalypt species that occur in the range of Grey-headed flying foxes (Table 4.2.). All members of *Corymbia* are used and 25% of *Angophora*. *Eucalyptus* is a highly diverse genus and various subgenera and sections have been recognised (Pryor and Johnson 1971 as modified by Harden 2002). Diet species are not dispersed evenly across these groups. Within the subgenus Symphyomyrtus, trees in the sections Transversaria (blue gums, grey gums, red mahoganies), Exsertaria (red gums) and Adnataria (boxes, ironbarks) are over represented, while Maidenaria (manna gums, river gums, apple boxes) and the subgenus Monocalyptus (white mahoganies, stringybarks, peppermints, ashes) are under represented.

4.1.2. Fruit diet

The fruit diet of Grey-headed flying foxes is taxonomically diverse. It contains 50 species of 29 families. The majority of families are represented by one species. Only the Moraceae (figs) and Myrtaceae (lilly pillies and cherries) are represented by more than three species. There are 42 trees on the list, seven liana or climbers, and one mistletoe. All but one species occur in rainforest vegetation. *Rhagodia candolleana* Seaberry saltbush is a scrambling climber found in saline or sandy coastal habitats.

Table 4.1. Species in the blossom diet of Grey-headed flying foxes and their flower scores. Where more than one score was assigned to the species, the range is given. No scores are given for species that were not identified in descriptions of vegetation types. Species with high (≥0.65) wt p*r scores are indicated by shading. These are considered significant food plants for the animals.

Family	Species	Common name	Prod	Relia	Wt p*r
Fabaceae	*Castanospermum australe*	Black bean	0.77	1	0.83
Proteaceae	*Banksia integrifolia v. int*	Coast Banksia	0.77	1	0.83
	B. serrata	Old Man Banksia	0.54	0.30	0.45
	Grevillea robusta	Silky Oak	1	1	1
Myrtaceae	*Angophora costata*	Smooth-barked Apple	0.37	0.30	0.35
	A. floribunda	Rough-barked Apple	0.54	0.30	0.45
	A. leiocarpa		0.37	0.30	0.35
	Corymbia citriodora citriodora	Lemon-scented Gum	0.91	0.30	0.65
	C. eximia	Yellow Bloodwood	0.70	0.30	0.54
	C. gummifera	Red Bloodwood	0.91	0.30	0.65
	C. henryi	Large-lved Spotted Gum	0.70	0.30	0.54
	C. intermedia	Pink Bloodwood	1	0.60	0.86
	C. maculata	Spotted Gum	0.91	0.30	0.65
	C. tessellaris	Carbeen	0.61	0.15	0.40
	C. trachyphloia	Brown Bloodwood	0.54	0.30	0.45
	C. variegata	Northern Spotted Gum	0.91	0.30	0.65
	Eucalyptus acmenoides	White Mahogany	0.37	0.60	0.43
	E. albens	White Box	0.70	0.30	0.54
	E. amplifolia	Cabbage Gum	0.70	0.15	0.44
	E. andrewsii	New England Blackbutt	0.59	0.80	0.65
	E. bancrofti	Orange Gum	0.70	0.30	0.54
	E. botryoides	Southern Mahogany	0.54	0.45	0.51
	E. camaldulensis	River Red Gum	0.70	0.60	0.67
	E. campanulata	New England Blackbutt	0.37-0.54	0.30-0.45	0.39-0.45
	E. cloeziana	Gympie Messmate	0.47	0.15	0.34
	E. deanei	Mtn Blue Gum	0.70	0.80	0.73
	E. fibrosa	Broad-leaved Ironbark	0.70	0.30	0.54
	E. grandis	Flooded Gum	0.54	0.60	0.56
	E. longirostrata	Grey Gum	0.54	0.15	0.37
	E. maidenii	Maiden's Gum	0.54	0.30	0.45
	E. major	Grey Gum	0.54	0.15	0.37
	E. melanophloia	Silver-leaved Ironbark	0.54-0.70	0.30	0.45-0.54
	E. melliodora	Yellow Box	0.32	0.60	0.39
	E. moluccana	Grey Box	0.37-0.59	0.30-0.80	0.35-0.65
	E. muelleriana	Yellow Stringybark	0.47	0.30	0.41
	E. paniculata	Grey Ironbark	0.61	0.30	0.49
	E. parramattensis	Parramatta Red Gum	0.54	0.30	0.45
	E. pilularis	Blackbutt	0.54-0.80	0.45	0.51-0.67
	E. piperita	Sydney Peppermint	0.59	0.45	0.55
	E. planchoniana	Needlebark	0.70	0.30	0.54
	E. propinqua	Small-fruited Grey Gum	0.47	0.15	0.34
	E. punctata	Large-fruited Grey Gum	0.54	0.60	0.56
	E. pyrocarpa	Large-fruited Blackbutt	0.70	0.30	0.54
	E. resinifera	Red Mahogany	0.54	0.15	0.37
	E. robusta	Swamp Mahogany	1	1	1
	E. rummeryi	Steel Box	0.70	0.30	0.54
	E. saligna	Sydney Blue Gum	0.70	0.80	0.73
	E. seeana	Narrow-leaved Red Gum	0.77	0.80	0.78
	E. siderophloia	Grey Ironbark	0.91	0.60	0.81
	E. sideroxylon	Mugga Ironbark	0.70	0.30	0.54
	E. tereticornis	Forest Red Gum	0.54-0.91	0.15-0.60	0.37-0.88
	E. tricarpa	Red Ironbark	0.47	0.15	0.34
	Lophostemon confertus	Brush box	0.41	0.63-0.80	0.46
	M. quinquenervia	Five-veined Paperbark	0.91	0.80	0.88
	Syncarpia glomulifera	Turpentine	0.54-0.59	0.60-0.80	0.56-0.65

Table 4.2. Associations between taxonomic groups of eucalypts in New South Wales and use by Grey-headed flying foxes. Groupings after Harden (2002). Presence within the range of the animals was determined from descriptions of distribution in Harden (2002) and clarified where needed from herbarium records (Botanic Gardens Trust 2008). *Angophora* with low growth form were not included in the assessment of available species. Genera are in bold italics, subgenera are underlined, sections or descriptive groups are in normal text.

	diet spp	spp in range of GHFF	proportion
Angophora	2	8	0.25
Corymbia	6	6	1
Eucalyptus			
Blakella	1	1	1
Eudesmia	0	1	0
Nothocalyptus	0	1	0
Symphyomyrtus			
Transversiana	8	14	0.57
Bisectaria	0	1	0
Dumaria	0	0	0
Exsertaria	6	13	0.46
Maidenaria	1	46	0.02
Adnataria	13	28	0.52
Total Symphyomyrtus	28	102	0.27
Monocalyptus			
White Mahoganies	1	4	0.25
Stringybarks	1	29	0.03
Peppermints	2	7	0.29
Green-leaved Ash	0	16	0
Black Sallies	0	4	0
Blue-leaved Ash Group A	2	7	0.29
Blue-leaved Ash Group B	2	12	0.17
Total Monocalyptus	8	79	0.10
Total	**46**	**198**	**0.23**

Table 4.3. Species in the fruit diet of Grey-headed flying foxes and an estimate of the southern limit to their range (decimal degrees). Species on this list have been confirmed by observations of feeding animals or by identification of faecal or spat material.

Family	Species	Common name	Latitude of southern limit
GYMNOSPERMAE			
Podocarpaceae	*Podocarpus elatus*	Plum Pine	35.7
ANGIOSPERMAE			
Anonaceae	*Rauwenhoffia leichardtii*	Zig Zag Vine	30.3
Apocynaceae	*Melodinus australis*	Southern Melodinus	34.5
Arecaceae	*Livistona australis*	Cabbage Palm	37.8
	Archontophoenix cunninghamiana	Bangalow Palm	35.7
Avicenniaceae	*Avicennia marina*	Grey Mangrove	39
Caprifoliaceae	*Sambucus australasica*	Yellow Elderberry	37.8
Chenopodiaceae	*Rhagodia candolleana*	Seaberry Saltbush	Tasmania
Cunoniaceae	*Schizomeria ovata*	Crabapple	36.2
Davidsoniaceae	*Davidsonia* spp.	Davidson's Plum	28.8
Ebenaceae	*Diospyros pentamera*	Myrtle Ebony	35.5
Ehretiaceae	*Ehretia acuminata*	Koda	36.7
Elaeocarpaceae	*Elaeocarpus obovatus*	Hard Quandong	33.3
	E. reticulatus	Blueberry Ash	Tasmania
	E. grandis	Blue Fig	30.7
Escalloniaceae	*Polyosma cunninghamii*	Featherwood	35.5
Euphorbiaceae	*Mallotus discolor*	White Kamala	29.7
Icacinaceae	*Pennantia cunninghamii*	Brown Beech	35.7
Meliaceae	*Melia azedarach*	White Cedar	34.9
Monimiaceae	*Hedycarya angustifolia*	Native Mulberry	Tasmania
Moraceae	*Ficus coronata*	Creek Sandpaper Fig	37.8
	F. fraseri	Sandpaper Fig	33.3
	F. macrophylla	Moreton Bay Fig	34.9
	F. obliqua	Small-leaved Fig	36.2
	F. rubiginosa	Rusty Fig	37
	F. superba	Deciduous Fig	35.3
	F. virens	White Fig	29.7
	F. watkinsiana	Strangler Fig	32.4
	Maclura cochinchinensis	Cockspur Thorn	35.3
Myrtaceae	*Acmena hemilampra*	Broad-leaved Lilly Pilly	29.4
	A. ingens	Red Apple	28.9
	A. smithii	Lilly Pilly	39
	Rhodamnia argentea	Malletwood	31.4
	Syzygium australe	Brush Cherry	35.7
	S. corynanthum	Sour Cherry	31.6
	S. crebrinerve	Purple Cherry	31.6
	S. luehmanii	Riberry	31

Family	**Species**	**Common name**	**Latitude of southern limit**
	S. oleosum	Blue Lilly Pilly	34.4
Passifloraceae	*Passiflora herbertiana*	Native Passionfruit sp.	36.2
Pittosporaceae	*Pittosporum undulatum*	Sweet Pittosporum	38.3
Rhamnaceae	*Alphitonia excelsa*	Red Ash	36.2
Rosaceae	*Rubus rosifolius*	Native Raspberry	38.1
Rubiaceae	*Morinda jasminoides*	Morinda	38.3
Sapindaceae	*Diploglottis australis*	Native Tamarind	34.6
Sapotaceae	*Planchonella australis*	Black Apple	34.4
Solanaceae	*Solanum aviculare*	Kangaroo Apple	Tasmania
Urticaceae	*Dendrocnide excelsa*	Giant Stinging Tree	36.7
	D. photinophylla	Shining-leaved Stinging Tree	33.5
Viscaceae	*Notothixos cornifolius*	Kurrajong Mistletoe	33.5
Vitidaceae	*Cissus hypoglauca*	Five-leaf Water Vine	38.2

4.2. Flower scores

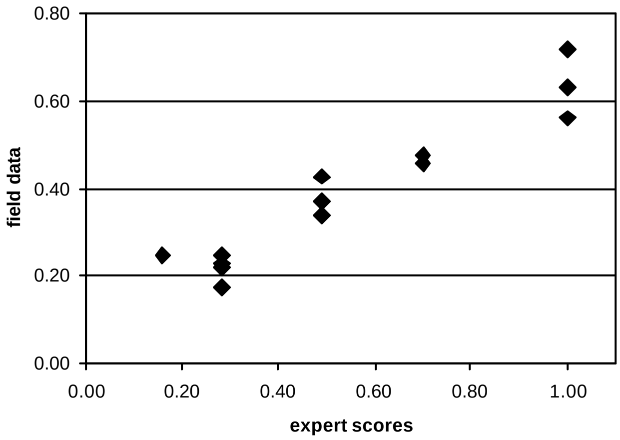
4.2.1 Comparison with field data

The scores of spatial synchrony, annual reliability and variation assigned to 13 diet species by experts, were compared to field data from a ten year study of flowering patterns in forests on the mid-north coast of NSW (Law *et al.* 2000 and unpublished data; Table 4.4). There was a high level of agreement between expert scores and field data in both annual reliability and variation. Commensurate with this result was the close association between reliability scores calculated from the two variables (Figure 4.5.). However, the spatial synchrony scores assigned by experts differed from field data in 30% of diet species. Only species with very low levels of spatial synchrony (field data <0.4) were affected. While field data for these species are within the bounds of the lowest category of scored spatial synchrony (0.4), experts consistently estimated spatial synchrony to fall between 0.4 and 0.7 and assigned the mid-range category of 0.7 (4 of 5 examples). It was outside the scope of this study to examine the impact on wt p*r scores of this bias in spatial synchrony and this should be examined in further work.

Table 4.4. Comparison between the measures of synchrony, annual reliability and variation from a ten-year field study (Law *et al.* 2000) and scores assigned by experts. Data are for 13 diet species. Experts were asked to assign plant species to scores with the following range of values: 0.4 (range: 0- 0.4); 0.7 (range: >0.4 – 0.7); 1 (range: >0.7). Where there were discrepancies, scores consistent with the field data are given in brackets.

