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Winter habitat use by the endangered, migratory Swift Parrot (*Lathamus discolor*) in New South Wales

Debra L. Saunders[A,B] *and Robert Heinsohn*[A]

[A]The Fenner School of Environment and Society, The Australian National University, Canberra, ACT 0200, Australia.
[B]Corresponding author. Email: debbie.saunders@anu.edu.au

Abstract. Migratory birds are dependent on a combination of suitable wintering, migration and breeding habitats. Identification and protection of these habitats is essential for the conservation of the birds. The endangered Swift Parrot (Psittacidae : *Lathamus discolor*) migrates north from Tasmania to south-eastern mainland Australia in search of suitable winter food resources. This 5-year study examines the use of known winter foraging habitats by Swift Parrots on a state-wide scale not previously attempted. Swift Parrots used a diversity of winter foraging habitats in regions of the coast and western slopes of New South Wales each year, including several habitats that occur in endangered ecological communities. The abundance of Swift Parrots in New South Wales fluctuated significantly between years and regions, with coastal areas providing important drought-refuge habitats for a large proportion of the population. Over half of all foraging sites were used repeatedly, highlighting their likely importance for conservation. Landscapes containing winter foraging habitat included scattered trees, remnant vegetation and continuous forests, and Swift Parrots foraged extensively on lerp and nectar from a diversity of tree species within these. The occurrence of Swift Parrots at foraging sites was primarily associated with the abundance of lerp, nectar and non-aggressive competitors.

Introduction

A major adaptive value of migration in birds is to locate and consume sufficient food over the wintering period. Successful location of food sources is essential for return migration and subsequent breeding efforts (Newton 2004). Although a large number of terrestrial birds in Australia undertake regular migratory movements (Chan 2001; Griffioen and Clarke 2002; Dingle 2004), there is little information currently available on their habitat use. The few studies that have been undertaken have focussed on breeding habitats (Legge and Heinsohn 2001; Boland 2004; van Dongen and Yocom 2005) or small areas within the wintering range of a species (Mac Nally and Horrocks 2000; Kennedy and Overs 2001; Kennedy and Tzaros 2005). There is an urgent need to improve our understanding of habitat use by these species, especially for those classified as threatened.

One such species is the Swift Parrot (Psittacidae : *Lathamus discolor*), an endangered austral migrant (total population estimate 2500 birds). It breeds in Tasmania in spring–summer then migrates north across Bass Strait before dispersing across a broad wintering range (~1 250 000 km^2) on the Australian mainland each year. Throughout their range, Swift Parrots use the most mature trees in the landscape, which provide suitable nesting and reliable foraging sources (Kennedy and Overs 2001; Brereton *et al*. 2004; Kennedy and Tzaros 2005). However, both breeding and wintering habitats for this species have been substantially lost or altered and therefore conservation efforts have been largely focussed on the protection and enhancement of remaining habitat (Swift Parrot Recovery Team 2001). However, detailed studies of wintering habitats have been restricted to box–ironbark woodlands within two regions – central Victoria (Mac Nally and Horrocks 2000; Kennedy and Tzaros 2005) and the south-western slopes of New South Wales (NSW) (Kennedy and Overs 2001) – and there is no detailed information on larger scale habitat use by this highly mobile species in other regions of its wintering range.

This study examines the use of winter foraging habitats by migratory Swift Parrots in NSW on a state-wide scale not previously attempted. We examine the variables affecting spatial and temporal use of known habitats across multiple regions and seasons. Such information increases our understanding of the ecological needs and movements of this species and provides a basis for improving the effectiveness of conservation measures.

Methods

Study area

The study area extended from the mid-north coast (Coffs Harbour area, 30°S, 154°E) to the south-western slopes (Culcairn area, 36°S, 146°E) of NSW (Fig. 1). This included five regions: the northern, central and southern coasts and the central and south-western slopes of the Great Dividing Range. The study was undertaken during the Swift Parrot wintering period (from April to October) each year from 2001 to 2005 in a variety of temperate woodland and forest landscapes.

Site selection

The aim was to identify foraging sites used by Swift Parrots and to document the variables that determined whether they were used each year. Swift Parrots are rare, broadly distributed and often cryptic by nature. At first, extensive aural and visual searches were conducted along access routes from a slow-

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moving vehicle in areas of potential habitat. Potential habitats were defined as areas of forest or woodland that had previous Swift Parrot records or contained tree species with suitable winter food resources. This included known forage tree species such as Swamp Mahogany (*Eucalyptus robusta*), Spotted Gum (*Corymbia maculata*), Red Bloodwood (*Corymbia gummifera*) and Forest Red Gum (*Eucalyptus tereticornis*) in coastal habitats, and Mugga Ironbark (*Eucalyptus sideroxylon*) and Grey Box (*Eucalyptus microcarpa*) in western slopes habitats (Swift Parrot Recovery Team 2001). When areas of increased bird activity were located from the vehicle, general bird surveys were undertaken on foot within a 50 m radius using Swift Parrot recovery program volunteer survey forms (available at http://www.birdsaustralia.com.au/birds/downloads/swift_regent_survey.pdf). However, study sites were only established when Swift Parrots were located and then observed foraging. Each study site extended to a radius of 500 m from the tree in which the birds were first observed foraging. Within this site, a 0.1-ha (20 m × 50 m) habitat plot and a 50-m-radius bird-survey plot were also established to provide a sample of the surrounding habitats and bird communities.

