

Ecology and conservation of the swift parrot - an endangered austral migrant



Swift parrots by Geoffrey Dabb (2004)

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Declaration

The research described in this thesis is my own original work and no part has been previously submitted for a degree. Where others have contributed they are duly acknowledged in the Preface and Acknowledgement sections.

A handwritten signature in black ink, appearing to read 'Debra L. Saunders', with a stylized, cursive script.

Debra L. Saunders

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Preface

With the exception of Chapter 1 (Introduction) and Chapter 6 (Conclusion), this thesis consists of a series of interrelated manuscripts that have been prepared (Chapter 2), submitted (Chapter 5), or accepted for publication (Chapters 3 and 4). Each of the submitted and accepted manuscripts is presented as it appears, or is expected to appear, in the relevant journal with the exception of minor changes in style and formatting. Since the primary chapters of this thesis are manuscripts developed for independent publication in scientific journals, some repetition between chapters was unavoidable. Although several chapters include work with collaborators, I carried out the vast majority of work, including literature searches, research design, data collection, analysis and interpretation, and writing. Other contributors are acknowledged at the start of each chapter as co-authors and/or their specific contributions are detailed below. My supervisor, Robert Heinsohn provided guidance, support and editing for all chapters. Swift Parrot Recovery Team members Raymond Brereton, Chris Tzaros, Mark Holdsworth and Rob Price all provided information from their respective areas of expertise for inclusion in Chapter 3, which I compiled, edited and interpreted. Jeff Wood, Christine Donnelly and Ross Cunningham provided statistical advice and review regarding the appropriate data analyses and interpretation in Chapters 4 and 5.

Abstract

The swift parrot (*Lathamus discolor*, Psittacidae) is an endangered, austral migrant that inhabits forests and woodlands of south-eastern Australia. With a small population size (2500 birds), broad winter distribution (1 250 000 km²) and often cryptic nature, the swift parrot is a challenging species to study. In autumn they migrate north from their Tasmanian breeding grounds in search of suitable food resources throughout their winter range on mainland Australia. They are therefore dependent on a combination of suitable wintering, migration and breeding habitats. Although they spend a large proportion of their lives within winter habitats, the spatial and temporal dynamics of habitat use in this part of their range is poorly understood. This thesis aims to provide a greater understanding of large-scale winter habitat use by swift parrots, in both historic and current contexts, and provide a basis for future conservation management.

Swift parrots, or red-shouldered paroquets as they were previously known, were among the first Australian birds to be scientifically described and illustrated following European settlement in 1788. However, within 60 years of settlement, habitats throughout the range of the species were being impacted upon. An important aspect of this habitat loss is the speed and spatial extent with which it occurred throughout the parrots' broad distribution. Although the most extensive habitat loss in some areas occurred during colonial times, habitats continue to be lost as a result of various land management practices. Such impacts are also likely to be exacerbated by the ongoing cumulative impact with rapid climate change. As a result the swift parrot is an endangered species and is the subject of an ongoing national recovery program, to which this thesis contributes.

Conserving habitat for the swift parrot, and other wide-ranging fauna species, is challenging since impacts in one area tend to be dismissed based on the assumption that there is sufficient habitat in other areas. These conservation challenges are discussed in regard to the national swift parrot recovery program. Although recovery program implementation for this species has been successful in identifying and protecting some important habitats, there are still many gaps in our knowledge that need to be addressed through a continuing and adaptive recovery effort, including an understanding of variable habitat use throughout their winter range.

A study of swift parrot winter habitat use was therefore conducted at 53 sites across New South Wales over five years (2001-2005). Swift parrots used a diversity of winter foraging habitats in coastal and/or western slopes regions of New South Wales each year, including

several habitats that occur in endangered ecological communities. 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. Although swift parrot abundance fluctuated significantly between years and regions, over half of all foraging sites were used repeatedly, highlighting their likely importance for conservation.

Patterns of habitat use throughout the species' winter range were also studied across five states/territories using volunteer data from 4140 surveys. These surveys were conducted by up to 300 volunteers twice a year, for seven years (1998-2004) with swift parrots detected in 19% of surveys. As a result, this study provided the first demonstration of large-scale drought related movements by a migratory population throughout their winter range. It also demonstrated the dynamic spatial and temporal patterns of winter habitat use, including repeated use of sites, by an austral migrant. Four regions in central Victoria were used most consistently, although the birds also visited other regions each year.

During drought swift parrot abundance was significantly correlated with rainfall, whereby most of the population either concentrated in a few regions or migrated longer distances (up to 1000km) to drought refuges in wetter coastal areas. However, swift parrot abundance was not associated with specific climate variables during years of average to high rainfall throughout most of their range. Instead they appeared to prefer habitats within particular regions. Importantly this study emphasises that conservation measures need to be implemented throughout the distribution of migratory species, including drought refuge habitats and areas outside conservation reserves.

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Chapter 1 – Introduction



Swift Parrakeet or Lorikeet by Greene (1884)

(Source: Debbie Saunders)

The swift parrot is an enigma (Brown 1989)

The swift parrot – an endangered, austral migrant

This thesis examines swift parrot *Lathamus discolor* (Shaw 1790) habitat use at various spatial and temporal scales throughout their winter range. This initial chapter introduces the current state of knowledge on this endangered species and the context and aim of this thesis. It then provides an overview of how each chapter contributes to addressing the research aim.

The swift parrot is an endangered species that inhabits forests and woodlands of south eastern Australia. With a single migratory population of less than 2500 individuals, it is listed as an endangered species under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2004). It is also listed as a threatened species in each state and territory in which it occurs (Swift Parrot Recovery Team 2001).

The swift parrot is a small fast-flying, nectarivorous parrot, which is bright grass green in colour, with patches of red on the throat, chin and forehead bordered by yellow. It also has red on the shoulder and under the wings and blue on the crown, cheeks and wings (Figure 1). Identification features include a distinctive alarm call, streamlined body, pointed tail and flashes of bright red under the wing (Saunders 2007b).

The swift parrot is from a monotypic genus and belongs to the subfamily Platycercidae. Although it superficially resembles lorikeets in habit and form (nectar feeder with brush tongue), it is generally accepted to be most closely related to the broad tailed parrots, such as rosellas (*Psephotus* genus) (Brown 1989; Christidis and Boles 1994; Higgins 1999). The similarities between the swift parrot and the lorikeets are considered to have arisen through convergence (Smith 1975; Christidis and Boles 1994; Gartrell *et al.* 2000; Forshaw 2002).