	Synchrony		**Annual reliability**		**Variation**	
Species	field data	expert scores	field data	expert scores	field data	expert scores
Angophora floribunda	0.52	0.7	0.33	0.4	0.66	0.7
Banksia integrifolia	0.8	1	0.9	1	0.7	1
Castanospermum australe	0.8	1	0.9	1	0.8	1
Corymbia gummifera	0.33	0.7 [0.4]	0.3	0.4	0.75	0.7
C. variegata	0.31	0.7 [0.4]	0.32	0.4	0.54	0.7
Eucalyptus acmenoides	0.34	0.7 [0.4]	0.52	0.7	0.71	0.7
E. grandis	0.55	0.7	0.5	0.7	0.68	0.7
E. propinqua	0.38	0.4	0.33	0.4	0.75	0.4 [1]
E. resinifera	0.47	0.7	0.34	0.4	0.73	0.7
E. siderophloia	0.34	0.7 [0.4]	0.6	0.7	0.71	0.7
E. tereticornis (coastal)	0.42	0.7	0.72	1	0.66	0.7
Lophostemon confertus	0.8	1	0.51	1 [0.7]	0.9	0.7 [1]

Figure 4.1. The relationship between the reliability scores (annual reliability * variation) of experts and reliability calculated from field data for 13 diet plants.

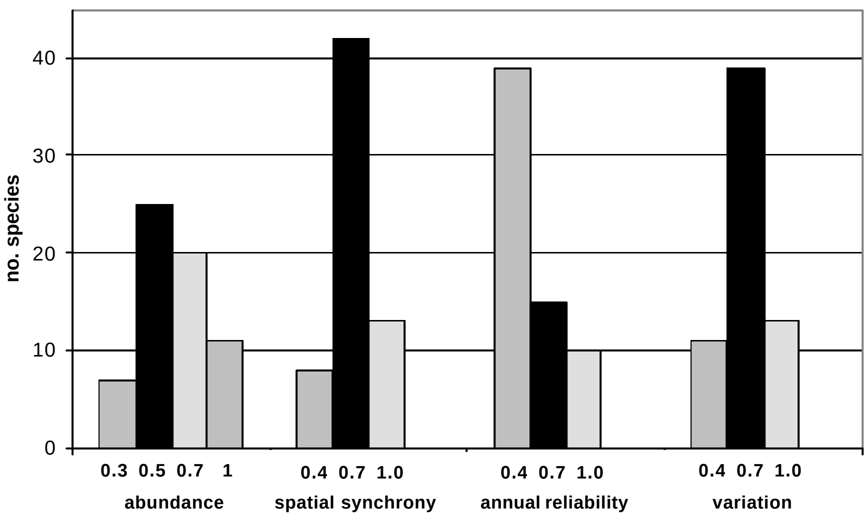


4.2.2. Species scores

The scores assigned to individual species for each of the four variables are listed in Regional Profiles (Chapters 7-11). As variables were scored separately in each of the five regions, there was scope for more than one combination of scores to be assigned to widespread species. The final dataset includes 64 sets of scores from 55 species.

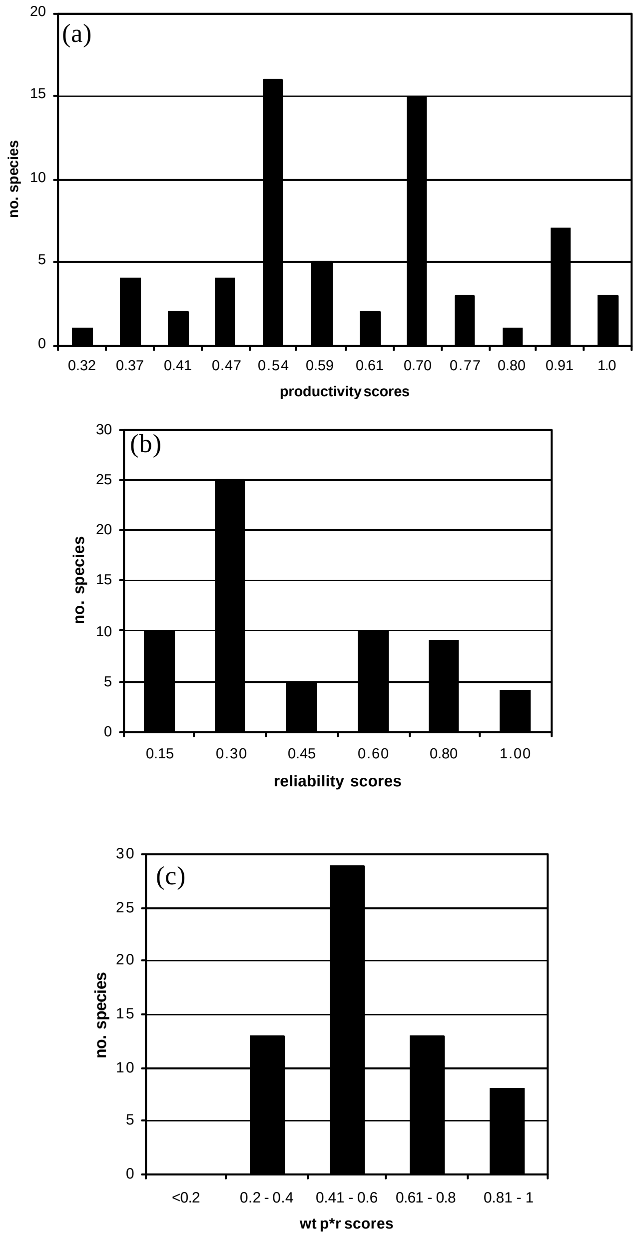
The scores of diet species were not evenly distributed across the possible categories (Figure 4.2). Between 60% and 70% of the scores for abundance, spatial synchrony and variation were attributed to the mid-range value. Scores for annual reliability were skewed to the lowest category with 61% of scores indicating flowering occurs in ≤40% of years. Only 10 scores (17%) indicating flower in >70% of years. We consider these results to reflect actual levels of flowering frequency of diet species, particularly eucalypts.

Figure 4.2. Frequency distributions of flower scores for all diet species across four variables. The scores for abundance are 0.3, 0.5, 0.7 & 1. Scores for the other variables are 0.4, 0.7 & 1.



Frequency distributions of productivity and reliability scores reflect those of the contributing variables (Figure 4.3). Productivity scores were distributed across twelve combinations of abundance and spatial synchrony. Scores generated from products of each of the two mid-range scores of abundance and the mid-range score of spatial synchrony (productivity = 0.54 & 0.70) were assigned to 49% of diet species. Reliability scores were distributed across six combinations of annual reliability and variation and the two lowest categories were assigned to 56% of species, reflecting the bias in annual reliability scores. Twenty-eight scores for weighted productivity x reliability were generated from the data, ranging from 0.335 to 1.0. Few species scored highly for both productivity and reliability, and 12% of wt p*r scores were > 0.8.

Figure 4.3. Frequency distributions of (a) productivity, (b) reliability and (c) weighted productivity x reliability scores of species in the blossom diet of Grey-headed flying foxes. All possible scores of productivity and reliability scores are shown, weighted productivity x reliability scores have been grouped at intervals of 0.2.



4.3.3. Bi-monthly phenologies

Bi-monthly flowering patterns were attributed to all diet species (Table 4.5). The majority of diet species displayed clear seasonal patterns which were consistent over the range of Grey-headed flying foxes. The flowering schedules of 62% of species was restricted to one or two bi-monthly periods.

However, in several wide-spread species, bi-monthly flowering phenologies varied between and within regions. Latitudinal and altitudinal relationships were often apparent. In general, flowering in affected species commenced earlier in northern regions. For example, in *C. maculata* flowering commenced in the December-January bi-month in the UNE NSW region (near Kempsey), in February-March in the LNE NSW region (lower Hunter Valley), and in April-May in the SE NSW region (near Batemans Bay). Within an individual region, flowering in affected species generally commenced earlier on coastal lowlands than on inland ranges. For example, in *E. tereticornis* in the SEQ region, flowering commenced in June-July on coastal lowlands, in August-September on coastal ranges and inland valleys and in October-November in inland ranges and the New England Tablelands. Individual flowering events lasted one or two months in 85% (n=48) of diet species (Table 4.5). However, in some diet species range-wide variations in phenology extended the number of bi-months of productivity, and 11% were recorded as productive in ≥4 bi-months.

Difficulties were encountered in reliably attributing bi-months to *E. pilularis* and *E. paniculata*. In many local areas, the phenological data collated for these species were highly inconsistent. This result is supported by field studies (Florence 1964, Law *et al*. 2000, Law and Chidel 2007). For example, in Sydney, *E. paniculata* flowers from May-August (Fairly and Moore 1989). Somerville and Barnes (1994) report that it flowers between November-January in the Batemans Bay area, while for Nowra it is reported to flower between July-December (Somerville and Colley 1990). Nectar was measured from flowers of this species on the south coast in February, July and December, with nectar production being most prolific in drought-free summers (Law and Chidel 2007). The rules set for identifying bi-months were relaxed for these two species and users of this work should be aware that they are likely be highly productive in bi-months not identified in the Regional Profiles.

The number of productive diet species varied substantially between seasons (Table 4.5). The majority were recorded as productive in the warm months from late spring to early autumn (Oct-Nov, Dec-Jan, Feb-Mar). A total of 52 diet species flower somewhere in the range of Grey-headed flying foxes during at least one of these bi-months, and the greatest number of species is productive in Dec-Jan. Relatively few species are productive in the cool months from late autumn to early spring (Apr-May, Jun-Jul, Aug-Sep). A total of 18 species flower in the range of Grey-headed flying foxes during at least one of these bi-months, and through this time bi-monthly totals range from 12 to13 species. Spatial patterns add a further level of complexity for Grey-headed flying foxes as described below.

Table 4.5. The flowering phenology of species contributing nectar and pollen to the diet of Grey-headed flying foxes assessed across the range of the animals. Data are compilations from all regions in the study. Each bi-monthly period assigned to a diet species is indicated. Scores of duration indicate the length in months of individual flowering events.

	D-J	F-M	A-M	J-J	A-S	O-N	Duration
Angophora costata	X					X	1
A. floribunda	X	X				X	1
A. leiocarpa	X					X	1
Banksia integrifolia			X	X	X		≥3
B. serrata	X	X	X				2
Castanospermum australe	X					X	2
Corymbia citriodora			X	X	X		≥3
C. eximia						X	1
C. gummifera	X	X	X				2
C. henryi	X					X	≥3
C. intermedia	X	X					2
C. maculata	X	X	X	X	X		≥3
C. tessellaris	X	X					1
C. trachyphloia	X	X					2
C. variegata	X	X	X	X		X	≥3
Eucalyptus acmenoides	X					X	1
E. albens				X	X		≥3
E. amplifolia	X					X	2
E. andrewsii	X	X					2
E. bancroftii	X					X	1
E. botryoides	X	X					1
E. camaldulensis	X	X					2
E. campanulata						X	1
E. cloeziana	X					X	1
E. deanii	X	X					1
E. fibrosa	X	X	X	X		X	2
E. grandis		X	X				2
E. longirostrata	X	X					2
E. maidenii		X					2
E. major	X	X					2
E. melanophloia	X			X		X	2
E. melliodora	X	X				X	2
E. mollucanna		X					2
E. muelleriana	X	X					2
E. paniculata	X	X	X	X	X	X	≥3
E. parramattensis	X						2
E. pilularis	X	X	X	X	X		2
E. piperita	X	X					1
E. planchoniana	X	X				X	2
E. propinqua	X	X					2
E. punctata	X	X					1
E. pyrocarpa		X					2
E. resinifera	X	X				X	2
E. robusta			X	X	X		≥3
E. rummeryi	X					X	2
E. saligna	X	X	X				1
E. seeana					X	X	2
E. siderophloia	X				X	X	2
E. sideroxylon				X	X	X	≥3
E. tereticornis	X	X		X	X	X	2
E. tricarpa		X	X	X			2
Grevillea robusta						X	1
Lophostemon confertus	X					X	1
Melaleuca quinquenervia		X	X	X			≥3
Syncarpia glomulifera					X	X	2
Total count	**40**	**32**	**13**	**13**	**12**	**27**	

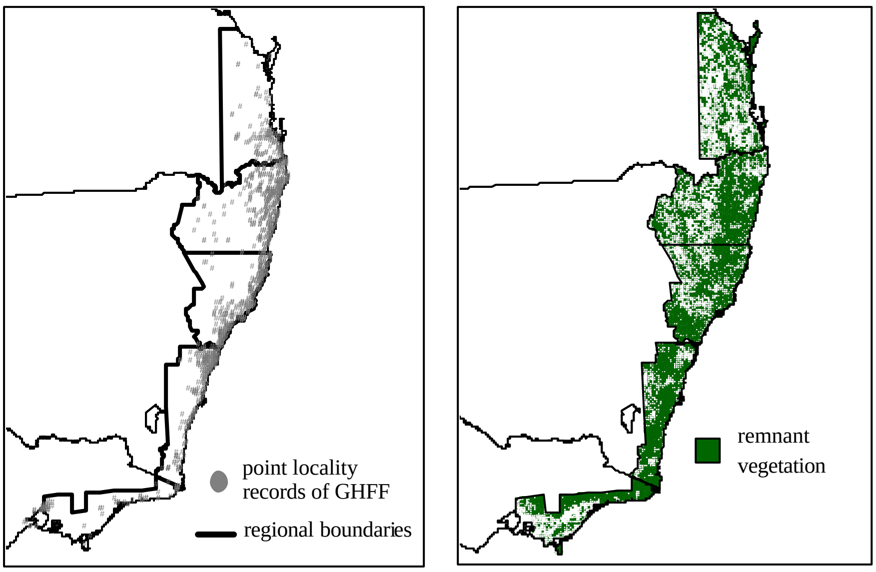
4.3. Habitat scores

Habitat data for this study were compiled from 24 vegetation classifications (see Regional Profiles for references). The accompanying digital maps provided nearly complete coverage of the study area and included approximately 26.4 million hectares of land (Figure 4.4). Over 5,200 vegetation types were defined within the study area.