The 53 sites used in this study (35 coastal, 18 western slopes) were, by necessity, added incrementally throughout the study period (nine sites in 2001, 28 sites 2002, three sites 2003, nine sites 2004, and four sites 2005) although most (53%) were established in 2002. Coastal and western slopes sites were examined separately given their different habitat types, bird assemblages, climatic conditions and surrounding land use.

Spatial and temporal habitat use

Once a site was established, repeated surveys were undertaken in each subsequent year (nine surveys in 2001, 30 surveys 2002, 40 surveys 2003, 49 surveys 2004, and 53 surveys 2005) to obtain data pertaining to both presence and abundance of Swift Parrots. An exception to this was during 2002 when there was widespread drought across Australia (Bureau of Meteorology 2002) and an influx of Swift Parrots into NSW habitats. During this year, survey efforts focussed on finding new sites and only two previous sites were re-surveyed. Each of the study sites was surveyed between one and five times over the study period (75% of sites were surveyed at least three times) resulting in a total of 181 surveys (131 coastal, 50 western slopes).

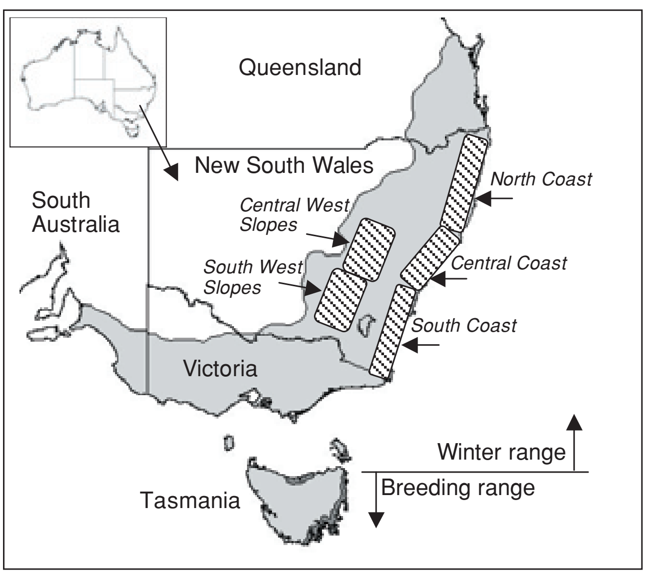

Fig. 1. Range of Swift Parrots in south-eastern Australia (light shading = non-breeding, dark shading = breeding), and the regions of the study area (hatched) in New South Wales.

Site-fidelity

Site-fidelity was defined as the repeated use of a site by the species (not necessarily the same individuals) in at least two of the five years. Site-fidelity between years was examined using occurrence data collected from the current study together with species records from long-term (1968–2000) databases (Atlas of NSW Wildlife http://wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas/watlas.jsp and Swift Parrot recovery program database, Department of the Environment, Water, Heritage, and the Arts, Canberra).

Landscape and habitat types

Potential Swift Parrot habitats were located within three main landscape types. These landscapes were classified as: (1) scattered tree (scattered individual trees within a rural or urban environment), (2) remnant vegetation (patches of natural vegetation, <10 000 ha, surrounded by rural or urban environments) or (3) continuous forest (extensive areas, ≥10 000 ha, of natural vegetation). Although the size of remnant patches of vegetation varied from <5 ha to 8400 ha, suitable habitat within the largest remnants was limited to ~10–20% of the total remnant area. We examined associations between these landscape types and abundance of Swift Parrots.

The tree species used for foraging, the types of food present and the number of times an individual was observed foraging on each of these were also documented. Data presented on food types consumed are limited to tree species in which Swift Parrots were observed foraging on lerp, nectar or both at least 100 times.

Site-use associations

We examined associations between Swift Parrot occurrence and changing abundance of food and competitors at known foraging sites over the study period. Abundance of food was estimated by counting the number of trees with lerp or flowers, or both, within the habitat plot. Flowers were used as a surrogate for nectar as it was not practical to collect detailed data on nectar production on the large-scale of this study. The abundance of all bird species seen or heard during a 10-min survey within the bird survey plot was recorded. Of these, all potential competitor bird species (those observed to consume the same food sources as Swift Parrots) were classified as aggressive or non-aggressive. Aggressive competitors were those observed to interact aggressively with the Swift Parrot resulting in a behavioural change (e.g. stopping of foraging or flying from tree). Non-aggressive competitors were those that did not display aggression towards the Swift Parrot despite occurring in close proximity (within 50 m) of the birds. Aggressive and non-aggressive competitors that occurred in at least 5% of the surveys were included in the analyses. There were insufficient data to consider the effect of potential predators.