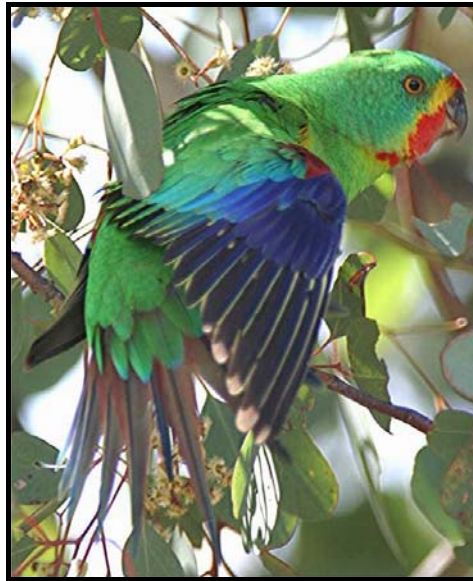


Figure 1 – Adult swift parrot stretching (Photo: Geoffrey Dabb)

The swift parrot breeds in Tasmania during the austral summer and the entire population migrates north across Bass Strait to mainland Australia for the austral winter (Figure 2). The core breeding range is restricted to the east and south-east coast of Tasmania where the parrot occupies an area of less than 500 km² and closely mirrors the distribution of Tasmanian Blue Gum *Eucalyptus globulus*. The parrots then undertake post-breeding dispersal across Tasmania (Brown 1989) before migrating up to 2,500 kilometers north to wintering habitats on the Australian mainland.

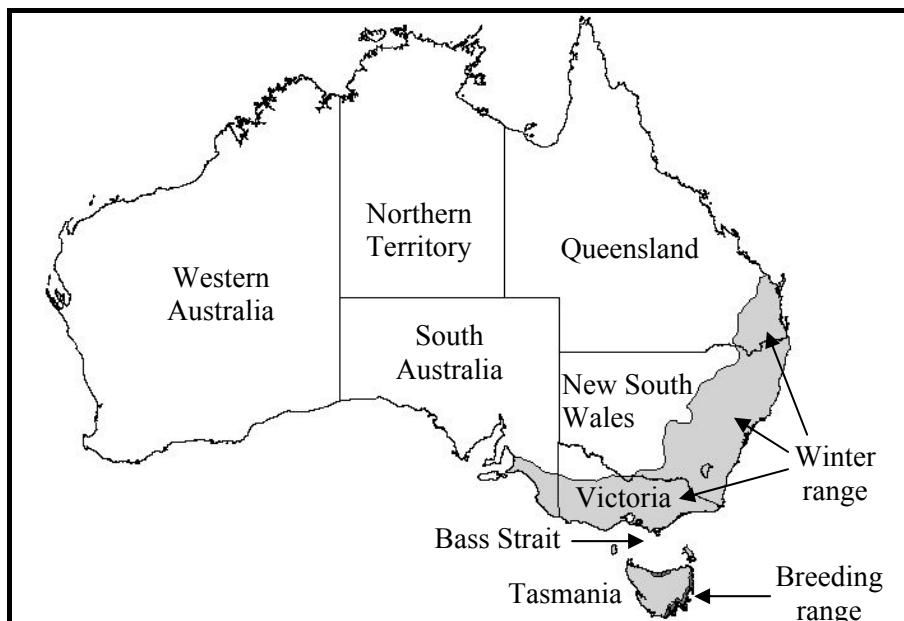


Figure 2 – Swift parrot distribution in south-eastern Australia.

Throughout their migration cycle, swift parrots predominantly forage on nectar and lerp (carbohydrates produced by sap sucking insects on leaves) in the canopy of temperate forests and woodlands (Hindwood and Sharland 1964; Brown 1989; Kennedy and Overs 2001; Brereton et al. 2004; Kennedy and Tzaros 2005) (Figure 3).

Swift parrots usually arrive in their breeding grounds in August/September where they nest in patches of forest that contain numerous old growth trees and hollows in close proximity to foraging resources (Voogdt 2006). These forests tend to occur within 10km of the coast and often contain key tree species such as stringybark *E. obliqua*, *E. pulchella* and/or blue gum *E. globulus* (Brown 1989; Brereton 1997; Voogdt 2006). Swift parrots remain within these breeding habitats until their chicks have fledged in November/December (Brown 1989).

Once the chicks have fledged, swift parrots undertake post-breeding dispersal across Tasmania in search of food from summer flowering eucalypt species such as stringybark *E. obliqua*, alpine ash *E. delegatensis* and white gum *E. viminalis* (Brown 1989; Swift Parrot Recovery Team 2001).

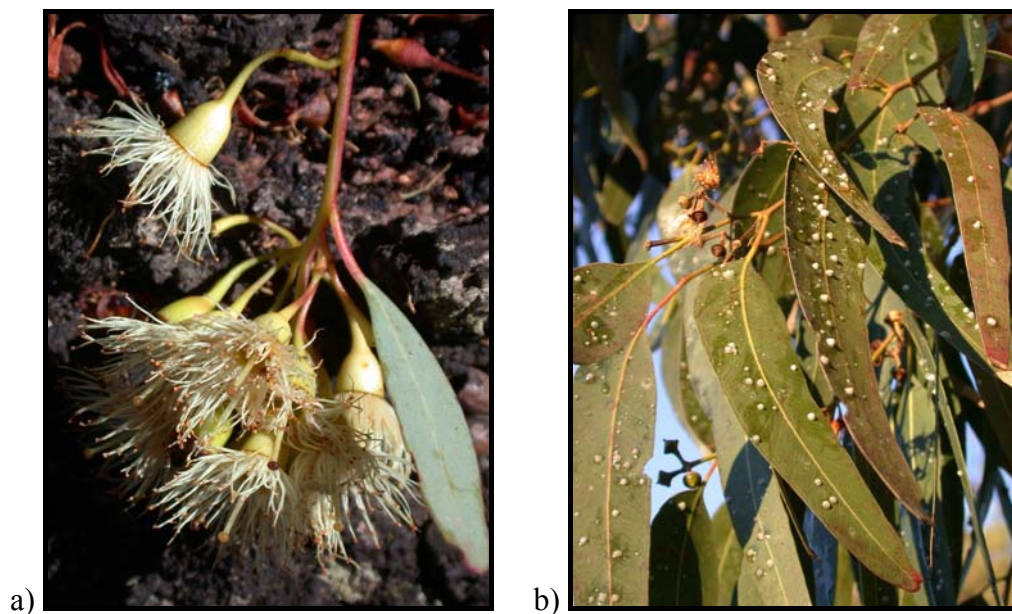


Figure 3 –Swift parrot food sources a) nectar from flowers b) lerp from insects on leaves (Photos: Debbie Saunders).