Approximately 50% of the land area was mapped as being cleared of native vegetation (Table 4.6). The definitions of cleared land varied between vegetation classifications, but the category generally included areas where all native vegetation had been removed (including urban land, areas of intensive agriculture, introduced plantings, mines, etc.); areas containing remnant patches of vegetation too small to be identified in API linework; and areas containing scattered trees (>1ha with <10% crown cover). Clearing patterns were uneven across the study area, primarily affecting vegetation in coastal lowlands, and on soils of medium to high fertility in plateaux, tablelands and slopes.

Few vegetation classifications provided assessments of habitat disturbance or of variations in canopy condition, and the methods used for such assessments differed. It was beyond the scope of this study to either reconcile different systems of measuring canopy condition or to incorporate condition into classifications that had not previously described this attribute. Variations in the condition of remnant vegetation were therefore not taken into account in this work. Grey-headed flying foxes are known to feed in highly disturbed vegetation, including isolated paddock trees, so long as flowering or fruiting persists, suggesting that condition *per se* would not preclude use by the animals (Eby 1996).

Figure 4.4. Maps of the study area showing (a) the extent of coverage of vegetation classifications and maps relative to the range of Grey-headed flying foxes as defined by areas of repeated use (see Section 1.2 for method). Point locality records in the far south-west are associated with urban areas of Melbourne and Geelong, Vic. Feeding habitats in these areas were not included in the study. (b) the extent of remnant native vegetation as mapped by the vegetation classification projects compiled for this study.



Nonetheless, the influences of canopy condition and unmapped scattered trees on overall assessments of habitat quality are not known and this is a topic recommended for further work (but see Law and Chidel 2007).

The scale of mapping varied not only between vegetation classifications, but within them. The scale was generally either 1:100,000 or 1:25,000, and the resolution of line work was finer than 1:25,000 in the urban areas of Brisbane and Sydney and in several local government areas along the coast. Further details are presented in Regional Profiles.

Vegetation classifications in SE NSW, the southern portion of LNE NSW and the Nandewar bioregion (far west UNE NSW and LNE NSW) used quantitative accounts to describe the floristic composition of vegetation types. Vegetation classifications elsewhere defined vegetation types using descriptive accounts.

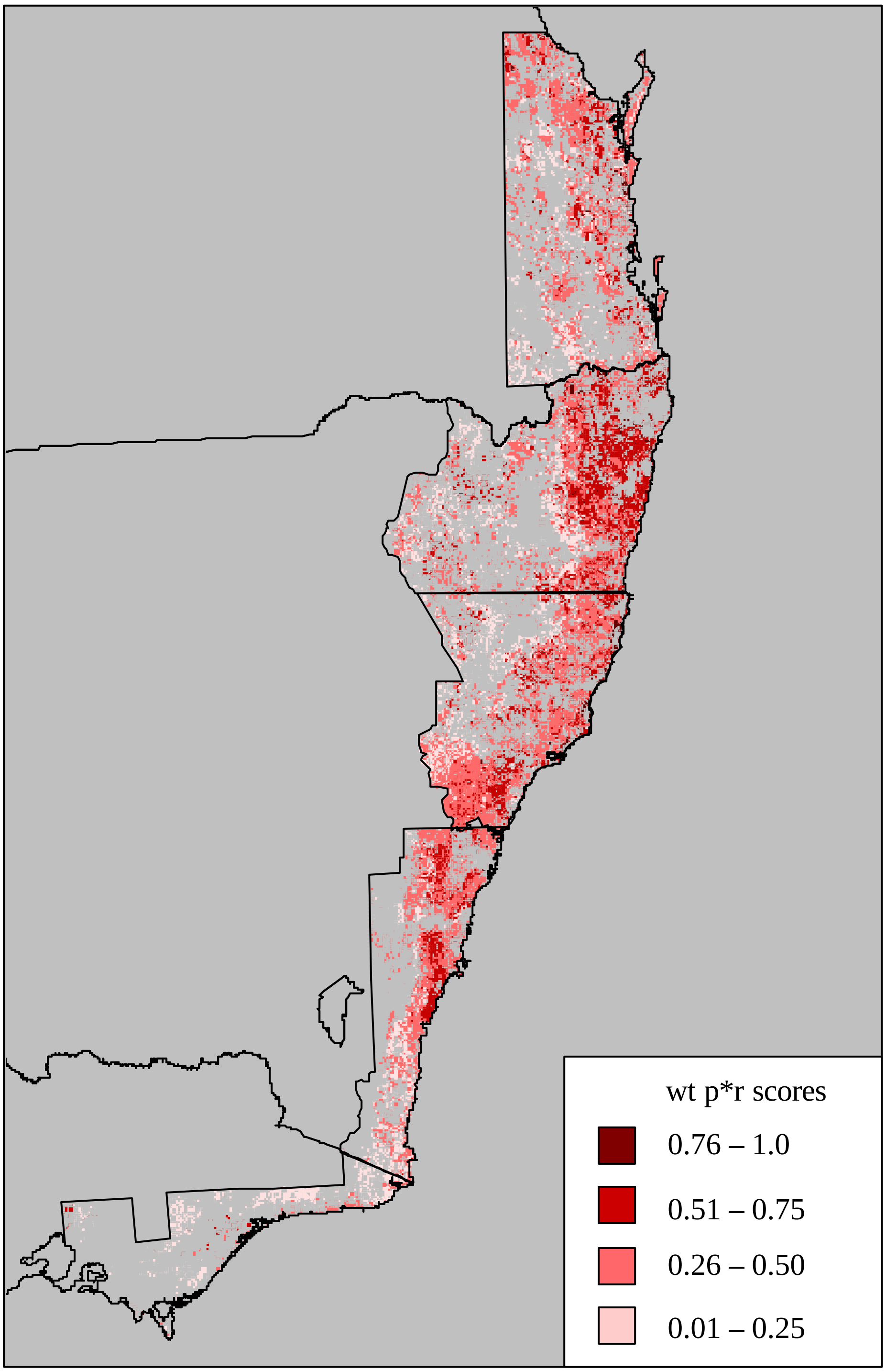
4.3.1. Total habitat scores

Interactions between the distribution, density, flower scores and flowering phenologies of diet plants produced diverse patterns of habitat productivity for Grey-headed flying foxes. Species in the blossom diet occurred as dominants or sub-dominants in the overstorey of 75% of the vegetation types described in the vegetation classifications used in the study (n = 3,761). Total weighted productivity x reliability scores were used to illustrate spatial patterns of overall habitat quality within the study area (Figure 4.5). It should be noted that these total habitat scores did not take seasonal variations into account and were not used to assess the significance of vegetation types for Grey-headed flying foxes.

Table 4.6. Regional comparisons of habitat productive for Grey-headed flying foxes and species richness of diet plants. The extent of remnant vegetation and productive habitat are given in hectares (rounded to 10^3) and as percentages of total land area. The area-weighted index is a measure of relative productivity between regions (wt p*r). See Section 2.3.4.

	SEQ	**UNE NSW**	**LNE NSW**	**SE NSW**	**VICTORIA**	**Range-wide totals**
Total land area (ha)	6,689,000	7,243,000	5,333,000	4,069,000	3,094,000	26,428,000
Remnant vegetation	2,679,000	3,895,000	3,103,000	2,076,000	1,783,000	13,556,000
Region (%)	40	54	58	51	58	51
Nectar habitat (ha)	2,144,000	2,536,000	2,382,000	1,442,000	366,000	8,767,000
Region (%)	32	35	45	35	12	33
Fruit habitat (ha)	108,000	187,000	174,000	48,000	7,000	524,000
Region (%)	2	3	3	1	0.2	2
Total productive area	2,252,000	2,723,000	2,556,000	1,491,000	373,000	9,292,000
Region (%)	34	38	48	37	12	35
Blossom species (n)	37	40	40	28	11	55
Fruit species (n)	50	50	43	34	13	50
Area-weighted index	0.12	0.15	0.18	0.14	0.035	0.13

Figure 4.5. A map of the study area showing the distribution of vegetation types that contain plants contributing nectar and pollen to the diet of Grey-headed flying foxes. Graduated (darkening) colours of red indicate increasing wt p*r scores. Total wt p*r scores are shown, seasonal variations are not taken into account. Polygons containing the highest-scoring vegetation (wt p*r = 0.76 – 1.0) are small, rare and generally not discernible at the scale of this map.

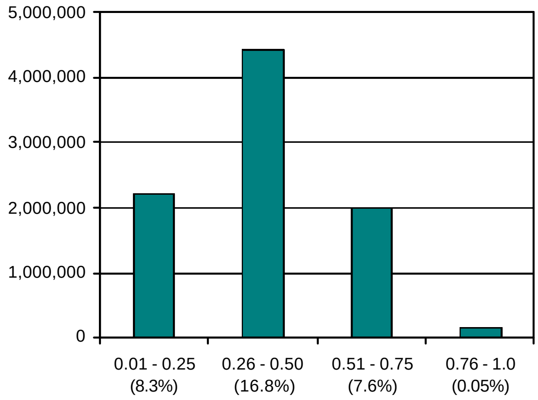


Forests and woodlands that produce nectar for Grey-headed flying foxes cover 33.2% of the study area, or 69% of remnant vegetation (Table 4.6., Figure 4.5.). The distribution of productive habitat was influenced by regional patterns of clearing and species richness of diet plants. Extensive tracts of productive habitat were located on land not suitable for human development or agriculture, such as slopes of the coastal ranges and less steep land of low soil fertility. In landscapes favoured for development and agriculture, such as coastal lowlands, plateaux, and fertile soils of the tablelands and inland slopes, productive habitat occurred primarily as small, disjunct remnants. The species richness of plants in the blossom diet was largely consistent between regions in northern NSW and SEQ. However, species richness fell substantially in SE NSW and Victoria (Table 4.). Only five diet species were mapped in native vegetation near the southern boundary of Grey-headed flying foxes, including *B. integrifolia, E. camaldulensis, E. melliodora* and *E. tricarpa.*

The total weighted productivity x reliability scores of individual vegetation types ranged from 0.1 to 1.0 (see Regional Profiles and Appendices for details). High scoring habitat (wt p*r >0.76) was rare (Figure 4.6.), and primarily comprised small remnants of coastal floodplain forest containing *E. robusta*, *E. tereticornis* or *M. quinquenervia.* Each of these species scored highly for both productivity and reliability. Extensive tracts of habitat with wt p*r scores in the range of 0.51 to 0.75 were unevenly distributed across coastal lowlands and ranges north from Narooma, NSW. These vegetation types commonly comprised wet and dry forests containing species of *Corymbia* (bloodwoods and spotted gums), ironbarks and blackbutt, and wet forests containing blue gums. Vegetation types of this quality also occurred west of the escarpment where they were associated with fertile soils and agricultural landscapes. They generally comprised small, isolated remnants of box woodland or floodplain woodlands with river red gum.

Over 75% of productive habitat scored in the range of 0.26 to 0.50. Types in this category were distributed throughout the range of Grey-headed flying foxes and overlapped the distribution of all diet species.

Figure 4.6. The area (ha) of habitat assigned to total weighted productivity x reliability scores categorised at four equal intervals. Percentages of the study area in each category are in parentheses.