Separate analyses were also undertaken for individual species from the aggressive and non-aggressive competitor groups to determine the species with the strongest associations with Swift Parrots.

Statistical analyses

We employed a statistical modelling approach using Genstat software (Genstat Committee 2007). This methodology allows a unified approach to the analysis of large datasets regardless of the underlying statistical distribution. Importantly, the biological factors of interest can be isolated and predicted with standard errors allowing comparisons and illustrations across a range of values. To account for potential pseudo-replication from repeated sampling of sites, preliminary analyses were conducted using generalised liner mixed models (GLMM) with survey 'site' as a random factor. However, there were no significant within-term correlations ($P > 0.05$) within 'site' in any of the models, suggesting that repeated-measures of the same site across different years were not of statistical concern. Therefore each site-visit was considered an independent data point and analyses were simplified to generalised linear models (GLM) with appropriate link functions (logit for binomial presence–absence data, or logarithmic for abundance data). Models initially included all potential explanatory variables, and all two-way interactions, except when this was prohibited by co-linearity of variables or over-parameterisation caused by including too many variables. Higher order interactions were not included owing to the likelihood of over-parameterising the models. Model terms were dropped progressively from the full model until the most parsimonious model with only significant terms remained. Models terms were also dropped in varying order to confirm consistency of effects.

Analyses were limited in some cases owing to violations of the assumptions inherent in the modelling approach. For example, abundance of Swift Parrots could not be modelled at the site-scale owing to the large influx of Swift Parrots into coastal areas during one year of the study, which meant the data could not easily be normalised via logarithmic or other transformations. In general, we list the effect of all variates and significant two-way interactions, but only plot the general effects of significant single variates.

Results

Over the 5-year study, a cumulative total of 2149 Swift Parrots were recorded at the 53 foraging sites (35 coastal, 18 western slopes). Swift Parrots were recorded in 36% of all surveys (43 coastal, 22 western slopes) and flock-sizes were up to 200 birds (median = 25 birds, s.d. 48) in coastal habitats and up to 60 birds (median = 20 birds, s.d. 18) in western slopes habitats.

Spatial and temporal use of habitat

Throughout the study period, the abundance of Swift Parrots in NSW habitats varied significantly between regions and years (region $\chi^2_2 = 3.73$, $P = 0.005$; all years $\chi^2_4 = 393.95$, $P < 0.001$). Similarly, the abundance of Swift Parrots varied significantly during both drought (2002 only, regions $\chi^2_2 = 49.08$, $P < 0.001$) and non-drought (regions $\chi^2_2 = 3.73$, $P = 0.005$; non-drought years $\chi^2_4 = 393.95$, $P < 0.001$) conditions (Fig. 2).

Variation in Swift Parrot abundance was most pronounced during the 2002 drought (Fig. 2*a*). In this year, the mean abundance of Swift Parrots was 21.7 times greater in the central coast region and 7.5 times greater in the northern coast region when compared with other years (Fig. 2*b*). An indication of the proportion of the population using these foraging habitats in 2002 is provided by an incidental observation of mass roosting by 650 Swift Parrots (some one-third of the estimated total population of the species) near foraging sites on the central coast (D. L. Saunders, personal observation). The south-western slopes regularly supported Swift Parrots in drought and non-drought years (Fig. 2*b*).

Site-fidelity

During the 5-year study period, Swift Parrots were recorded using 21% of the study sites repeatedly between years (not necessarily consecutively), despite sites being surveyed only once each year and the associated potential to miss birds. However, when Swift Parrot records before this study were included (since 1968), there was evidence of long-term repeated use, with 53% of sites used in multiple years (37% coastal, 83% western slopes) (Fig. 3).

Landscape and habitat types

Swift Parrot foraging sites were located within scattered tree, remnant vegetation and continuous forest landscapes. In coastal habitats, most sites were in scattered trees (69% *v.* 17%