Austral migration

The swift parrot is an austral migrant, which flies north to wintering habitats across a vast area (approximately 1, 250, 000 km²) of south eastern Australia in March/April each year. It is one of only a handful of migratory parrot species in the world (Juniper and Parr 1998). Although they migrate annually, their movements and use of migration pathways and habitats remain unknown. The complexity of their migratory movements is highlighted by a previous unsuccessful attempt to examine their movement patterns across south eastern Australia using bird atlas data (Griffioen and Clarke 2002).

Although swift parrots use foraging habitats in both inland and coastal regions of their wintering range (Saunders 2007a), published research has been restricted to box-ironbark woodlands of central Victoria (Mac Nally and Horrocks 2000; Kennedy and Tzaros 2005) and the south-western slopes region of NSW (Kennedy and Overs 2001). In these studies swift parrots were found to use the most mature trees in the landscape, which were considered to provide the most reliable foraging sources (Kennedy and Overs 2001; Kennedy and Tzaros 2005). Key forage tree species noted in these studies include Yellow Gum *E. leucoxylon*, Red Ironbark *E. tricarpa*, Mugga Ironbark *E. sideroxylon*, Grey Box *E. microcarpa*, White Box *E. albens*, and Yellow Box *E. melliodora* (Saunders 2007a). Although swift parrots are also known to use coastal habitats of NSW, such as swamp mahogany *E. robusta* (Swift Parrot Recovery Team 2001), the importance of these habitats for the swift parrot remains largely unknown.

Recovery program

A national recovery program for swift parrots was established in 1995. This highlighted the need for ecological research, monitoring and education programs to increase understanding of its habitat requirements throughout the migratory cycle, and to guide conservation management (Figure 4). With substantial losses of both breeding and wintering habitats for the swift parrot considered to be the major threats to the species, conservation efforts have largely focused on population monitoring and on the protection and enhancement of remaining habitat (Swift Parrot Recovery Team 2001). Given the small population size and broad winter distribution of the species, the recovery team established a population and habitat monitoring program in Tasmania as well as a volunteer survey program on the mainland. The aims of the volunteer surveys were to provide snapshots of the spatial distribution of winter habitat use by the swift parrot and to increase our understanding of their use of habitats across the landscape. The surveys initially focused on central Victoria. However, over time they grew to include volunteers and habitats throughout the swift

parrot's winter range. To complement the large-scale volunteer survey information, detailed ecological research was also conducted in central Victoria (Kennedy and Tzaros 2005).



Figure 4 – Swift parrot as a symbol of threatened species education programs (WWF 2002)

In 2000 the need for more information on winter habitat use by swift parrots in NSW was recognised and a study was conducted within the south west slopes region (Kennedy and Overs 2001). This study highlighted the importance of NSW habitats and the need for further research within this state. Therefore, upon my commencement as coordinator of the recovery program in 2001, I began undertaking detailed research on swift parrot winter habitat use throughout both coastal and inland areas of NSW. I also coordinated the volunteer surveys across the mainland states. I continued in this position for five years and during this time began to appreciate the immense value of the large-scale and long-term data that was being collected by volunteers, especially in combination with my own ecological surveys. Hence my enrollment in a PhD. Although there will always be limitations on the use of data from volunteer surveys, they provide invaluable information not otherwise available for this highly mobile and rare species. This thesis is therefore largely based on my experiences as a researcher and recovery team member over the past seven years, and the extensive survey data collected by volunteers in thousands of surveys since the recovery program started 12 years ago.

Thesis overview

Despite spending a large proportion of their annual cycle within wintering habitats, our knowledge of swift parrots' ecological and geographical requirements has been limited to two small regions within their broad wintering range. There is a particular dearth of information on swift parrot habitat use in coastal areas of New South Wales and of large-scale movements throughout the parrots wintering range. This represents a serious gap in our knowledge for effective conservation management. Therefore the aim of the research outlined in this thesis was to gain a greater understanding of dynamic winter habitat use by this unusual, endangered, and migratory parrot. The scale of this task meant that the birds' breeding requirements and behaviour were beyond the scope of this thesis. Some of this work is being conducted by others in the recovery program.

This thesis is organized as six discrete chapters in two sections. The first section (chapters one to three) critically evaluates what is known about the species and its habitats, major impacts on the species, and important knowledge gaps. This provides the necessary context for the second section (chapters four to six) of the thesis, which addresses the species' variable spatial and temporal use of winter habitats. Chapters two to five are either intended for submission, or have already been submitted or accepted in scientific journals. Although the style I have adopted entails some repetition, especially in the introduction to each chapter, it also provides an efficient route to the publication of the important results.

Chapter two provides important context and background for the current plight of swift parrots. I do this by illustrating the historical and ongoing impacts on swift parrots and their habitats throughout their range.

Chapter three then discusses information obtained on the species through the recovery program and the difficulties of conserving wide-ranging threatened species. It highlights the need for a greater understanding of the species' habitat requirements in NSW as well as the need to better understand their dynamic large-scale use of habitat. This chapter also serves as an important outline of the methodologies concerning volunteer participation which have been employed to great effect in chapter five.

Chapter four provides detailed research on winter habitat use by the swift parrot on a state-wide scale. It examines the variables affecting spatial and temporal use of foraging habitats across multiple regions and seasons on a large scale not previously attempted. Such information increases our understanding of the ecological needs of this species and provides a basis for improving the effectiveness of conservation measures within New South Wales.

Chapter five examines the current level of knowledge of migratory systems in the northern hemisphere and how this relates to austral migration systems and the swift parrot. It uses the long-term and large-scale surveys conducted by volunteers, and provides the first demonstration of large-scale drought related movements by a migratory population throughout its winter range. It also demonstrates the dynamic spatial and temporal patterns of winter habitat use by swift parrots, including their repeated use of foraging sites.

Chapter six summarises the main findings, provides a conclusion to the thesis and provides recommendations for future research.

Chapter 2 - Settlement and swift parrots - an ecological interpretation of historic information on swift parrots and their habitats (1788-2008)



Red-shouldered Paroquet by George Raper (1788-1790)
(Source: Ducie Collection, National Library of Australia)

...these blossoms are so charged with saccharine matter, that the birds soon fill themselves with honey, even to their very throats: several of those I shot, upon being held up by the feet, discharged from their mouths a stream of liquid to the amount of a dessert-spoonful or more, as clear as water...(Gould 1848)

Abstract

The swift parrot was among the first Australian birds to be scientifically described and illustrated following European settlement in 1788. This chapter provides a unique interpretation of historical information on swift parrots and their habitats in an ecological context. It illustrates the important influence of past events on the predicament of this species and its habitats today. Images of swift parrots and their habitats in combination with other historical information are used to illustrate key impacts on the species since European settlement, which have contributed to its current endangered status. Within 60 years of settlement, habitats throughout its range in south-eastern Australia were being lost. An important aspect of the loss is the speed and spatial extent at which it occurred. Although the most extensive habitat loss in some areas happened during colonial times, habitats continue to be lost as a result of various land management practices today. Consequently, the swift parrot is an endangered species and is the subject of an ongoing national recovery program.