4.3.2. Bimonthly habitat scores

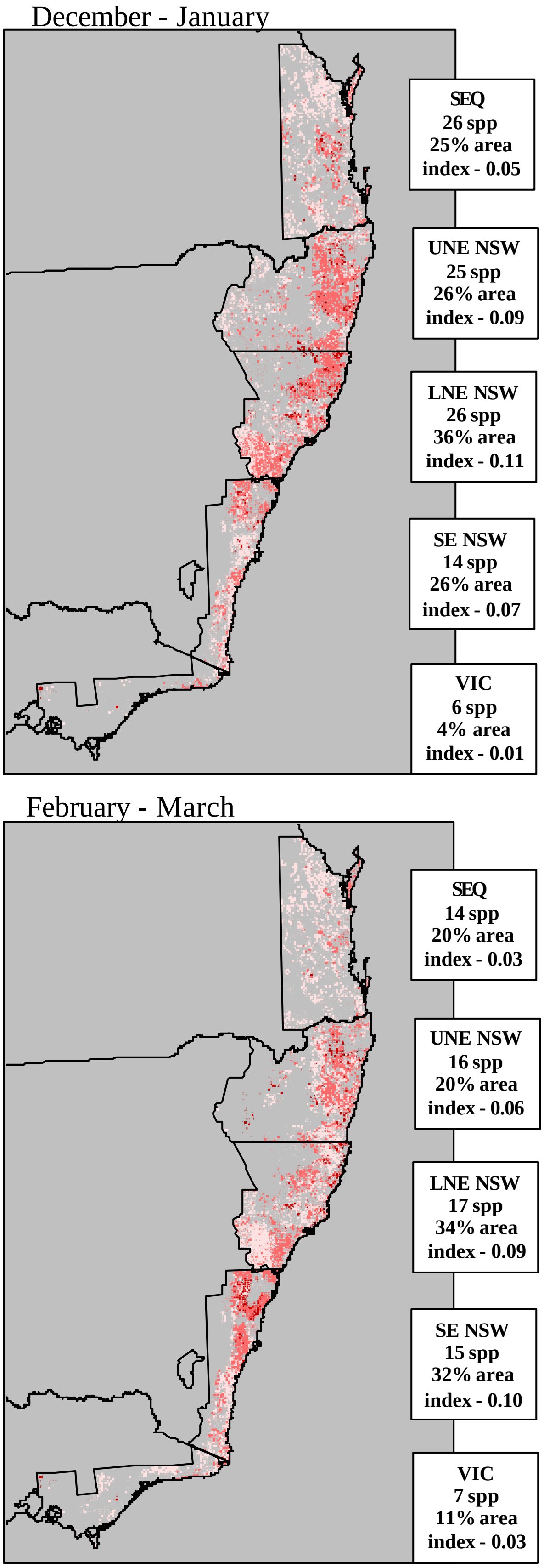
Blossom resources are not static and we found distinct seasonal patterns in the extent and distribution of productive habitat in bi-monthly maps of weighted productivity x reliability scores (Figure 4.6). Two broad seasonal patterns were apparent in the extent of nectar-producing habitat. Expansive areas are productive from late spring to early autumn, and the extent of productive habitat is reduced from late autumn to early spring.

Variations in the distributions of resources across regions add complexity. Productivity is consistently low in Victoria. However, elsewhere in the range the locations of centres of productivity vary between seasons. A large proportion of the diet plants found in each region flowers during December-January. The most highly productive habitats occur in coastal lowlands, plateaux and coastal ranges of UNE NSW and LNE NSW, and regional measures of productivity are relatively high in these areas. Centres of high productivity shift south during February-March to include SE NSW, particularly coastal lowlands and ranges north from Batemans Bay. The extent of productive habitat falls substantially in April-May and the range-wide area-weighted index of productivity falls to approximately one third of the high levels achieved in summer and early autumn. Few diet plants flower during this time and few vegetation types are productive. However, they are evenly distributed between regions and a number, such as those dominated by *M. quinquenervia*, are highly productive.

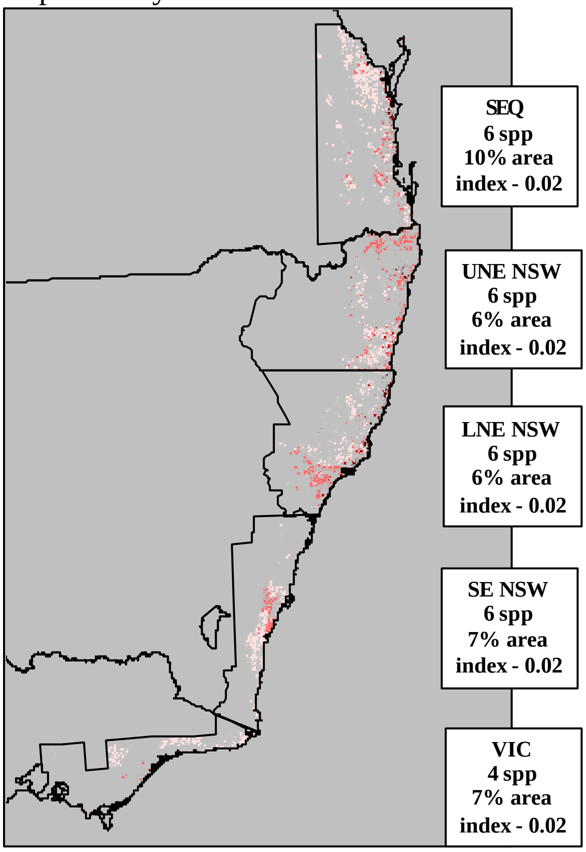
Although the number of flowering diet trees and the range-wide index of productivity do not vary from late autumn to mid-winter (June-July) changes occur in the distribution of feeding habitat across the study area. Productive areas are concentrated in SEQ and northern NSW where flowering occurs in small remnants in coastal floodplains, coastal dunes and inland slopes. More extensive forest and woodland types dominated by Spotted Gums are productive in northern SEQ and coastal SE NSW. While these latter vegetation types have high productivity scores, they score poorly for reliability and are expected to be productive in <30% of years.

During spring (August-September & October-November) the extent of productive habitat increases in northern regions, expanding from the coastal lowlands onto the coastal ranges and valleys. However, productivity continues to be low in SE NSW and Victoria. By October-November the number of diet species that flower is more than double that in cooler periods, as is the range-wide index of productivity.

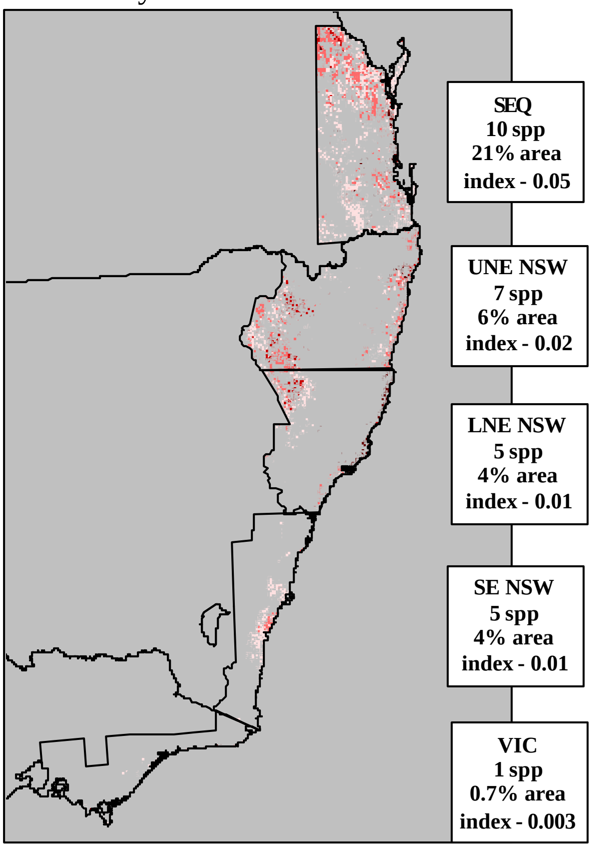
Figure 4.6. Bi-monthly patterns of distribution of nectar-producing habitat for Grey-headed flying foxes. Graduated colours of red indicate increasing wt p*r scores. See Figure 4.5. for key. Wt p*r scores of vegetation types were calculated from diet species that flower in each bi-monthly interval. For each region, data are provided on the species richness of productive diet plants, the proportion of land area that is productive and the area-weighted index of wt p*r.



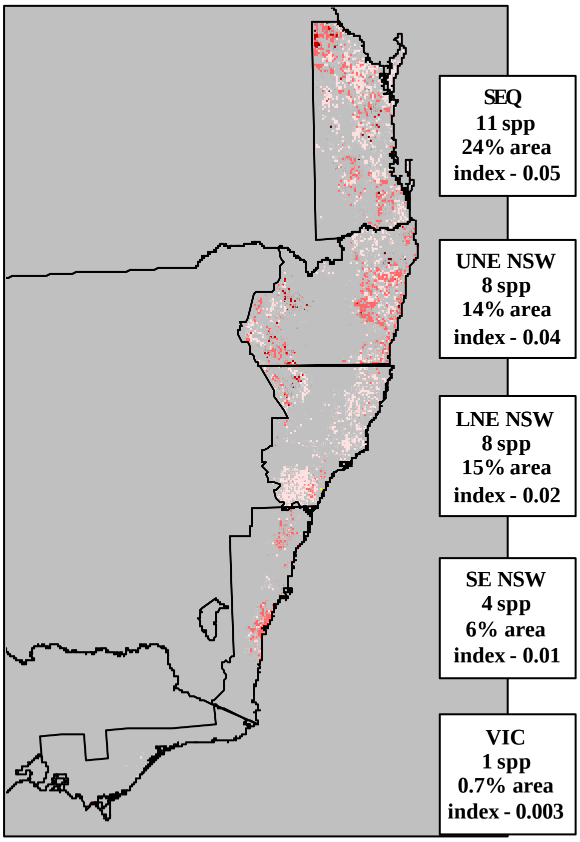
April - May



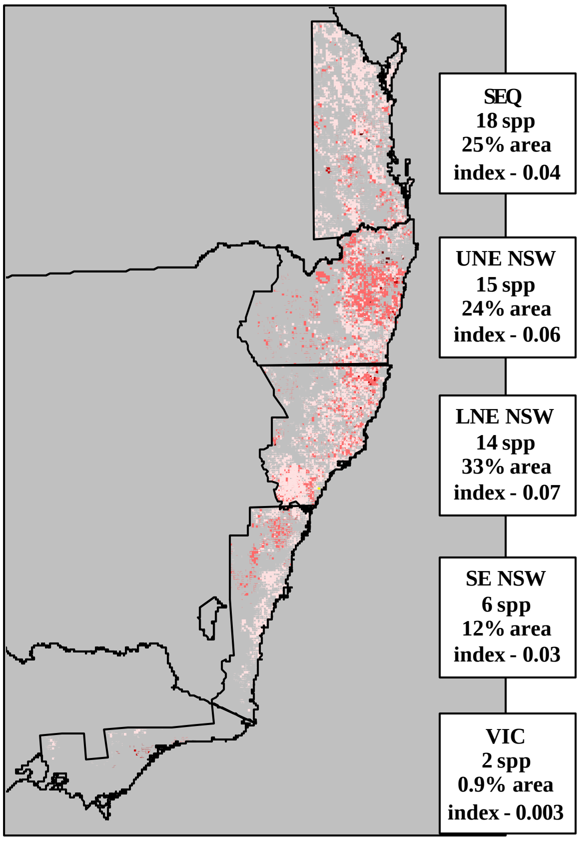
June - July



August - September



October - November

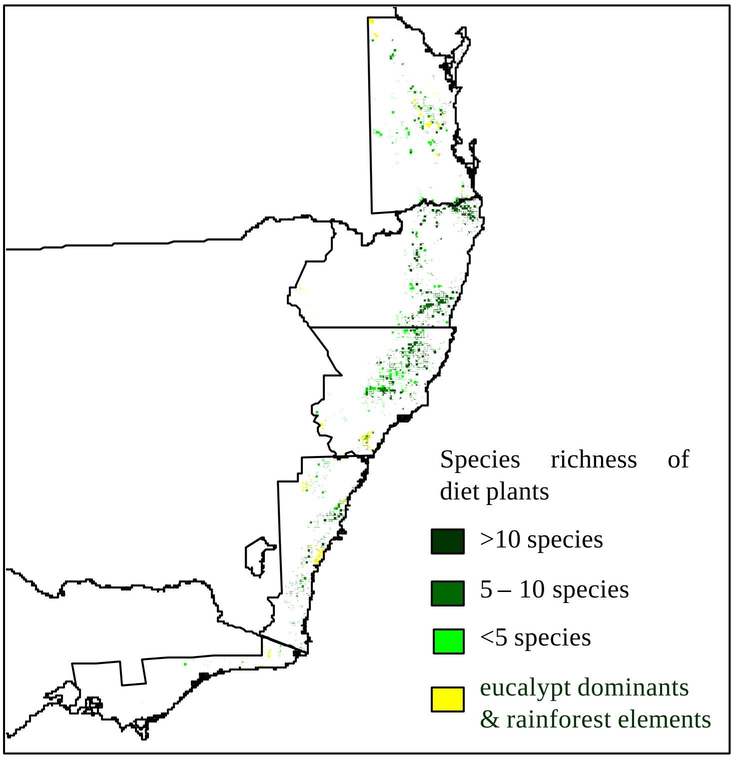


4.4. Habitat scores - Fruit

Vegetation types identified as rainforest were uncommon in each of the 24 vegetation classifications. Overall, 0.05% of vegetation types contained plants in the fruit diet of Grey-headed flying foxes. This limited resource covered 2% of land in the study area (Table 4.6.; Figure 4.7.). The relative extent of rainforest was approximately equivalent in the SEQ, UNE NSW and LNE NSW regions. It diminished substantially south of the Illawarra and was reduced to 0.02% in Victoria where rainforest vegetation was limited to small disjunct patches in gullies and slopes east from Wilsons Promontory.