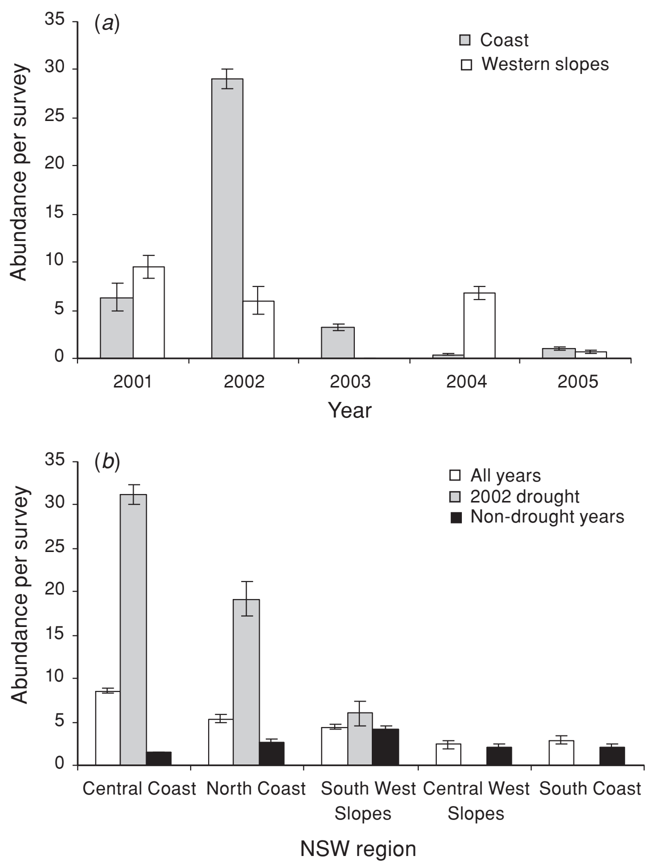

Fig. 2. Predicted (*a*) temporal and (*b*) spatial variation in mean abundance of Swift Parrots (per survey, ± s.e.) within five regions of NSW 2001–05.

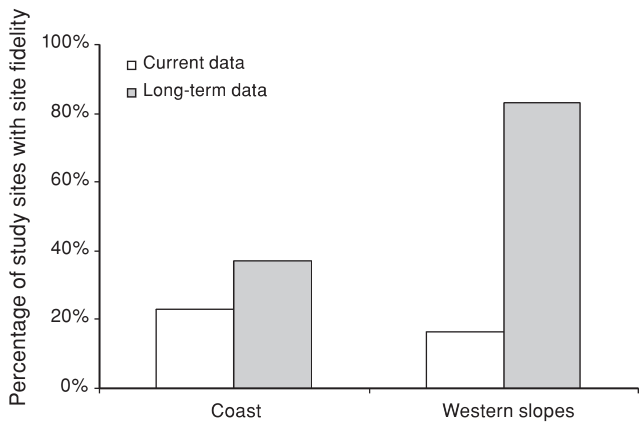

Fig. 3. Percentage of study sites repeatedly used by Swift Parrots in coastal and western slopes habitats of NSW based on both current records (this study) and longer term records.

in remnant vegetation and 14% in continuous forest). However, mean abundance was significantly greater in remnant vegetation ($\chi^2_2 = 142.22$, $P < 0.001$) than in the other landscape types (Fig. 4). Within western slopes habitats, most sites were in remnant vegetation (89%) with all remaining sites in scattered trees. Mean abundance of Swift Parrots did not differ significantly between the remnant vegetation and scattered tree landscapes for western slopes habitats ($\chi^2_2 = 0.48$, $P = 0.49$).

Swift Parrots were observed foraging on lerp and nectar 11 306 times over the 5-year study period. The proportion of foraging observations on lerp and nectar were similar for both coastal and western slopes habitats (Table 1). Swift Parrots were observed foraging more than 100 times in 11 foraging tree-species (seven coastal, four western slopes), consuming lerp from all and nectar from eight (Table 1). Seven of these species of tree have been so extensively cleared they now occur within endangered ecological communities, and yet they account for 75% of all foraging observations (Table 1). In particular, Forest Red Gum accounted for 49% of all coastal foraging observations and White Box accounted for 43% of all western slopes foraging observations (Table 1).

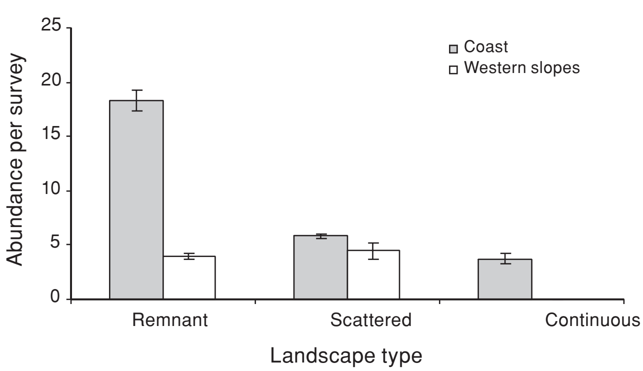

Fig. 4. Predicted abundance of Swift Parrots (per survey, ± s.e.) within different landscape types in coastal and western slopes areas of NSW.