Introduction

Swift parrots are nectarivorous birds that have attracted much attention with their charismatic behaviour and beautiful calls and plumage. Indeed they have attracted so much attention that they have been shot, eaten, collected, painted and admired by many who have encountered them. Such is the charm of this species that John Gould recalled:

No one of the Australian birds will be more deeply imprinted upon my memory than the Swift Lorikeet, associated as it is with many of the most pleasing recollections connected with my visit to that part of the world (Gould 1848, p. 48).

The swift parrot is one of only a small number of migratory parrots around the world (Juniper and Parr 1998). It predominantly forages on nectar and lerp in the woodlands and forests of south-eastern Australia, migrating each year between breeding habitat in eastern Tasmania and wintering habitat in south-east mainland Australia. With an estimated population of less than 2500 individuals, the species is listed as endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2004) and the national *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). A number of threats to this species have been identified (Brown 1989; Swift Parrot Recovery Team 2001), the most significant being habitat loss. However, early historical information on the timing, extent and causes of this loss have not previously been

examined in detail. An appreciation of the historical spatial and temporal extent of impacts on species and their habitats can potentially yield a greater understanding of the factors that have driven their patterns of habitat use across fragmented landscapes, and can help guide research and conservation management (Lunt and Spooner 2005). However it should be noted that historical accounts of clearing are likely to be biased by the location of the observers in those parts of the landscape most likely to have been cleared.

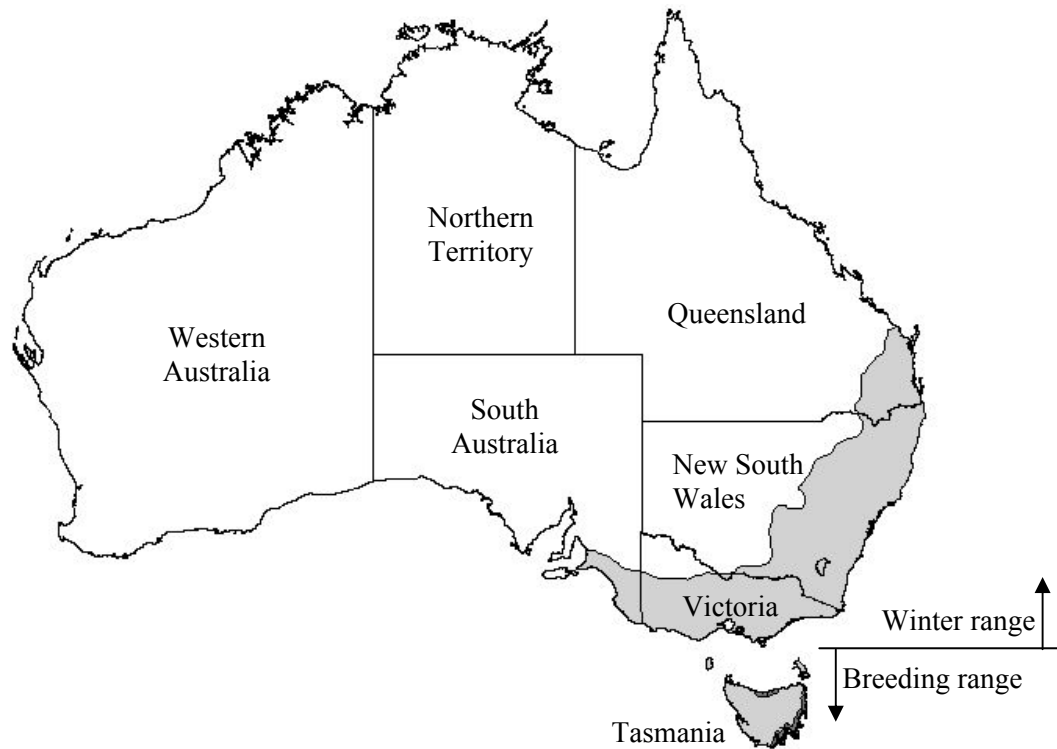


Figure 5 – Distribution of the swift parrot in south eastern Australia

By interpreting historical information on swift parrots and their habitats in an ecological context, this chapter aims to illustrate the important influence of past events on the predicament of this species and its habitats today. In this chapter I use images of swift parrots and their habitats in combination with historical anecdotes and specimen information to illustrate key impacts on the species since European settlement. This compilation builds on previous detailed discussions of the species and its habitats (Gould 1848; Mathews 1916; Hindwood and Sharland 1964; Brown 1989) and illustrates both the historical and ongoing loss of habitat throughout core areas of the species' range, which have contributed to its current endangered status.

The red-shouldered paroquet

First impressions

Following European settlement at Port Jackson in 1788, red-shouldered paroquets, or swift parrots as they are now known, were among the first Australian birds to be scientifically described and illustrated. The species' initial description and scientific name *Psittacus discolor*, are credited to George Shaw in John White's Journal of a Voyage to New South Wales:

Long-tailed Green Parrot, with the tail feathers ferruginous towards the base, the shoulders blood-red beneath.

This species, which appears to be new, is of that sort generally termed Paroquets. It is about ten inches in length: the general colour of the bird a fine green: the outer edge of the wing, near the shoulders, blue: the edge of the shoulders deep red; the under part the same. On the sides of the body a patch of red: round the beak a few red feathers: long feathers of the wings of a deep blackish-blue, edged slightly with yellow: tail deep ferruginous toward the base, each feather becoming blue at the tip: bill and feet pale brown (White 1790).

Although the species was illustrated by Sarah Stone (Figure 6a) opposite the original species description in White's journal (1790), it is unknown whether the 'type specimen' (from which the species was first described) was a specimen or an illustration (Schodde and Mason 1997). Around the same time Governor Arthur Phillip's journal (Phillip 1789) also described the species, calling it the red-shouldered parrakeet and displaying it with an illustration by Mazell (Figure 6b). However no scientific name was provided.



Figure 6 - a) Red-shouldered paroquet (1790) by Sarah Stone (from White's Journal of a Voyage to New South Wales) (Source: Project Gutenberg Australia);
 b) Red-shouldered Parrakeet (1789) by Mazell (from Phillip's The Voyage of Governor Phillip to Botany Bay 1790) (Source: State Library of Victoria).