Commensurate with the reduction in the extent of rainforest at increasing latitudes was a reduction in the species richness of plants in the fruit diet of Grey-headed flying foxes. In general, subtropical rainforests were the most species-rich, followed by warm temperate, littoral and dry rainforests. Species on the diet list were rarely identified in descriptions of cool temperate rainforest types. The subtropical and warm temperate rainforests found north from the Illawarra were structurally complex, floristically diverse and contained relatively large numbers of diet plants. However, at higher latitudes, several diet species reached their southern limit. While rainforest types persisted south of the Illawarra in SE NSW, few contained as many as ten diet plants. Nonetheless, the potential for these species-poor types to provide reliable food resources is recognised and many are known to be used by Grey-headed flying foxes (W. Peel, Gippsland CMA).

Figure 4.7. The distribution across the study area of rainforest vegetation containing plants in the fruit diet of Grey-headed flying foxes. Graduated colours of green indicate the species richness of diet plants in vegetation types, with deeper colours assigned to more diverse types. Layered vegetation containing emergent eucalypts over rainforest canopy, or mosaics of rainforest and other types are indicated by yellow.



4.5. Habitat ranks

4.5.1. Bi-monthly ranks

Bi-monthly maps of the distribution of habitat assigned to each rank appear in Regional Profiles as do tables of the bounds of the weighted productivity x reliability scores used to classify each bi-monthly rank.

Lists and maps of bi-monthly ranks were scrutinised for consistency with our field experience of habitat use by Grey-headed flying foxes. In general, the ranks assigned were in keeping with our expectations. Exceptions arose in a small number of vegetation types which contained low densities of highly productive species with low reliability scores. Lower ranks than expected were often assigned to those vegetation types in bi-months when the species of interest was the only diet plant that flowered in the type. For example, Lowland Dry Shrub Forest (SCIVI type e46) in the south-east corner of NSW contains *C. gummifera* Red Bloodwood at low densities. *C. gummifera* scores high for productivity (0.91 Table 4.1) and low for reliability (0.3), and the local camp at Pambula can reach a population of approximately 50,000 Grey-headed flying foxes in years when the species flowers well (P. Eby unpublished data). However, the density of *C. gummifera* in Lowland Dry Shrub Forest is relatively low. During April-May when it is the only diet plant in flower the habitat score is 0.21 and the bi-monthly rank is 3. This result does not reflect the significance of the habitat to the animals during April-May. This limit to the ranking method is overcome in this and some circumstances when final ranks are elevated to expected levels by a higher habitat score achieved in other bi-months. Nonetheless, the issue is recognised and further attention is recommended.

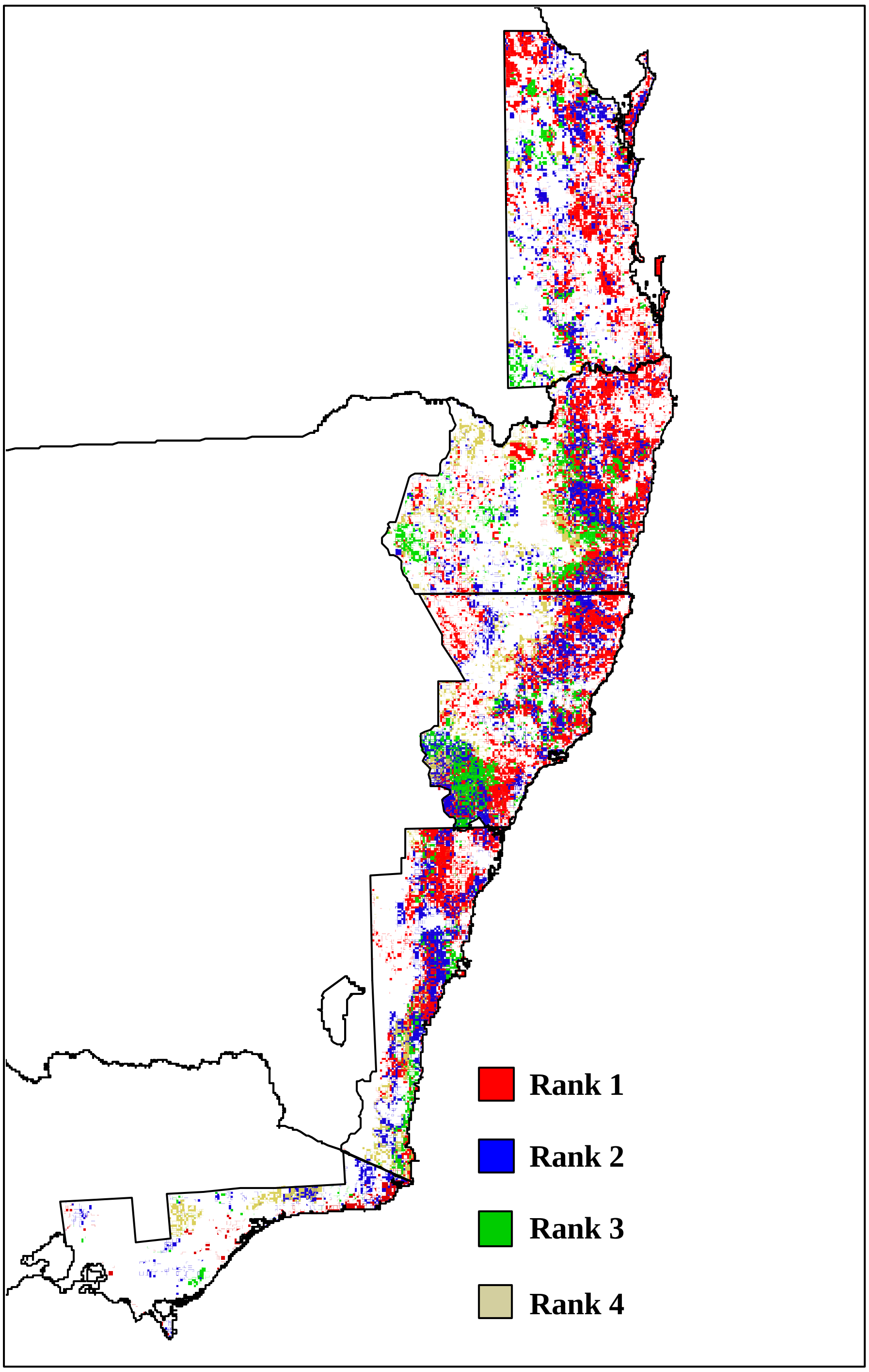
4.5.2. Final habitat ranks

The highest bi-monthly rank for each of the nectar-producing vegetation types was taken as the final nectar rank for that type. This procedure increased the area of habitat allocated to rank 1 and rank 2 beyond parity (Table 4.7.). In addition, each rainforest type that contained >5 plants in the diet of Grey-headed flying foxes was assigned a rank of 1. Those containing <5 were assigned ranks of 2. Overall, vegetation covering 19% of the study area was allocated rank of 1 and 9% rank of 2 (Table 4.7.). Lists of each vegetation type in the study area and its final rank are provided in the data files that accompany this report.

Table 4.7. The extent of vegetation assigned to each of four final habitat ranks in each region.

		Rank 1	Rank 2	Rank 3	Rank 4
SEQ	Area (ha)	1,444,000	533,000	162,000	55,000
	% region	21.6%	8.0%	2.4%	0.8%
UNE NSW	Area (ha)	1,537,000	461,000	458,000	258,000
	% region	21.2%	6.4%	6.3%	3.6%
LNE NSW	Area (ha)	1,283,000	771,000	291,000	211,000
	% region	24.1%	14.5%	5.5%	4.0%
SE NSW	Area (ha)	679,000	494,000	165,000	153,000
	% region	16.7%	12.1%	4.1%	3.7%
VIC	Area (ha)	110,000	129,000	29,000	106,000
	% region	3.6%	4.2%	0.9%	3.4%
TOTAL	Area (ha)	5,053,000	2,387,000	1,105,000	783,000
	% study area	19.1%	9.0%	4.2%	2.9%

Figure 6.7. A map of the study area showing the distribution of vegetation assigned each of four final ranks.



5. Discussion

Mobile, migratory animals present specific challenges to wildlife managers. Their wide-spread and complex habitat requirements prevent them from being preserved within systems of conservation reserves and leave them exposed to land use change in unreserved areas (Pressey *et al.*1996). Broad-scale, integrated programs of conservation are recommended for migratory bats (Racey and Entwhistle 2003, Fleming and Eby 2003), although examples are rare (but see Walker 1995 and Racey 1998). This project provides the basic information necessary to develop and implement such a program for Grey-headed flying foxes. It defines feeding habitat for the animals and sets range-wide priorities for conserving key resources.

We consider this to be the initial version of the project and recommend the outcomes be exposed to an ongoing process of development and improvement. We have taken a repeatable, systematic approach and documented our methods and assumptions carefully so that the work can be revised and refined over time. Sufficient information has been provided in this report and the accompanying databases and digital maps to enable revisions to be made.

Efforts were made to incorporate the best information available to the project at the time. However, improvements continue to be made in many areas and these should be incorporated as they become available. In particular, we are aware of various vegetation classifications and maps within the study area that are near completion (D. Connelly, DECC NSW personal communication). The reliability and defensibility of the outcomes will be enhanced by including them in the work. Our expectation is that future mapping projects will produce more accurate classifications and more reliable and precise maps than currently available. This is likely to have some impact on the final ranks as highlighted for *C. gummifera* occurring in Dry Shrubby Forest in the south-east corner of NSW. In addition, it was beyond the scope of this study to pursue all potential sources of data on local flowering and fruiting patterns. Further efforts in this area would be of benefit. Finally, there were various tree species that we expected Grey-headed flying foxes to use, but for which there were no field observations. Greater effort could be directed into confirming use of these plants. They include ironbarks such as *E. beyeriana, E. caleyi* and *E. crebra* and rainforest trees such as species of *Syzygium* and *Elaeocarpus*. Elsewhere in Australia rainforest species can provide significant nectar and pollen for bats (Law 2001).

The classification system developed here to evaluate the flowering characteristics of diet plants has value beyond its use as a tool for guiding conservation and land management decisions. It can also be used to enhance our understanding of the biology and ecology of Grey-headed flying foxes and the landscapes they inhabit. For example, there is scope for exploring relationships between flowering attributes (abundance, annual reliability, etc.) and a range of environmental parameters such as soil fertility and structure, topography and climatic variables. There is an opportunity to use models of pre-European vegetation cover to investigate the implications of broad-scale patterns of clearing on feeding opportunities for Grey-headed flying foxes. Basic questions about the biology of the species can also be addressed, such as relationships between their annual life history schedule and seasonal dynamics in food availability. Importantly, the data on flowering attributes presented here are based on patterns observed largely during the late 20th and initial stages of the 21st century. There is scope for viewing them as baseline information against which to measure change from a warming climate in the decades to come.

5.1. *Reliability of the model*

The main sources of error and uncertainty in this project were the flower variables used to assess habitat quality and they way they were combined in calculating productivity and reliability scores; the allocation of flower scores to individual species; and errors inherent in the vegetation classifications and maps. Potential sources of error in classifications and maps are described elsewhere (Section 2.3.1.).

Two lines of evidence were gathered regarding the reliability of flower scores. The comparison between expert scores and field data suggested that, overall, the scores assigned by experts reflected real world conditions. However, a specific area of weakness was flagged and we recommend that sensitivity analyses be used to examine the implications for the work of the inaccurate scoring of low levels of spatial synchrony.

There was an unexpectedly high level of agreement between experts in scores for all variables. While this result conferred a level of confidence in the scores, it also suggested that experts may have been able to discern finer differences in variables than was asked of them, making it possible to incorporate additional categories into the assessments. This would produce an outcome more sensitive to the natural variations that occur between diet species, and increase the amount of information provided by the scores.

Uncertainties associated with the flower variables we selected to measure habitat quality and the way those variables were combined were not explored numerically. Sensitivity analyses and similar techniques would assist and are recommended. However, a general assessment of the reliability of the work can be made by drawing comparisons with real world observations (Breierova and Choudhari 2001). Patterns presented in the large-scale, bi-monthly maps of habitat productivity (Figure 4.6.) closely align with our understanding of annual migration patterns in Grey-headed flying foxes. Although there is a high degree of annual variation in the occurrence of animals at a local scale, regular annual cycles of migration in the species are apparent at regional scales (Eby and Lunney 2002, Eby 2006). In general, the population congregates on coastal lowlands in the northern part of its range during winter, progressively moves south and west during spring and summer and occupies coastal regions throughout its full latitudinal range in autumn. These trends are reflected in bi-monthly changes in regional area weighted wt p*r indices, giving some indication that the outcome indeed reflects the responses of Grey-headed flying foxes to real world changes in habitat quality.