Site-use associations

Variables significantly affecting the occurrence of Swift Parrots at known foraging sites included the abundance of trees with flowers or lerp, or both, and non-aggressive competitors (Table 2). They were more likely to occur at both coastal and western slopes sites as abundance of flowers increased (Fig. 5*a*). However, in coastal areas, the positive influence of flowering trees varied with the number of trees with lerp and non-aggressive competitors (Table 2). The number of trees with lerp also had a positive influence on occurrence of Swift Parrots in coastal habitats (Fig. 5*b*). Within both coastal and western slopes habitats, Swift Parrots were more likely to occur as the number of non-aggressive competitor species increased (Fig. 5*c*).

There were no significant interactions affecting occurrence of Swift Parrots on the western slopes. All other variables failed to improve the models significantly (coast $0.06 \leq \chi^2_1 \leq 2.75$, $0.097 \leq P \leq 0.808$; western slopes $0.05 \leq \chi^2_1 \leq 2.78$, $0.096 \leq P \leq 0.824$).

One-third (32) of the 97 bird species recorded at Swift Parrot winter foraging sites were potential competitors. Eighteen species occurred regularly enough for inclusion in analyses, and these were further categorised as aggressive or non-aggressive (Table 3). Occurrence of Swift Parrots was significantly associated with seven of these species. Five species had positive and two had negative effects (Table 4). The remaining 11 species did not significantly contribute to the models ($0 \leq \chi^2_1$ 2.94, $0.086 \leq P \leq 0.971$).

The Little Lorikeet (*Glossopsitta pusilla*) was the only species found to have a significant positive association with Swift Parrots in both coastal and western slopes habitats (Table 4). Within coastal habitats the Noisy Friarbird (*Philemon corniculatus*) also had a significant positive association with Swift Parrots. Similarly, the Red Wattlebird (*Anthochaera carnunculata*), Dusky Woodswallow (*Artamus cyanopterus*) and Fuscous Honeyeater (*Lichenostomus fuscus*) all had significant positive associations with Swift Parrots in western slopes habitats (Table 4). Significant negative associations with Swift Parrot occurrence were found for the Rainbow Lorikeet (*Trichoglossus haematodus*) in coastal habitats and the Noisy Miner (*Manorina melanocephala*) within western slopes habitats (Table 4).

Discussion

The small numbers and often secretive habits of Swift Parrots make them difficult to locate across their vast wintering range in south-eastern Australia. Nonetheless the survey approach used in this 5-year study led to sufficient encounter rates (2149 Swift Parrots at 53 sites) to enable analysis of the factors determining their use of foraging sites. Our study thus provides valuable information on the spatial and temporal variability in habitat use, and influential variables, in both coastal and western slopes regions of NSW, as well as highlighting the importance of site-fidelity for this migratory species.

Spatial and temporal use of habitat

The abundance of Swift Parrots at our NSW study sites fluctuated markedly between years and regions. This is consistent

Table 1. Tree species in which Swift Parrots foraged, the regions and landscape types in which these occurred, and types of food taken and the number of foraging actions in each tree species in wintering habitats of NSW

Tree species	Region	Landscape type	Food type and number of foraging observations		
			Lerp	Nectar	Total
Coastal NSW					
Forest Red Gum (*Eucalyptus tereticornis*)[A]	Central and north coasts	Scattered, remnant	841	3040	3881
Swamp Mahogany (*Eucalyptus robusta*)[A]	Central and north coasts	Scattered, remnant	1441	738	2179
Blackbutt (*Eucalyptus pilularis*)	Central and north coasts	Scattered, remnant, continuous	831	278	1109
Spotted Gum (*Corymbia maculata*)[A]	South, central, and north coasts	Scattered, remnant, continuous	175	234	409
Coastal Grey Box (*Eucalyptus mollucana*)[A]	Central and north coasts	Scattered, remnant	111	12	123
Red Bloodwood (*Corymbia gummifera*)	North coast	Scattered	130	0	130
Rough-barked Angophora (*Angophora subvelutina*)	North coast	Remnant	116	0	116
Total foraging observations coastal NSW			3645	4302	7947
Western slopes of NSW					
Mugga Ironbark (*Eucalyptus sideroxylon*)[A]	South-western and central western slopes	Remnant	847	619	1466
White Box (*Eucalyptus albens*)[A]	South-western and central western slopes	Scattered, remnant	301	845	1146
Grey Box (*Eucalyptus microcarpa*)[A]	south-western slopes	Remnant	503	8	511
Yellow Box (*Eucalyptus melliodora*)[A]	South-western and central western slopes	Remnant	236	0	236
Total foraging observations western slopes			1887	1472	3359
Total foraging observations			5532	5774	11306

[A]Occurs within an endangered ecological community (NSW Scientific Committee 1997, 1998, 2000, 2002*a*, 2002*b*, 2002*c*, 2004*a*, 2004*b*, 2005, 2006).

with previous studies in central Victoria (Mac Nally and Horrocks 2000; Kennedy and Tzaros 2005), indicating that patterns of habitat use vary throughout the wintering range of this species. Such variable patterns in use of habitat by migrants often result from variable climatic conditions and the corresponding spatial and temporal patterns of plant, and hence food, productivity (Nix 1976; Newton 2004; Bureau of Meteorology 2006).