In the late 18th and early 19th centuries swift parrots were also painted by other artists including George Raper (c. 1789) (Figure 7a,e), Captain John Hunter (1788-1790) (Figure 7b), Robert Seton (c. 1800) (Figure 7c), Thomas Watling/Port Jackson Painter (1792-1794) (Figure 7f) and François Levillant (1803) (Levillant 1989). The remarkable likeness of these paintings suggest that they were either illustrating the same specimens or were reproducing each other's artworks. Although Seton's image is a copy of Hunter's, which is also considered a copy of Raper's (National Library of Australia 2006) the Seton album and Hunter Sketchbook contain what are rare (and possibly the only) written references to Aboriginal knowledge of the species (Hindwood 1965; Troy 1994). In Hunter's sketchbook the inscription "Gorail" was above the image (Figure 7b) and in Seton's album index swift parrots were referred to as "Wang-u-wang" (Figure 7c,d). The name "Gorail" is not unique to swift parrots since it was also used for rosellas (*Platycercus* sp) and lorikeets (*Glossopsitta* and *Trichoglossus* sp.), as recorded by both Hunter and Seton (Hunter 1788-1790; Seton c. 1800). Although slightly different, the name "Wangawang"

was also a name used by the Dharawal People from the Sydney region for the ground parrot (*Pezoporus wallicus*) (Troy 1994).

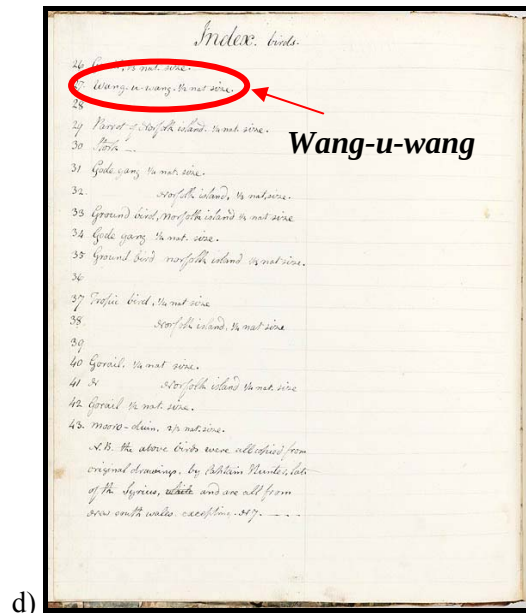




Figure 7 - a) [Swift parrot (*Lathamus discolor*)] (c. 1789) by George Raper (Source: National Library of Australia)

b) [Swift parrot (*Lathamus discolor*) and yellow pittosporum (*Pittosporum revolutum*)] (Hunter 1788-1790), by John Hunter, with the inscription “Gorail” (Source: National Library of Australia)

c) Red-shouldered Parrakeet Phillip Bot Bay [sic] (possibly) by Robert Seton (c. 1800) (Source: State Library of NSW)

d) Robert Seton (c. 1800) index reference to “Wang-u-wang” (Source: State Library of NSW)

e) Parroquet and Flower of Port Jackson ([1789]) by George Raper (Source: Natural History Museum London)

f) Red-shouldered Parrot (1788-1797) by Port Jackson Painter in Watling Collection (Source: Natural History Museum London)

The images of swift parrots from the late 18th and early 19th century provide an indication of the suitability of the original woodlands and forests in the environs of Sydney as habitat. Although the many illustrations and documents describing swift parrots within the first 10 years of European settlement (see ‘First impressions’ above) do not necessarily reflect its abundance, they do indicate that the species occurred near the settlement and was sufficiently common to be described early and illustrated alongside other common bird species.

Further details on the natural history of this species were not available until John Gould (1848) published *The Birds of Australia*. The valuable ecological information he provided 50 years after the species was first described included descriptions of food sources, flocking and foraging behaviour, and habitats, such as the following:

...The tree to which they are so eagerly attracted, and a branch of which is figured in the accompanying Plate, is the *Eucalyptus gibbosus* [now known as Tasmanian blue gum, *Eucalyptus globulus*].... Their plumage so closely assimilates in colour to the leaves of the trees they frequent, and they moreover creep so quietly yet actively from branch to branch, clinging in the every possible position, that were it not for their movements and the trembling leaves, it would be difficult to perceive them without a minute examination of the tree upon which they have alighted. I found them breeding about midway between Hobart Town and Brown's River, but was not fortunate enough to obtain their eggs, in consequence of the situations selected for their reception being holes in the loftiest and most inaccessible trees;... (Gould 1848, p. 48).



Figure 8 – Swift parrots in *Eucalyptus gibbosus* from Gould (1848).

Taxonomic confusion

Despite swift parrots being described scientifically soon after European settlement, uncertainty over their taxonomic classification prevailed for more than 120 years. Gould noted that:

...the single species known of this form has been assigned to a different genus by almost every writer in ornithology...(Gould 1972 p. 89, first edition 1865).

The following list provides a brief summary of the key taxonomic classifications leading to the final species name of *Lathamus discolor* (Shaw, 1790) (Schodde and Mason 1997):

Psittacus discolor 1790 by Shaw in White's Journal (original nomenclature)

Lathamus rubrifrons 1830 Lesson (first use of the genus *Lathamus*)

Lathamus discolor 1837 Lesson (current nomenclature).

The most comprehensive analysis of swift parrot taxonomy was done by Forbes in 1879. He concluded that swift parrots were most closely related to the broad-tailed parrots but also had features suited to the arboreal and nectarivorous habits similar to lorikeets (Forbes 1879) (Figure 9). Swift parrots appear to have an important ecological role as a result of their unique combination of characteristics. When feeding on flowers their short, broad heads and beaks and brush tongues lead to a high likelihood of nectar and pollen getting stuck on them and being transferred to flower stigmata resulting in pollination. Pollination is likely to occur more often with swift parrots than honeyeaters with long slender bills. Swift parrots are therefore one of the most effective and important pollinators of tree species such as the Tasmanian Blue Gum (Hingston *et al.* 2004).