5.2. Benefits to other threatened species and populations

The conservation recommendations made in this work through habitat ranks provide direct benefits to various species of threatened fauna and threatened species and communities of flora (Table 5.1.). The Australian continent is characterised by a high diversity of species with a nectarivorous diet. Nectar- and fruit-feeding birds, bats and arboreal mammals will benefit directly as will a range of other fauna that occupy the forest and woodland communities used by Grey-headed flying foxes. Some of these are listed at the state level as Vulnerable, such as the Yellow-bellied Glider *Petaurus australis*, the Squirrel Glider *P. norfolkensis*, the Eastern Blossom Bat *Syconycteris australis* and the Eastern Tube-nosed Fruit Bat *Nyctimene robinsoni*, while others are recognised as endangered at both state and federal level, like the Swift Parrot *Lathamus discolour*, Coxen's Fig Parrot *Cyclopsitta diophthalma coxeni* and the Regent Honeyeater *Xanthomyza phrygia*. In addition, several high ranking habitats are listed as threatened vegetation communities or as containing threatened plants. These plants and communities will benefit directly through enhanced recognition of their conservation value. Land use decisions that serve to protect feeding habitat and therefore arrest the decline of Grey-headed flying foxes will benefit all the vegetation types they utilise through preservation of the seed and pollen dispersal functions (Eby 1996, Southerton *et al.* 2004, Birt 2005).

Fauna species that are not listed under threatened species legislation will also benefit from habitat conservation programs for Grey-headed flying foxes including Black flying foxes, Little red flying foxes, and many species of nectar- and fruit-feeding birds and arboreal mammals.

Table 5.1. Species and communities listed under commonwealth and state threatened species legislation that will benefit from retaining feeding habitat for Grey-headed flying foxes. This list is not exhaustive. Codes for threatened categories: E = endangered, V = vulnerable, T = threatened, R = rare. The fauna on this list are limited to birds and mammals.

Species or community	**Common-wealth**	**Qld**	**NSW**	**Vic**
Vegetation communities or populations				
Bega Dry Grass Forest South East Corner Bioregion			E	
Candelo Dry Grass Forest South East Corner Bioregion			E	
Blue Gum High Forest Sydney Basin Bioregion	CE		E	
Brogo Wet Vine Forest South East Corner Bioregion			E	
Castlereagh Swamp Woodland			E	
Casuarina glauca open forest		E		
Central Gippsland Plains Grassland				T
Corymbia citriodora open forest		E		
Cumberland Plain Woodland	E		E	
Dry Rainforest South East Forests of the South East Corner Bioregion			E	
Eastern Suburbs Banksia Scrub Sydney Basin Bioregion	E		E	
Eucalyptus melanophloia, E. crebra woodland on sedimentary rocks		E		
Eucalyptus seeana, Corymbia intermedia, Angophora leiocarpa woodland		E		
Eucalyptus siderophloia, E. propinqua, E. microcorys and/or *E. pilularis* tall open forest		E		

Species or community	Common-wealth	Qld	NSW	Vic
Eucalyptus tereticornis, Corymbia intermedia on remnant Tertiary surfaces		E		
Eucalyptus tereticornis woodland to open forest on alluvial plains		E		
Eucalyptus tindaliae and/or *E. racemosa* open forest		E		
Forest Red Gum Grassy Woodland				T
Gallery rainforest (notophyll vine forest) alluvial plains		E		
Grassy White Box Woodlands	E			
Herb-rich Plains Grassy Wetland (West Gippsland)				T
Limestone Grassy Woodland Community				T
Littoral Rainforest NSW North Coast, Sydney Basin and South East Corner Bioregions			E	
Lower Hunter Valley Dry Rainforest in the Sydney Basin and NSW North Coast Bioregions			V	
Lower Hunter Spotted Gum - Ironbark Forest in the Sydney Basin Bioregion			E	
River-Flat Eucalypt Forest on Coastal Floodplains of NSW North Coast, Sydney Basin and South East Corner Bioregions			E	
Shale Gravel Transition Forest Sydney Basin Bioregion	E		E	
Shale/ Sandstone Transition Forest			E	
Subtropical Coastal Floodplain Forest NSW North Coast Bioregion			E	
Sun Valley Cabbage Gum Forest Sydney Basin Bioregion			E	
Swamp Oak Floodplain Forest NSW North Coast, Sydney Basin and South East Corner Bioregions			E	
Swamp Sclerophyll Forest on Coastal Floodplains of NSW North Coast, Sydney Basin and South East Corner Bioregions			E	
Sydney Turpentine-Ironbark Forest	CE		E	
Syncarpia glomulifera open forest		E		
Tall open forest with *Eucalyptus cloeziana*		E		
Tall open forest of *Eucalyptus pilularis*		E		
Warm Temperate Rainforest (Coastal East Gippsland)				T
Warm Temperate Rainforest (Far East Gippsland)				T
Warm Temperate Rainforest (East Gippsland Alluvial Terraces)				T
White Box Yellow Box Blakely's Red Gum Woodland			E	
Yellow Box Red Gum Grassy Woodlands	CE			
Eucalyptus seeana (Taree)			E	
E. parramattensis parramattensis (Wyong and Lake Macquarie)			E	
Davidsonia spp	E		E	
Eucalyptus tetrapleura	V		V	
Syzygium paniculatum	V		V	
Fauna (birds and mammals only)				
Birds				
Coxen's Fig Parrot	E	E	E	
Swift Parrot	E	E	E	T
Regent Honeyeater	E	E	E	T
Black-chinned Honeyeater		R	V	
Mangrove Honeyeater			V	
Wompoo Fruit-dove			V	
Rose-Crowned Fruit-dove			V	

Species or community	Common-wealth	Qld	NSW	Vic
Superb Fruit-dove			V	
Barking Owl			V	T
Masked Owl		V	V	T
Powerful Owl		V	V	T
Marbled Frogmouth		V	V	
Mammals				
Eastern Blossom Bat			V	
Eastern Tube-nosed Fruit Bat			V	
Eastern Pygmy-possum			V	
Koala		T	V	
Spotted-tail Quoll		T	V	T
Squirrel Glider			V	T
Yellow-bellied Glider			V	

5.3. Using the output

The output of this project is supplied in three formats: a written report, regional databases and regional maps (shape files) for use in ARCView Geographic Information System.

The report provides an overview of the project, including aims, methodology, results, general discussion and profiles specific to each of the five regions. It is self-explanatory.

5.3.1. Guide to regional databases

Databases that provide details of the data and calculations that support the habitat ranks have been generated for each region. The files (Microsoft Excel) are of a standard format. They contain a series of worksheets that present basic data on diet species and habitats, as well as formulae for various scores and ranks.

The worksheets and their contents are as follows:

1. **flower scores**
    a. a list of all nectar-producing diet plants identified in the descriptions of vegetation types in the region. These lists are not fully comprehensive as some species were revised after the vegetation mapping had been completed and others occur in such low densities or restricted distributions as not to be captured in the vegetation classifications and type descriptions.
    b. nectar scores for each of these diet plants. The scores for the initial five variables (abundance, synchrony, %years, variation and duration) are given as are calculated productivity, reliability and weighted productivity * reliability scores.

       Two sets of scores are provided for plants such as *E. pilularis* that are less productive in some conditions.

2. **phenology**
    a. the annual flowering schedule of diet plants presented as bi-monthly presence/absence data.

b. A small number of widely-distributed plants have been allocated more than one set of bi-monthly data to take into account reported differences between areas within a region.

3. **master**

This is the working sheet for estimating the relative densities of species and calculating bi-monthly and total habitat scores. It contains:

a. a list of all vegetation types identified in regional classifications and maps and the formula used to calculate the densities of diet plants in each habitat.
b. Across the top of this sheet is a list of diet plants and their nectar scores. The habitat formula refer to these lists. Habitat scores are calculated separately for weighted productivity*reliability, productivity and reliability.
c. The phenology data in worksheet 2 are used to derive bi-monthly habitat scores – only plants that flower in a particular bi-month are incorporated into the calculations for that period.

4. **join**

a. the table of data joined to the digital information contained in ARCView shape files from the mapping projects. It includes:
   i. a code and name for all mapped habitats
   ii. a list of diet plants in the habitats
   iii. rainforest score (based on number of diet species present)
   iv. an overall habitat rank based on nectar plants (see 7)
   v. an overall rank based on nectar and rainforest fruit (see 7)
   vi. a rank for each bi-month (see 6)
   vii. weighted productivity*reliability, productivity and reliability scores. Tot = all diet plants included; bi-monthly scores as indicated.

5. **Summary stats**

a. Tables of summary data

6. **Calc ranks**

This is the working sheet for calculating bi-monthly and total habitat ranks

a. Bi-monthly ranks. The process for setting ranks in each bi-month is given in Section 2.5.2.
b. 'Rank nectar only' and 'rank n&f" columns contain logic formula used to set overall ranks
   i. Total nectar ranks are taken as the highest bi-monthly rank scored for each habitat.
   ii. Total nectar + fruit ranks assign ranks to rainforest scores and add these to nectar ranks.

7. **Area-weighted index**

a. area-weighted indices can be used to compare nectar scores between regions and between bi-months. They are calculated as Σ(habitat score*habitat area)/total land area of region.

   Bi-monthly indices for wt prod*relia, productivity and reliability are calculated in this worksheet and summarised in the Summary Stats worksheet.

5.3.2. Guide to digital map layers

Digital map layers are provided in a uniform projection (AGM Zone 56). A standard table of habitat attributes has been joined to ARCView shape files of the various map layers compiled for this project.

The resulting data layer contains relevant information provided by the original vegetation classifications and maps as well as 23 fields of data from this work that can be queried. These are:

1. vegetation type – the name given to the plant assemblage in the relevant vegetation classification and map
2. source – a citation for the source classification and map
3. nectar species – list of diet plants in the vegetation type as defined in the source material. A standard five letter code is used. The first two letters identify the genus, the following letters identify the species. Additional letters are added where needed to differentiate species with similar names. Refer to regional profiles.
4. rank n & f – the final habitat scores for all vegetation types
5. rank nectar only – the final habitat score of nectar-producing vegetation types
6. rainforest score – the species richness score attributed to rainforest vegetation
7. tot wt pr – weighted productivity * reliability scores for each vegetation type using data from all diet species (bi-monthly phenologies not taken into account).
8. total prod – productivity scores for each vegetation type using data from all diet species
9. total reliability – reliability scores for each vegetation type using data from all diet species

10 – 23. bi-monthly nectar habitat ranks and nectar scores for each vegetation type. Nectar habitat ranks, area-weighted productivity * reliability scores, productivity scores and reliability scores are presented for each bi-month.

5.3.3. Guide to using maps

"No map is the truth" (D. Keith 2005)
It is important for users of this project to be aware of the limitations of the habitat maps. The maps are representations of vegetation patterns across a landscape and should not be interpreted as accurate depictions. Levels of spatial accuracy vary between and within the various mapping projects that were compiled to define feeding habitat for Grey-headed flying foxes. Nonetheless, the maps are sufficiently accurate at a regional scale to support the method used to rank habitat.

The maps do not replace site assessments by land managers. Rather, they provide a context for determining whether a site assessment is needed and for interpreting the results. It is possible from these maps to establish whether feeding habitat for Grey-headed flying foxes occurs in the vicinity of a site of interest and to determine the ranks assigned to those habitats. If feeding habitat occurs within the surrounding area, then field inspections should be used to clarify the vegetation type(s) present in the actual site of interest and to confirm the occurrence of key diet species (wt p*r $\geq$0.65) as listed in the regional profiles. The material presented in this report and the accompanying databases can then be used to assess the significance of the vegetation as feeding habitat for Grey-headed flying foxes.

5.4. Recommendations for future work

1. Incorporate the conservation status of vegetation types into the ranking process.
2. Continue to update the quality of vegetation maps as new products become available. This includes updates of descriptions of current vegetation types to convert descriptive accounts to numeric accounts (e.g. scheduled updates of Qld REs).
3. Adjust the boundaries of the study area as further data on the range of Grey-headed flying foxes becomes available (Satellite telemetry work suggests the current northern extent of the species is outside the boundary of this project. (B. Roberts Griffith University, unpublished data)
4. Improve the database of species nectar scores.
5. Assess the impact of bias in low level spatial synchrony scores on final wt p*r scores and habitat ranks.
6. Collate phenology records for rainforest fruit and incorporate bi-monthly data.
7. Refine observations of flying foxes foraging on tree species not previously well documented; eg ironbarks and rainforest species.

6. References

Accad, A, Neldner, V.J, Wilson, B. A, and Niehus, R.E. 2006. *Remnant Vegetation in Queensland. Analysis of remnant vegetation 1997-1999-2000-2001-2003, including regional ecosystem information*. Brisbane: Queensland Herbarium, Environmental Protection Agency.

Bell, S.A.J. 1998. *Wollemi National Park Vegetation Survey Vol 2. A Fire Management Document.* Report to NSW National Parks and Wildlife Service. East Coast Flora Survey, Warners Bay, NSW.

Bell, S.A.J. 2002. *The natural vegetation of the Wyong Local Government Area, Central Coast, New South Wales: Technical Report*. Unpublished Final Report to Wyong Shire Council, August 2002. Eastcoast Flora Survey.