The greatest variability in use of habitat in this study occurred on the central and northern coasts of NSW. Although these coastal regions often supported small numbers of Swift Parrots, this changed dramatically during drought conditions in 2002 (Bureau of Meteorology 2002; Bureau of Meteorology 2006). The numbers of Swift Parrots foraging in these coastal regions increased substantially during this year, with a large proportion of the population apparently using these areas as drought refuges. Our study draws attention to the importance of these refuge areas for the long-term viability of the Swift Parrot population, as for other fauna dependent on highly variable environments (Manning *et al*. 2007). In addition, Swift Parrots were regularly observed foraging in habitats on the south-western slopes during both drought and non-drought conditions. This emphasises the importance of these inland habitats for conservation since they appear to provide reliable and accessible food sources for the Swift Parrot.

Site-fidelity

Our study also showed that many of the foraging sites were used repeatedly over many years. Such site-fidelity was evident within all coastal and western slopes regions over the 5-year period. This is consistent with a previous study on the south-western slopes of NSW (Kennedy and Overs 2001). Another study in central Victoria found little evidence of site-fidelity by Swift Parrots (Mac Nally and Horrocks 2000), though this may have been a result of the small spatial (single region) and temporal (2 years) scales of the study. The repeated use of sites over time suggests that some sites or habitats provide valuable resources that are repeatedly selected and used by Swift Parrots when conditions and food supplies are suitable. Such site-fidelity has been demonstrated for migratory landbird species within wintering and migration habitats around the world, and is thought to reduce the energy expenditure needed for locating and consuming sufficient food for the wintering period, return migration and subsequent breeding (Purchase 1985; Terrill 1990; Ganusevich *et al*. 2004; Markovets and Yosef 2005). The

Table 2. Significant terms and interactions associated with occurence of Swift Parrots in coastal and western slopes foraging habitats

	d.f.	χ^2	*P*
Coastal model			
Flowering trees	1	2.41	0.12
Lerp trees	1	11.04	<0.001
Non-aggressors	1	5.07	0.024
Flowering trees + lerp trees	1	7.79	0.005
Flowering trees + non-aggressors	1	5.62	0.018
Western slopes model			
Flowering trees	1	6.94	0.008
Non-aggressors	1	14.64	<0.001

importance of such sites for conservation is well recognised (Warkentin and Hernandez 1996; Mehlman *et al*. 2005) and our study suggests that they are also important for Swift Parrots.

Landscape and habitat types

Winter foraging sites for Swift Parrots in NSW occurred within all three landscapes: scattered tree, remnant vegetation and continuous forest landscapes. This finding is consistent with previous studies, which found that Swift Parrots were capable of locating small fragments and remnants within agricultural landscapes as well as more extensive areas of habitat (Mac Nally and Horrocks 2000; Kennedy and Overs 2001; Kennedy and Tzaros 2005). Although most coastal foraging sites were within scattered trees, the greatest abundance of Swift Parrots occurred within remnant vegetation landscapes, emphasising the importance of this landscape type within the increasingly urbanised coastal environment (Natural Resource Management Ministerial Council 2003). On the western slopes, foraging sites were predominantly in remnant vegetation, though Swift Parrots were similarly abundant in scattered tree landscapes. Few, if any, continuous areas of Swift Parrot winter foraging habitat remain on the central and south-western slopes owing to the agricultural land-use that dominates the area. This emphasises the importance of protecting and maintaining the health of the remaining scattered trees and remnants, as well as increasing the amount of critical habitat through restoration and regeneration programs in these regions (Reid 1999; Gibbons and Boak 2002; Manning *et al*. 2006*a*, 2006*b*).