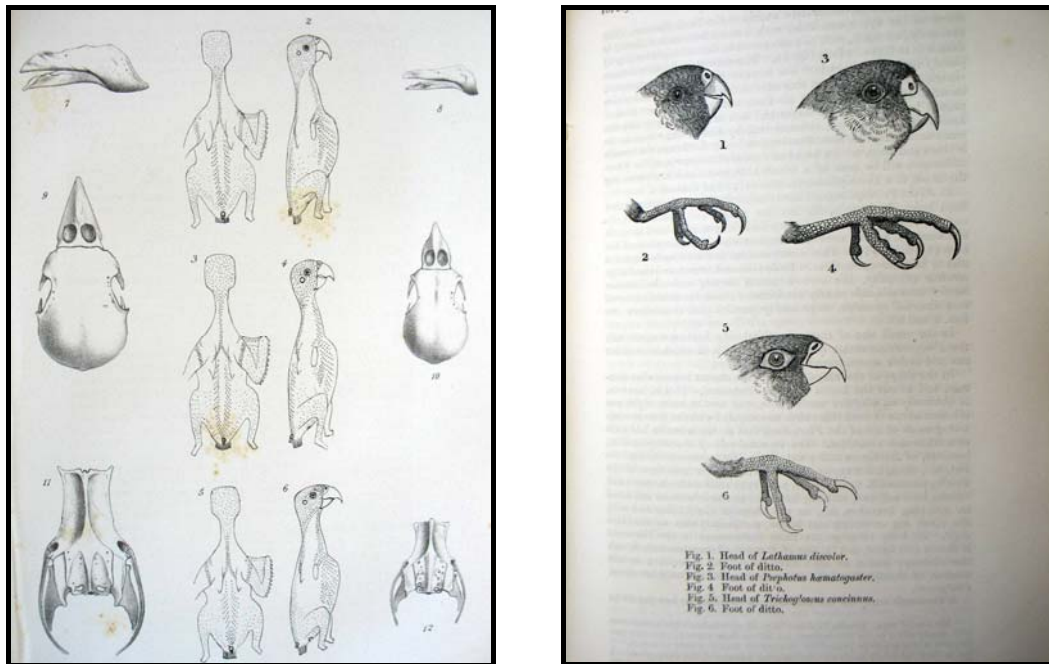


Figure 9 – Taxonomic classification of swift parrots in relation to broad-tailed parrots (such as blue bonnets *Psephotus haematogaster*, now known as *Northiella haematogaster*) and lorikeets (such as musk lorikeets *Trichoglossus concinnus*, now known as *Glossopsitta concinna*) (Forbes 1879).

Collections, cage birds and cuisine

In colonial times, swift parrots were collected for a variety of purposes. For example, some would have been shot as a source of fresh food, such as for inclusion in “parrot pies”(Olsen 2007a). However, others were shot for scientific or personal collections, or trapped for aviculture.

The popularity of swift parrots with specimen collectors is evidenced by more than 293 specimens collected during the 19th and 20th centuries (and possibly the 18th century for some of the 89 undated specimens), which are stored in collections around the world. The majority of these were skins, however there were also some clutches of eggs, skeletons and an entire birds in spirits (Appendix 1). In the 1840s dated specimens were collected in Tasmania, including one by Sir Thomas Mitchell and four by Dr Wilson for the John Gould collection. Dr Wilson also collected a single specimen from wintering habitats in New South Wales (Appendix 1). John Gould noted the large quantity of nectar that had been consumed by the swift parrots before they were shot:

... several of those I shot, upon being held up by the feet, discharged from their mouths a stream of liquid to the amount of a dessert-spoonful or more, as clear as water...(Gould 1848, p. 48).

Near Blackwood, South Australia Mr Edwin Ashby collected over 10 per cent of a visiting swift parrot flock for both scientific (Appendix 1) and personal purposes:

I secured two pair [sic] for the South Australian Museum and a pair for myself, and my son got another pair. When getting these I saw fully fifty birds within a quarter of a mile of my house (Mathews 1916, p. 472).

The abundant Australian wildlife was also seen by many first immigrants as a source of food, as noted by Jacob Baker who wrote to his family in Hodson, United Kingdom in the 1850s:

This is the contrey, my boys. I have borte a dog for shutting [shooting]. Tim and me can take our guns and dog, and go out and shut all we can without licences; we have plenty of buteful parets [beautiful parrots] and wil tuckes [wild turkeys] and ducks and other birds. Poor pipel in Hodson do not know what good living is. We have got a goint of fresh meat on our table every day...(Olsen 2007a, p. 37).

There were also markets in which large numbers of locally caught wild birds were brought to town for consumption, and when collectors were out in the field away from human habitation they would commonly sample the local fauna and flora (Datta 1997).

There is also evidence of swift parrots being shot at the penal colony of Port Arthur, Tasmania, where W.B. Gould painted a dead bird among other Tasmanian bird species in the 1840s. His painting was simply titled “Birds” and was of a collection of Tasmanian birds, including a Swift Parrot that had been shot and hung up on a string (Figure 10).



Figure 10 - Birds (1840s) William Buelow Gould (1803-1853) (Source: Ballarat Fine Art Gallery Collection).

In addition, swift parrots have long been captured for the lucrative bird trade. Groen (1965 in Brown 1989) noted that swift parrots were sufficiently popular as cage birds in Europe in the 1880s that a bird dealer imported 106 birds (53 pairs) into London, and Butler noted the following about swift parakeets in his book on foreign cage birds:

...since 1879 this species has been imported now and again during the spring months in several pairs, at other times rarely... They are fond of climbing, fly little. Close cage-bars are necessary, because they recklessly force their heads through. Not yet bred... The first two specimens to reach the London Zoological Gardens were purchased in 1863, the last pair (recorded in the ninth edition of the List of Animals) in 1884 (Butler 1909?, p. 238).

Blakston (c. 1880) also included the species in his book on cage birds. Blakston's painting of a swift parrot was done from a stuffed specimen that had been in his possession when alive (Figure 11). He noted that the swift lorikeet was one of the most beautiful Australian parakeets:

...and although not rare in Australia it is not often brought to Europe, where high prices are readily obtained for the species. Immediately after arrival these birds are delicate, and require careful

feeding....however...this parakeet, like many other Australians, becomes so hardy when fairly acclimatized, that swift parakeets have been wintered in perfect health in out-door aviaries...(Blakston c. 1880)

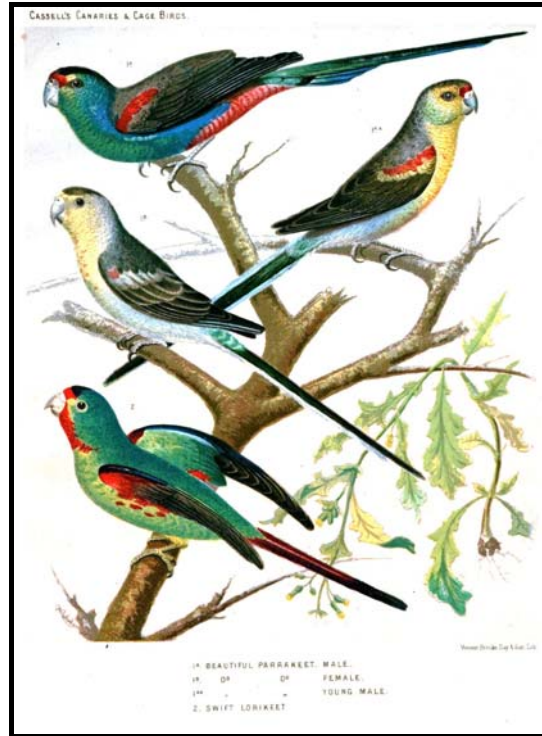


Figure 11 – Captive swift lorikeet (c. 1880) by W.A. Blakston (Source: Debbie Saunders)