Bell, S.A.J. 2004. *The natural vegetation of Gosford Local Government Area, Central Coast, New South Wales: Technical Report*. Unpublished Report to Gosford City Council, April 2004. Eastcoast Flora Survey.

Bell, S. and Driscoll, C. 2006. *Vegetation mapping of Watagans National Park and Jilliby State Conservation Area*. Summary Report to Department of Environment and Conservation NSW. East Coast Flora Survey, Kotara Fair, NSW.

Birt, P. 2005. *Mutualistic interactions between the nectar-feeding little red flying fox* Pteropus scapulatus *(Chiroptera: Pteropodidae) and eucalypts: habitat utilisation and pollination*. PhD thesis. University of Queensland, Brisbane.

Botanic Gardens Trust. 2008. *PlantNet - The Plant Information Network System of Botanic Gardens Trust, Sydney*. http://plantnet.rbgsyd.gov.au. Accessed variously 2006 – 2008.

Braun-Blanquet, J. 1929. *Pflanzensoziologie*. Springer, Berlin.

Breierova, L. and Choudhari, M. 2001. *An Introduction to Sensitivity Analysis*, MIT System Dynamics in Education Project, Massachusetts Institute of Technology, Cambridge Mass.

Burgman M. A., Breininger D. R., Duncan B. W. and Ferson S. 2001. Setting reliability bounds on habitat suitability indices. *Ecological Applications.* **11**: 70–78.

Clemson, A. 1985. *Honey and Pollen Flora.* Inkata Press, Melbourne.

Cocks K.D. & Dennis C. 1978. Apiculture. Pp 23-9 in *Land Use on the South Coast of New South Wales* ed. by M.P. Austin and K.D. Cocks. CSIRO, Canberra.

Collins, L. 2000. Impact of periods of food shortage on the body weight of Grey-headed Flying-foxes. Pp. 99-101. in *Proceedings of a Workshop to Assess the Status of the Grey-headed Flying-fox in New South Wales* edited by G. Richards, Australasian Bat Society.

Council of Heads of Australasian Herbaria. 2008. Australia's Virtual Herbarium. www.anbg.gov.au/avh.html. Accessed variously 2005 - 2008.

Davies, J.B., A.M. Oates and A.V. Trumbull-Ward. 2002. *Ecological vegetation class mapping at 1:25:000 in Gippsland*. Department of Natural Resources and Environment (Victoria), Gippsland Region.

Department of Environment and Climate Change (NSW) 2005. Priority Actions Statement - Grey-headed flying fox. Accessed October 2008. www.threatenedspecies.environment.nsw.gov.au/tsprofile/pas_profile.aspx?id=10697

Department of Environment and Climate Change (NSW). 2008a. *The Native Vegetation of Yengo and Parr Reserves and Surrounds.* Department of Environment and Climate Change NSW, Hurstville.

Department of Environment and Climate Change (NSW). 2008b. *The Native Vegetation of the Putty Valley.* Department of Environment and Climate Change NSW, Hurstville.

Department of Environment and Climate Change (NSW). 2008c. *The Native Vegetation of Northern Hawkesbury Local Government Area* Department of Environment and Climate Change NSW, Hurstville.

Dickman and Fleming 2002

Eby, P. 1991. Seasonal movements of Grey-headed Flying-foxes, *Pteropus poliocephalus* (Chiroptera: Pteropodidae), from two maternity camps in northern New South Wales. *Wildlife Research* **18**: 547-559.

Eby, P. 1995. *Biology and Management of* Pteropus *in New South Wales. Species Report*. Hurstville, NSW: NSW National Parks and Wildlife Service.

Eby, P. 1996. *Interactions between the Grey-headed Flying-fox Pteropus poliocephalus (Chiroptera: Pteropodidae) and its diet plants - seasonal movements and seed dispersal*. PhD Thesis, University of New England, Armidale, NSW.

Eby, P. 1998. An analysis of diet specialization in frugivorous *Pteropus poliocephalus* in Australian subtropical rainforest. *Australian Journal of Ecology* **23**: 443-56.

Eby, P. 1999. Low reproductive output in Grey-headed Flying-foxes associated with a short period of food scarcity. *Australasian Bat Society Newsletter* **14**: 17-20.

Eby, P. 2004. *National Count of Grey-headed Flying-foxes -April 3 & 4, 2004.* A report to the Department of Environment and Heritage, Canberra.

Eby, P., Collins, L., Richards, G. and Parry-Jones, K. 1999. The distribution, abundance and vulnerability to population reduction of a nomadic nectarivore, *Pteropus poliocephalus* during a period of resource concentration. *Australian Zoologist* **31**: 240-253.

Eby, P. and Lunney, D. 2002. Managing the Grey-headed Flying-fox *Pteropus poliocephalus* as a threatened species in NSW: adjusting to a long-term vision. Pp. 273-284 in *Managing the Grey-headed Flying-fox as a Threatened Species in NSW,* edited by P. Eby and D. Lunney. Royal Zoological Society of NSW, Mosman, NSW.

Eco Logical Australia. 2005. *A Vegetation Map for the Northern Rivers Catchment Management Authority to support application of the Biodiversity Forecasting Toolkit*. Eco Logical Australia Pty Ltd., Sutherland, NSW.

Eco Logical Australia. 2006. *A Vegetation Map for the Mid North Coast of New South Wales*. Report prepares for Department of Environment and Conservation. Report No. 99-01. December 2005. 32 pp. Eco Logical Australia Pty Ltd., Sutherland, NSW.

Fairly, A. and Moore, P. 1989. *Native Plants of the Sydney District: An Identification Guide*. Kangaroo Press, Sydney.

Fleming, T.H. and Eby, P. 2003. Ecology of bat migration. Pp. 156-208 in *Ecology of Bats*. edited by T.H. Kunz and M.B. Fenton. University of Chicago Press.

Floyd, A.G. 1990. *Australian Rainforests in New South Wales.* Surrey Beatty & Sons Pty Ltd. Sydney.

Forestry Commission of NSW 1989. *Forest Types in New South Wales*. Research Note 17. Forestry Commission of NSW.

Frankl R., Wanning S., Braun R., 2005. Quantitative floral phenology at the landscape scale: is a comparative spatio-temporal description of “flowering landscapes” possible? *J. Nature Conservation* **13**: 219-229.

Goldingay R. L. 1990. The foraging behaviour of a nectar feeding marsupial, *Petaurus australis*. *Oecologia* **85**: 191-9.

Goldingay R. 2005. Is there a diel pattern to nectar secretion in the Red Bloodwood *Corymbia gummifera? Cunninghamia* **9:** 325-29.

Gullan, P.K. 1978. Vegetation of the Royal Botanic Gardens at Cranbourne, Victoria. *Proc. Roy. Soc. Vic*. **70**: 225-40.

Hall, L.S. and Richards, G. 2000. *Flying Foxes: Fruit and Blossom Bats of Australia.* UNSW Press: Sydney.

Harden, G.J.(ed). 1990, 1991, 1992, 1993, 2002. *Flora of New South Wales: Volumes 1-4*. University of New South Wales Press, Sydney.

Henderson, R.J.F. (ed.) 2002. *Names and Distribution of Queensland Plants, Algae and Lichens*. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Hughes, L.,Cawsey, E.M. and Westoby. M. 1996. Climatic range sizes of species in relation to future climate change. *Global Ecology and Biogeography Letters* **5**:23 –29.

Hughes, L., 2003. Climate change and Australia: trends, projections and impacts. *Austral Ecology* **28**: 423-443.

Jessup, L.W. 2002. *Flora of South-eastern Queensland*, Volume 2. Changes to names or status of taxa. Queensland Herbarium. Environmental Protection Agency, Toowong.

Jessup, L.W. 2003. *Flora of South-eastern Queensland*, Volume 1. Changes to names or status of taxa. Queensland Herbarium. Environmental Protection Agency, Toowong.

Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee (JANIS). 1997. *Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia.* Commonwealth of Australia.

Keith, D.A. 2002. *A Compilation Map of Native Vegetation for New South Wales.* NSW National Parks and Wildlife Service, Hurstville, NSW.

Keith, D.A. 2004. *Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT.* Department of Environment and Conservation, Hurstville.

Keith, D.A. and Scott, J. 2005. Native vegetation of coastal floodplains– a diagnosis of the major plant communities in New South Wales. *Pacific Conservation Biology*. **11**: 81-104.

Law, B.S., 1992. The maintenance nitrogen requirements of the Queensland blossom bat (*Syconycteris australis*) on a sugar/pollen diet: is nitrogen a limiting resource? *Physiological Zoology* 65: 634-48.

Law B.S. 1993. Sugar preferences of the Queensland Blossom bat (*Syconycteris australis*): a pilot study. *Aust. Mammal.* **16**: 17-22.

Law B.S. 1994. Nectar and pollen: dietary items affecting the abundance of the common blossom bat *Syconycteris australis* in south-eastern Australia. *Aust. J. Ecol.* **19**: 425-434.

Law, B.S., 2001. The diet of the common blossom bat *Syconycteris australis* in upland tropical rainforest and the importance of riparian areas. *Wildlife Research* **28**: 619-26.

Law B.S. and Chidel M. 2007. *The effect of logging on nectar production by eucalypts: spotted gum and grey ironbark*. Final Report (Project SFN-2A) to RIRDC, Canberra.

Law, B.S., Eby, P. and Sommerville, D. 2002. Tree-planting to conserve flying-foxes and reduce orchard damage. Pp. 84-90 in *Managing the Grey-headed Flying-fox as a Threatened Species in NSW*, edited by P. Eby and D. Lunney. Royal Zoological Society of NSW, Mosman, NSW.

Law, B., Mackowski, C., Schoer, L. and Tweedie, T. 2000. Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales. *Austral Ecology* 25: 160-178.

Lunney D., Matthews A., Moon C., Ferrier S., 2001. Incorporating Habitat Mapping into Practical Koala Conservation on Private Lands. *Conservation Biology* **14**: 669-680

Martin, L., Kennedy, J.H., Little, L., Luckhoff, H.C., O'Brien, G.M., Pow, C.S.T., Towers, P.A., Waldon, A.K. and Wang, D.Y. 1996. The reproductive biology of Australian flying-foxes (genus *Pteropus*). *Symp. Zool. Soc. Lond.* **67**: 167-184.

McWilliam, A.N. 1986. The feeding ecology of *Pteropus* in north-eastern New South Wales, Australia. *Myotis* **23-24:** 201-208.

Natural Resources and Environment (Vic). in prep. A typology of vegetation in Victoria: Towards a census of Victorian plant communities. Department of Natural Resources and Environment, Melbourne.

Natural Resources and Environment (Vic) and Commonwealth of Australia. 1997. *Central Highlands Comprehensive Regional Assessment Report.* Published by the joint Commonwealth and Victorian Regional Forest Agreement (RFA) Steering Committee. Natural Resources and Environment, Victoria.

Natural Resources and Environment (Vic) and Commonwealth of Australia. 1999. *Gippsland Comprehensive Regional Assessment Biodiversity Report.* Published by the joint Commonwealth and Victorian Regional Forest Agreement (RFA) Steering Committee. Natural Resources and Environment, Victoria.

Neldner, V.J., Wilson, B.A., Thompson, E.J., and Dillewaard H.A. 2005. *Methodology for Survey* and *Mapping of Regional Ecosystems and Vegetation Communities in Queensland.* Version 3.1, Queensland Herbarium, Environmental Protection Agency, Brisbane 128pp.

Nelson, J. E. W. 1965. Behavior of Australian Pteropodidae (Megachiroptera). *Animal Behavior* **13**: 544-557.

NSW Department of Environment and Conservation. 2004. Eastern Suburbs Banksia Scrub Endangered Ecological Community Recovery Plan. NSW Department of Environment and Conservation.

NSW National Parks and Wildlife Service. 1998. *CRAFTI UNE and LNE Report.* A project undertaken as part of the NSW Comprehensive Regional Assessments. Unpubl. report. 58 pp.

NSW National Parks and Wildlife Service. 1999. *Forest Ecosystem Classifications for Upper and Lower North East CRA Regions.* A report undertaken for the NSW CRA/RFA Steering Committee. Forests Taskforce, Department of the Prime Minister and Cabinet, Canberra. Project number NA35/EH.

NSW National Parks and Wildlife Service. 2000. *Vegetation Survey, Classification and Mapping Lower Hunter and Central Coast*. Unpublished. A project undertaken for the Lower Hunter and Central Coast Regional Environmental Management Strategy

NSW National Parks and Wildlife Service. 2003a. *The Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments.* Unpublished Report. NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service. 2003b. *The Native Vegetation of the Warragamba Special Area.* Unpublished Report. NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service. 2004. *The Native Vegetation of the Nattai and Bargo reserves*. Unpublished Report. NSW National Parks and Wildlife Service, Hurstville.

NSW Scientific Committee 2001. Final determination to list Grey-headed flying foxes as a Vulnerable Species under the NSW Threatened Species Conservation Act 1995.

NSW Scientific Committee. 2002. Final determination to list White Box Yellow Box Blakely's Red Gum Woodland as an Endangered Ecological Community under the NSW Threatened Species Conservation Act 1995.