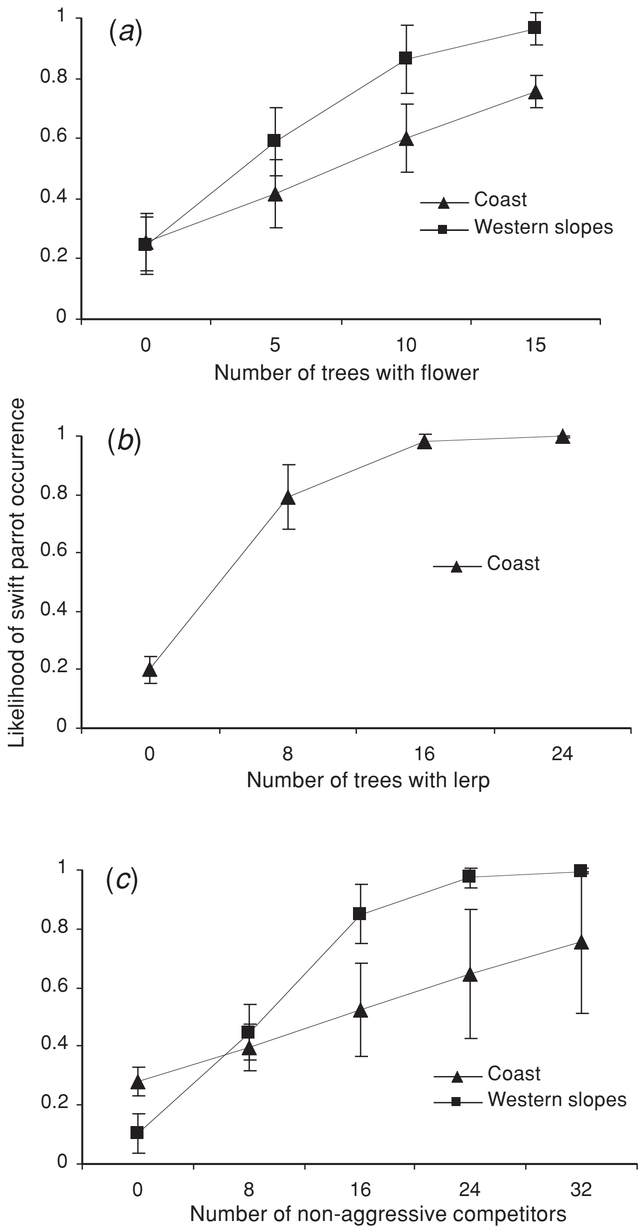

Fig. 5. Predicted likelihood of occurrence of Swift Parrots (± s.e.) in relation to the number of trees with (*a*) flowers and (*b*) lerps and (*c*) the abundance of non-aggressive competitor species in coastal and western slopes habitats of NSW. Note that (*b*) does not include western slopes data because trees with lerp did not significantly contribute to the model.

Table 3. Aggressive and non-aggressive competitor bird species recorded at Swift Parrot foraging sites

Bird	Category
Yellow-faced Honeyeater (*Lichenostomus chrysops*)	Non-aggressive
Fuscous Honeyeater (*Lichenostomus fuscus*)	Non-aggressive
Yellow-tufted Honeyeater (*Lichenostomus melanops*)	Non-aggressive
White-plumed Honeyeater (*Lichenostomus penicillatus*)	Non-aggressive
New Holland Honeyeater (*Phylidonyris novaehollandiae*)	Non-aggressive
Lewin's Honeyeater (*Meliphaga lewinii*)	Non-aggressive
Black-chinned Honeyeater (*Melithreptus gularis*)	Non-aggressive
White-naped Honeyeater (*Melithreptus lunatus*)	Non-aggressive
Spotted Pardalote (*Pardalotus punctatus*)	Non-aggressive
Striated Pardalote (*Pardalotus striatus*)	Non-aggressive
Dusky Woodswallow (*Artamus cyanopterus*)	Non-aggressive
Little Lorikeet (*Glossopsitta pusilla*)	Non-aggressive
Musk Lorikeet (*Glossopsitta concinna*)	Aggressive
Scaly-breasted Lorikeet (*Trichoglossus chlorolepidotus*)	Aggressive
Rainbow Lorikeet (*Trichoglossus haematodus*)	Aggressive
Red Wattlebird (*Anthochaera carnunculata*)	Aggressive
Noisy Friarbird (*Philemon corniculatus*)	Aggressive
Noisy Miner (*Manorina melanocephala*)	Aggressive

Table 4. Competitor species significantly associated with Swift Parrot occurrence in coastal and western slopes areas

'Effect' indicates an increase (↑) or decrease (↓) in the likelihood of Swift Parrot occurrence. Scientific names as in Table 3

Bird	d.f.	χ^2	*P*	Effect
Coastal areas				
Little Lorikeet	1	15.1	<0.001	↑
Noisy Friarbird	1	15.0	<0.001	↑
Rainbow Lorikeet	1	16.4	<0.001	↓
Western slopes areas				
Little Lorikeet	1	4.85	0.028	↑
Red Wattlebird	1	9.15	0.002	↑
Dusky Woodswallow	1	4.34	0.037	↑
Fuscous Honeyeater	1	7.17	0.007	↑
Noisy Miner	1	9.86	0.002	↓