An unknown number of swift parrots was reportedly being bred in captivity in Belgium by 1887 (Harman 1981) and the inclusion of four specimens from captivity in the British Natural History Museum's collection provide further evidence of captive swift parrots in the early 1900s (Appendix 1). However, swift parrots were only first successfully bred in Australia 50 years later (Harman 1981; Brown 1989). Aviculturalists have often had difficulty in maintaining and breeding the species in captivity; many died suddenly but lost birds were often replaced with additional birds trapped from the wild (Lendon 1979). With the refinement of animal husbandry techniques for this species, it is now a common cage bird in Europe (Laubscher 1999) and Australia (G.Masters and B. Boyd pers.comm. and state licensing data). In 2004 there were 258 swift parrots held in captivity under license, which is the equivalent of 10% of the current estimate of the total wild population (Appendix 2).

Swift parrots were collected as specimens, as food and as cage birds and although such collections may have only had a small effect on the population at the time, the cumulative impact of collecting across their range and for various purposes was likely to be greater. Although it is likely that the illegal trapping and trade of swift parrots is not as common as it has been in the past with increased regulation of such activities, it still continues to some extent in the 21st century (Saunders 2002b). Apart from simply reducing numbers of birds in the wild, it is unknown whether removal of individuals from flocks impacts on the ability of the remaining flock members to successfully locate and compete for sufficient resources.

Migratory parrot?

Neither White nor Phillip were naturalists and therefore they were more interested in the classification of species than their behavioural characteristics and natural history. However sixty years after the species was first described, and following an increased level of interest in migration elsewhere in the world in the late 18th and early 19th century (Berthold 2001), John Gould noted the species' migratory behaviour:

It is a migratory species, passing the summer and breeding-season only in the more southern parts of the Australian continent and Van Diemen's Land, and retiring northward for the remainder of the year (Gould 1848, p. 48).

Its migratory habits were again noted by T.A.F. Leith in 1883:

...a few of these parakeets may be throughout the colony (Tasmania) at all seasons, but, as a rule, they are migratory birds, and are said to cross Bass Strait in large flocks, flying fast and high, steering northward (Hindwood and Sharland 1964, p. 314).

Mathews (1916) doubted that swift parrots were migrants. However by the mid 20th century, Hindwood and Sharland (1964) provided conclusive evidence. They noted that while migration routes had not yet been clearly defined, it was evident that many individuals left Tasmania after the breeding season and crossed Bass Strait to disperse throughout south-eastern Australia, returning to Tasmania the following spring (August/September).

Many aspects of swift parrot migration remain unknown in the 21st century. Ironically the most notable aspect of their migration seems to be that it is rarely observed. Most observations are of birds that seem to rapidly disappear from their habitats in Tasmania and then appear suddenly within wintering habitats on the mainland. In general they do not

appear to use the Bass Strait islands, although there are some observations from these areas of small flocks flying overhead during the day (Brown 1989). It is currently unknown what migratory routes the birds use or if they migrate directly or need to use stop-over sites. It is also unknown whether the birds are primarily nocturnal or diurnal migrants, with only limited evidence to suggest that one or both of these migration strategies may be used by the species (Hindwood and Sharland 1964).

An interesting observation from Hindwood suggests that the birds may migrate nocturnally, but may equally refer to a lost, exhausted bird:

...a swift parrot... flew through a port-hole into the mess-room of a freighter some ten miles off Cape Everard and about 100 miles east of Lakes Entrance [eastern Victoria]. The incident occurred at 8pm on May 8, 1937; the night was “pitch dark” and a mild gale (between 25 and 40 miles per hour) was blowing from the direction of the land. The bird must have been attracted by the ship’s lights after being blown off-course by strong winds while migrating across Bass Strait. It landed on the ship three hours after sunset (Hindwood 1937, p. 68).

Another interesting aspect of swift parrot migration, first noted in the early 20th century, was its variability (Batey 1907). Hindwood and Sharland noted:

A feature of the movements of the species is the occurrence of large numbers of birds in areas from which they may have been absent for years; these irruptions, while unpredictable, appear to be influenced by the presence of a plentiful supply of suitable food such as nectar, lerps and other insects and seeds (Hindwood and Sharland 1964, p. 310).

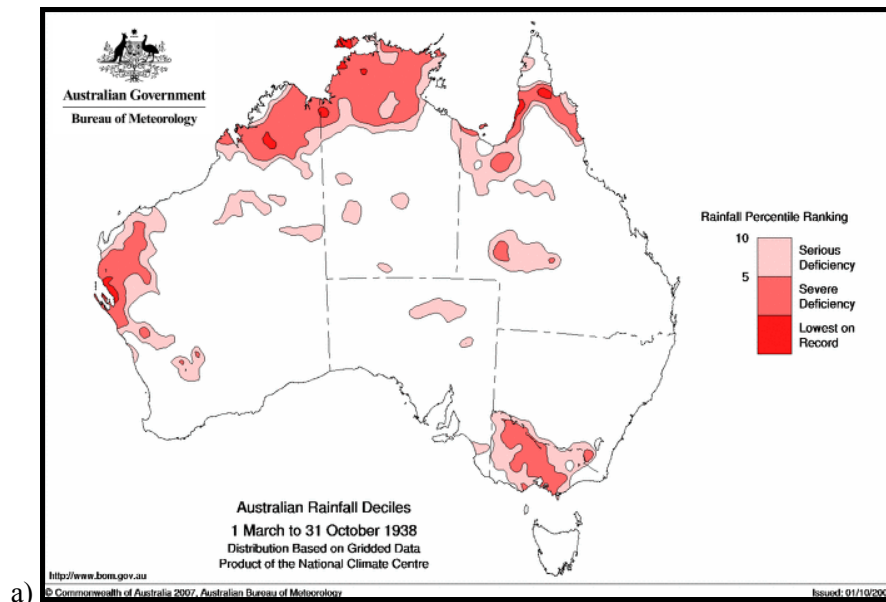
Such variable habitat use continued to be observed throughout the species’ range in the 20th and 21st centuries (Saunders 2007a), including large influxes of swift parrots in coastal habitats of New South Wales, as noted by Hindwood and Sharland:

Throughout the autumn and winter of 1938 there was a profuse flowering of *Eucalyptus* trees in localities close to Sydney...In the Mona Vale-Avalon district, 20 miles north of Sydney, Swift Parrots were present in considerable numbers. Flocks of 100 or more birds were often noted as they flew through the forests to settle among the foliage of the flowering gums...they remained near Sydney for at least

three months...Twenty years passed before observers were able to report another “invasion” of the species...