NSW Scientific Committee. 2004a. Final determination to list River-Flat Eucalypt Forest on Coastal Floodplains of NSW North Coast, Sydney Basin and South East Corner Bioregions as an Endangered Ecological Community under the NSW Threatened Species Conservation Act 1995.

NSW Scientific Committee. 2004b. Final determination to list Swamp Sclerophyll Forest on Coastal Floodplains of NSW North Coast, Sydney Basin and South East Corner Bioregions as an Endangered Ecological Community under the NSW Threatened Species Conservation Act 1995.

NSW Scientific Committee. 2004c. Final determination to list Subtropical Coastal Floodplain Forest of the NSW North Coast Bioregion as an Endangered Ecological Community under the NSW Threatened Species Conservation Act 1995.

Nicolson S.W. 1995. Direct demonstration of nectar reabsorption in the flowers of *Grevillea robusta* (Proteacaea). *Functional Ecology* **9**, 584-88.

Nunez J. 1977. Nectar flow by melliferous flora and gathering flow by *Apis mellifera ligustica. J. Insect. Physiol.* **23**, 265-75.

Oates, A., and Taranto, M. 2001. *Vegetation (EVC) Mapping of the Port Phillip and Westernport Region.* Arthur Rylah Institute (ARI) for Environmental Research, Department of Natural Resources and Environment (DNRE), Melbourne

Parry-Jones, K. A. and Augee, M. 1991. Food selection by Grey-headed Flying-foxes (*Pteropus poliocephalus*) occupying a summer colony site near Gosford, N.S.W. *Wildlife Research* **18**: 111-124.

Parry-Jones, K.A. and Augee. M.L. 2001. Factors affecting the occupation of a colony site in Sydney, New South Wales by the Grey-headed Flying-fox, *Pteropus poliocephalus* (Pteropodidae). *Austral Ecology* **26**: 47-55.

Paton D.C. 1985. Food supply, population structure and behaviour of New Holland Honeyeaters *Phylidonyris noaehollandiae* in woodland near Horsham, Victoria. Pp 219-30 in *Birds of the eucalypt forests and woodlands: ecology, conservation, management* ed. By A. Keast, H.F. Recher, H. Ford and D. Saunders. Royal Australasian Ornithologists Union and Surrey Beatty and Sons, Sydney.

Peake, T.C. 2006. *The Vegetation of the Central Hunter Valley, New South Wales.* A Report on the Findings of the Hunter Remnant Vegetation Project.. Hunter – Central Rivers Catchment Management Authority, Paterson

Pook, E.W., Gill, A.M. and Moore, P.H.R. 1997. long term variation of litter fall, canopy leaf area and flowering in a *Eucalyptus maculata* forest on the south coast of New South Wales. *Aust. J. Botany* **45**: 737-755.

Pyke G.H. 1985. The relationships between abundances of honeyeaters and their food resources in open forest areas near Sydney. Pp 65-77 in *Birds of the eucalypt forests and woodlands: ecology, conservation, management* ed. By A. Keast, H.F. Recher, H. Ford and D. Saunders. Royal Australasian Ornithologists Union and Surrey Beatty and Sons, Sydney.

Qld Environmental Protection Agency. 2003. *State of the Environment Queensland 2003*. Environmental Protection Agency, Brisbane.

Qld Environmental Protection Agency 2005. *Regional Ecosystem Description Database (REDD), Version 5.0.* Environmental Protection Agency, Brisbane.

Ratcliffe, F. N. 1931. The flying-fox (*Pteropus*) in Australia. *Bulletin of the Council for Scientific and Industrial Research* **53**: 1–80.

Regan H. M., Colyvan M. and Burgman M. A. 2002. A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications* **12**: 618–628.

Ryan, K., Fisher, M. and Schaeper L. 1996. The Natural Vegetation of the St Albans 1:100 000 map sheet. *Cunninghamia* 4:433-482.

Sattler P.S. and Williams R.D. (eds). 1999. *The Conservation Status of Queensland Bioregional Ecosystems*. Brisbane: Environmental Protection Agency.

Sivertsen, D.P. and Smith, P.L. (eds) 2001. *Guidelines for mapping native vegetation: Version 2.1 - Guidelines and Appendices*. Unpublished report. New South Wales Department of Land and Water Conservation, Sydney.

Somerville, D. & Barnes I. 1994. Batemans Bay Forestry District Apiary Management Survey September 1994. Report prepared by NSW Agriculture and State Forests of NSW.

Somerville, D. & Colley C. 1990. Nowra State Forest Apiary Management Survey August 1990. Report prepared by NSW Agriculture & Fisheries and Forestry Commission of NSW.

Southerton, S.G., Birt, P., Porter, J. Ford, H.A. 2004. Review of gene movement by bats and birds and its potential significance for eucalypt plantation forestry. *Australian Forestry* **67(1)**: 44-53.

Teagle, S. 2002. Flying fox Consultative Committee – Formation, Outcomes and Future Strategies. Pp. 109-116 in *Managing the Grey-headed Flying-fox as a Threatened Species in NSW*, edited by P. Eby and D. Lunney. Royal Zoological Society of NSW, Mosman, NSW.

Thackway, R. and Cresswell, D. 1995. *An interim biogeographic regionalisation for Australia: a framework for setting priorities in the national reserves system cooperative program.* Australian Nature Conservation Agency, Canberra.

Tidemann, C.R. 1999. Biology and management of the Grey-headed Flying-fox, *Pteropus poloiocephalus. Acta Chiropterologica* **1**: 151-164.

Tidemann, C., Eby, P., Parry-Jones, K. and Vardon, M. 1999. Grey-headed Flying-fox. In A. Duncan, G. B. Baker and N. Montgomery (eds), *The Action Plan for Australian Bats.* Pp 31-35. Environment Australia, Canberra.

Timewell C.A.R. and MacNally, R. 2004. Diurnal foraging-mode shifts and food availability in nectarivore assemblages during winter. *Austral Ecology* **29**: 264-77.

Tozer, M.G, Turner, K., Simpson, C., Keith, D.A., Beukers, P., MacKenzie, B., Tindall,D., and Pennay,C. 2006. *Native Vegetation of Southeast NSW: a revised classification and map for the coast and eastern tablelands Version 1.0.* NSW Department of Environment and Conservation, NSW Department of Infrastructure, Planning and Natural Resources, Sydney

Tweed Shire Council 1999. *Communities Working Together: A community development plan for Tweed Shire.* **Tweed Shire Council. Murwillumbah.**

van der Ree, R., McDonnell, M.J., Temby, I., Nelson, J. and Whittingham, E. 2006. The establishment and dynamics of a recently established urban camp of *Pteropus poliocephlaus* outside their geographic range. *J. Zool Lond.* **268**: 177-185.

Wall, J. 2004. *Biodiversity Surrogates – Vegetation. NSW Western Regional Assessment Nandewar*. Resource and Conservation Council, Sydney, NSW.

Wilson, B.A., Neldner, V.J. and Accad, A. 2002. The extent and status of remnant vegetation in Queensland and its implications for statewide vegetation management and legislation. *The Rangeland Journal* **24**:6-35.

Woinarski, J.C.Z., Connors, G. and Franklin, D.C. 2000. Thinking honeyeater: nectar maps for the Northern Territory, Australia. *Pacific Conservation Biology*. **6:** 61-80.

Woodgate P. W., Peel B. D., Coram J. E., Farrell S., J., Ritman K. T. and Lewis A. 1996. Oldgrowth forest studies in Victoria, Australia: concepts and principles. Forest *Ecology and Management* **85:** 79–94.

Woodgate, P.W., Peel, W.D., Ritman, K.T., Coram, J.E., Brady, A., Rule, A.J. and Banks, J.G.C. 1994. *A Study of the Old-Growth Forests of East Gippsland*. Department of Conservation and Natural Resources, Victoria, Melbourne.

6.1. References - flower attributes

The following list of references used to gather data on flowering characteristics is indicative, not comprehensive.

Birt, P. 2005. *Mutualistic interactions between the nectar-feeding little red flying fox* Pteropus scapulatus *(Chiroptera: Pteropodidae) and eucalypts: habitat utilisation and pollination*. PhD thesis. University of Queensland, Brisbane.

Blake, S.T. and Rolf, C. 1987. *Honey Flora of Queensland* (3rd Edition). Qld Department of Primary Industries, Brisbane, Qld.

Burgess, I.P. and Griffin, A.R. 1991. *Flowering Time of Eucalyptus Species in their Natural Habitat*. CSIRO Division of Forestry, Canberra, ACT.

Clemson, A. 1985. *Honey and Pollen Flora*. Inkata Press, Melbourne.

Dale, J.A. and Hawkins, P.J. 1983. *Phenological Studies of Spotted Gum in Southern Inland Queensland*. Department of Forestry Qld.

Dobson, M., Goldingay, R.L. and Sharpe, D. 2004. Feeding behaviour of the squirrel glider in remnant habitat in Brisbane. *Australian Mammalogy*. **26**: 27-35.

Fairly, A. and Moore, P. 1989. *Native Plants of the Sydney District: An Identification Guide*. Kangaroo Press, Sydney.

Goldingay R. L. 1990. The foraging behaviour of a nectar feeding marsupial, *Petaurus australis*. *Oecologia* **85**: 191-9.

Goldingay R. 2005. Is there a diel pattern to nectar secretion in the Red Bloodwood *Corymbia gummifera? Cunninghamia* **9:** 325-29.

Law B.S. 1994. Nectar and pollen: dietary items affecting the abundance of the common blossom bat *Syconycteris australis* in south-eastern Australia. *Australian Journal of Ecology* **19**: 425-434.

Law B.S. and Chidel M. 2007. *The effect of logging on nectar production by eucalypts: spotted gum and grey ironbark*. Final Report (Project SFN-2A) to RIRDC, Canberra.

Law, B., Mackowski, C., Schoer, L. and Tweedie, T. 2000. Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales. *Austral Ecology* 25: 160-178.

McWilliam, A.N. 1986. The feeding ecology of *Pteropus* in north-eastern New South Wales, Australia. *Myotis* **23-24:** 201-208.

Parry-Jones, K. A. and Augee, M. 1991. Food selection by Grey-headed Flying-foxes (*Pteropus poliocephalus*) occupying a summer colony site near Gosford, N.S.W. *Wildlife Research* **18**: 111-124.

Pook, E.W., Gill, A.M. and Moore, P.H.R. 1997. long term variation of litter fall, canopy leaf area and flowering in a *Eucalyptus maculata* forest on the south coast of New South Wales. *Aust. J. Botany* **45**: 737-755.

Sommerville, D. 1996-1999. *Floral Resource Database for the NSW Apiary Industry*. Rural Industries Research and Development Corporation, Barton, ACT.

Somerville, D. 1997a. *Beekeeping in the Bulahdelah State Forests*. Report prepared by NSW Agriculture, Goulburn, NSW.

Somerville, D. 1997b. *Beekeeping in the Glenn Innes State Forests*. Report prepared by NSW Agriculture, Goulburn, NSW.

Somerville, D. 1997c. *Beekeeping in the Urbenville State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Barnes, I. 1994. *Batemans Bay Forestry District Apiary Management Survey September 1994*. Report prepared by NSW Agriculture and State Forests of NSW.

Somerville, D. and Bishop, S. 1997. *Beekeeping in the Kempsey State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Colley, C. 1990. *Nowra State Forest Apiary Management Survey August 1990*. Report prepared by NSW Agriculture & Fisheries and Forestry Commission of NSW.

Somerville, D. and Cooper, M. 1997. *Beekeeping in the Morisset State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Croft, A. 1997. *Beekeeping in the Bathurst-Oberon State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Dodds, S. 1995. *Narooma Forestry District Apiary Management Survey Results 1995*. Report prepared by NSW Agriculture and State Forests of NSW.

Somerville, D. and Hoffman, T. 1997. *Beekeeping in the Wauchope State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Murray, J. 1997a. *Beekeeping in the Grafton State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Murray, J. 1997b. *Beekeeping in the Taree State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Murray, J. 1997c. *Beekeeping in the Urunga State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Raper, E. 1997. *Eden-Bombala Forestry District Study of Beekeeper Usage & Importance – March 1997*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Rienstra, R. 1997. *Beekeeping in the Inverell State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Robertson, I. 1997. *Beekeeping in the Casino State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Somerville, D. and Shannon, R. 1995. *Queanbeyan/Badja State Forest Management Area Apiary Management Potential February 1995*. Report prepared by NSW Agriculture and State Forests of NSW.

Somerville, D. and Signor, A. 1997. *Beekeeping in the Walcha & Gloucester State Forests*. Report prepared by NSW Agriculture and State Forests of NSW.

Somerville, D. and Wilson, M. 1997. *Beekeeping in the Dorrigo State Forests*. Report prepared by NSW Agriculture and State Forests NSW.

Trueman, F. 1997. *The Development of a Natural Resource Database for the Queensland Apiary Industry. Appendix 4. Plants targeted by beekeepers shown by map grid location number and months of use.* Animal Research Institute, Qld DPI, Moorooka, Qld.