Swift Parrots occurred in several known winter foraging habitats, including Swamp Mahogany, Spotted Gum and Red Bloodwood forests on the coast, and Mugga Ironbark and Grey Box woodlands on the western slopes (Kennedy and Overs 2001; Swift Parrot Recovery Team 2001). However, this study found two further tree species of potential importance, Coastal Grey Box (*Eucalyptus mollucana*) and Rough-barked Angophora (*Angophora floribunda*), although we only observed Swift Parrots foraging on lerp from Rough-barked Angophora during drought conditions. Our study also provided evidence of more extensive regional use of four tree species known to be used for foraging (Forest Red Gum, Blackbutt (*Eucalyptus pilularis*), White Box (*E. albens*) and Yellow Box (*E. melliodora*)). Although Forest Red Gum and Blackbutt have previously been mentioned in the Swift Parrot Recovery Plan (Swift Parrot Recovery Team 2001), this study identified their importance as sources of lerp and nectar in the northern and central coastal regions of NSW. Similarly, our study provides the first foraging observations in White Box and Yellow Box on the western slopes of NSW. Swift Parrots were found to forage predominantly (75% of foraging observations) within habitats that have been so extensively cleared they are classified as endangered ecological communities (Endangered Species Scientific Subcommittee 2005). This highlights the urgent need to conserve a diversity of habitat types, including several endangered ecological communities, across a range of landscape types and regions to ensure suitable foraging resources are available each year and in all environmental conditions.

Use of foraging sites

This is the first state-wide study to demonstrate the influence of food resources and competitor species on the winter habitat use of a terrestrial migratory bird within the Australian migration system. Within coastal habitats, Swift Parrots were more likely to occur as the abundance of lerp, nectar and non-aggressive competitors increased. Similarly, within western slopes habitats, Swift Parrots were more likely to occur as the abundance of nectar and non-aggressive competitors increased. This is not surprising given that a principal purpose of migration is to locate and consume sufficient food (Newton 2004). Although non-aggressive competitors may simply converge on the same food resources, it is also possible that they affect where Swift Parrots forage by providing them with information on the presence and accessibility of food resources (e.g. heterospecific attraction; Thomson *et al*. 2003).

Although lerp and nectar are both recognised foods of the Swift Parrot (Cole 1919; Hindwood and Sharland 1964; Brown 1989), there have been no assessments of Swift Parrot occurrence in relation to the abundance of these foods. Previous studies focussed primarily on nectar and were unable to find strong dependence of Swift Parrots on this resource (Mac Nally and Horrocks 2000; Kennedy and Overs 2001; Kennedy and Tzaros 2005). Similarly, other studies attempting to examine relationships between nectarivorous birds and nectar availability (Paton 1980; Pyke 1983, 1985; Ford and Paton 1985; McFarland 1986*a*, 1986*b*; Ford 1991; Timewell and Mac Nally 2004) have had mixed success. This is possibly because honeyeaters also eat alternative carbohydrate resources, such as lerp, manna or honeydew (Clark 1964; Paton 1980, 1985; Woinarski 1984; Pyke 1985; Woinarski *et al*. 1989). In this study, consumption of lerp and nectar comprised similar proportions of the foraging observations, emphasising the importance of both foods, although it is not clear why lerp had a greater influence in coastal habitats.

The diversity of bird species, and more specifically competitor species, recorded in Swift Parrot winter habitats was similar to that found in previous studies (Mac Nally and Horrocks 2000; Kennedy and Overs 2001; Kennedy and Tzaros 2005). Of the 18 competitors we recorded (regularly enough for inclusion in the analyses) only seven were associated with Swift Parrots, five positively and two negatively. Of those with positive associations, three were non-aggressive (Little Lorikeet, Fuscous Honeyeater and Dusky Woodswallow) and two were aggressive (Noisy Friarbird and Red Wattlebird). Unfortunately we cannot determine whether these positive associations were a result of similar habitat preferences, heterospecific attraction or other inter-specific interactions (Forsman *et al*. 1998; Thomson *et al*. 2003; Monkkonen *et al*. 2004). Negative associations with the two remaining aggressive competitors, the Rainbow Lorikeet and Noisy Miner, were not surprising as both are known to have negative impacts on other bird species through interference competition, dominating areas with rich food sources and aggressively excluding more passive species (Dow 1977; Loyn 1985; Lamont 1996; Grey *et al*. 1997, 1998; French *et al*. 2003; Shukuroglou and McCarthy 2006).

In summary, this study provides valuable insights into the spatial and temporal variation in use of winter foraging habitats by Swift Parrots on a state-wide scale, and highlights the importance of conserving these habitats across NSW. However, further research that encompasses the entire winter range of this species (i.e. several states) would provide a more complete understanding of the ecological requirements of the population. Further monitoring of known foraging sites may also reveal additional evidence of site-fidelity, and the application of remote tracking devices, once they can be made small enough for use on Swift Parrots, may reveal important information on individual survival, site-fidelity and migration strategies (Wikelski *et al*. 2007). This study also focussed on readily accessible public land, but additional habitat on private land needs to be included for a more complete picture of habitat use. Given that lerp were eaten in similar proportions to nectar in this study, we recommend that both of these food sources be considered in any future studies examining food resources for this species. Furthermore our results highlight the potential importance and complexity of interspecific associations with Swift Parrots, suggesting that further behavioural research in this regard may yield valuable information about these associations.

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