The 1958 influx of Swift Parrots was first noted in May and June. The population built up considerably towards the end of the latter month and remained fairly static throughout July. August saw a falling off in numbers, though there were still plenty of birds within 100 miles of Sydney and doubtless in other parts of eastern New South Wales (Hindwood and Sharland 1964, pp. 318-319).

Although these irruptions have previously been considered unpredictable (Hindwood and Sharland 1964), it now appears that it may be the result of extreme drought conditions in some parts of the species range, as illustrated by the rainfall deficiency maps for 1938 and 2002 (see chapters 4 and 5) (Bureau of Meteorology 2002) (Figure 12). Drought reduces food availability and forces birds to travel further and concentrate in locations that have suitable food. The initial presence of birds in Sydney during first settlement and the repeated large influxes of swift parrots in coastal areas near Sydney suggests that such variability is part of a natural cycle to which swift parrots are adapted (see chapters 4 and 5).



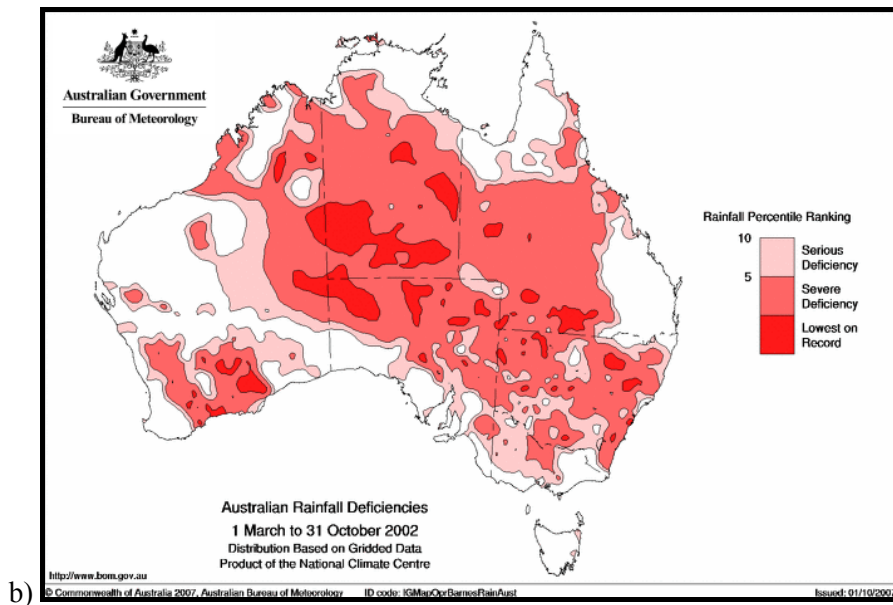


Figure 12 –Extensive drought conditions in a) 1938 and b) 2002 (Bureau of Meteorology 2007b) when large influxes of swift parrots were observed in coastal New South Wales.

Notes on abundance

Although swift parrots have been shot, eaten, collected, painted and admired by many throughout the 18th and 19th centuries, information on the species' abundance was limited to observations such as those by Gould who remarked on their flocking behaviour and great abundance around Hobart:

'During September and the four following months, it is not only abundant in all the gum-forests of Tasmania, but is very common in the shrubberies and gardens of Hobart Town. It is frequently to be seen on the gum-trees bordering the streets, within a few feet of the heads of the passing inhabitants, and so intent upon gathering the honey from the fresh-blown flowers which daily expand, as almost to entirely disregard their presence... Small flocks of from four to twenty in number are also frequently to be seen passing over the town to the forests at the foot of Mount Wellington, or vice versa (Gould 1848, p. 48).

These types of observations continued throughout the 20th century, including notes on a few spectacular irruptions of swift parrots in coastal NSW, such as in 1958:

Close to Sydney it was not uncommon to note small parties of 20 or 30 to groups of 200 or more birds. A flock of between five to six hundred

individuals were recorded at west Pymble and it was estimated that, in some localities, thousands of birds were present throughout June and July. One of us (K.A.H.) watched a movement at Lane Cove on June 29, and considered that more than 1,000 individuals passed between two clumps of trees, in which they were feeding, during a period of note more than twenty minutes (Hindwood and Sharland 1964, p. 319).

There was another influx of birds into the spotted gum forests on the central coast of New South Wales in 1966 as noted by Bill Boyd, an experienced swift parrot aviculturalist and bird watcher:

Small flocks of 10 to 15 birds left the trees and flew out over the water in an easterly direction then turned...they were heading for Pulbah Island (Pulbah is an island in Lake Macquarie about 1km south of Wangi). More and more birds left from nearby trees and others were coming from a western direction. These birds were gathering into flocks that gradually grew larger as they headed out over the water and some of these flocks contained more than a hundred birds. Then something unexpected happened...Flocks at least as large as the Wangi flocks were coming from the opposite direction. These birds were coming from the direction of Cams Wharf, Nords Wharf, Summerland Point and Mannering Park on the southern and eastern side of the lake. I watched for as long as I could see clearly and by that time the birds were only in twos and threes but if all the birds were added together there were at least 2000 swifts roosting on Pulbah that night. The following weekend I drove around the areas mentioned and found swift parrots in all of them, they were plentiful and in these areas Forest Red Gum was the tree of choice (Boyd 2004, p. 4).

Although the anecdotal nature of these records and the variability of habitat use by the species limit inference with regard to population trends, they provide valuable insights into the flocking behaviour of this species and their irruptive nature in some years. For example during the influxes in the 1950-60s the maximum flock sizes were up to three times those of the influx in 2002 when the largest flock observed (despite a large number of targeted surveys in the area) was of 650 birds (*personal observation*).

In the late 20th century Brown (1989) provided a comprehensive report on the natural history of swift parrots, including detailed information on habitats (Figure 13a), food

sources and the first assessment of population size. From his population estimates throughout their breeding range, Brown was surprised to end up with a total of only 1320 breeding pairs. He also noted that there was no yardstick with which to gauge this population against its abundance in the past and therefore used these surveys to provide baseline data with which to compare future population estimates. These surveys were then repeated during the 1995/96 breeding season when 940 breeding pairs were detected, representing a severe decline (29%) in the breeding population size (Swift Parrot Recovery Team 2001). With a small population size, limited breeding range and ongoing threats to their habitats throughout their range, swift parrots were recognised as a threatened species in 1995, triggering the development of a recovery program (Brereton 1996).

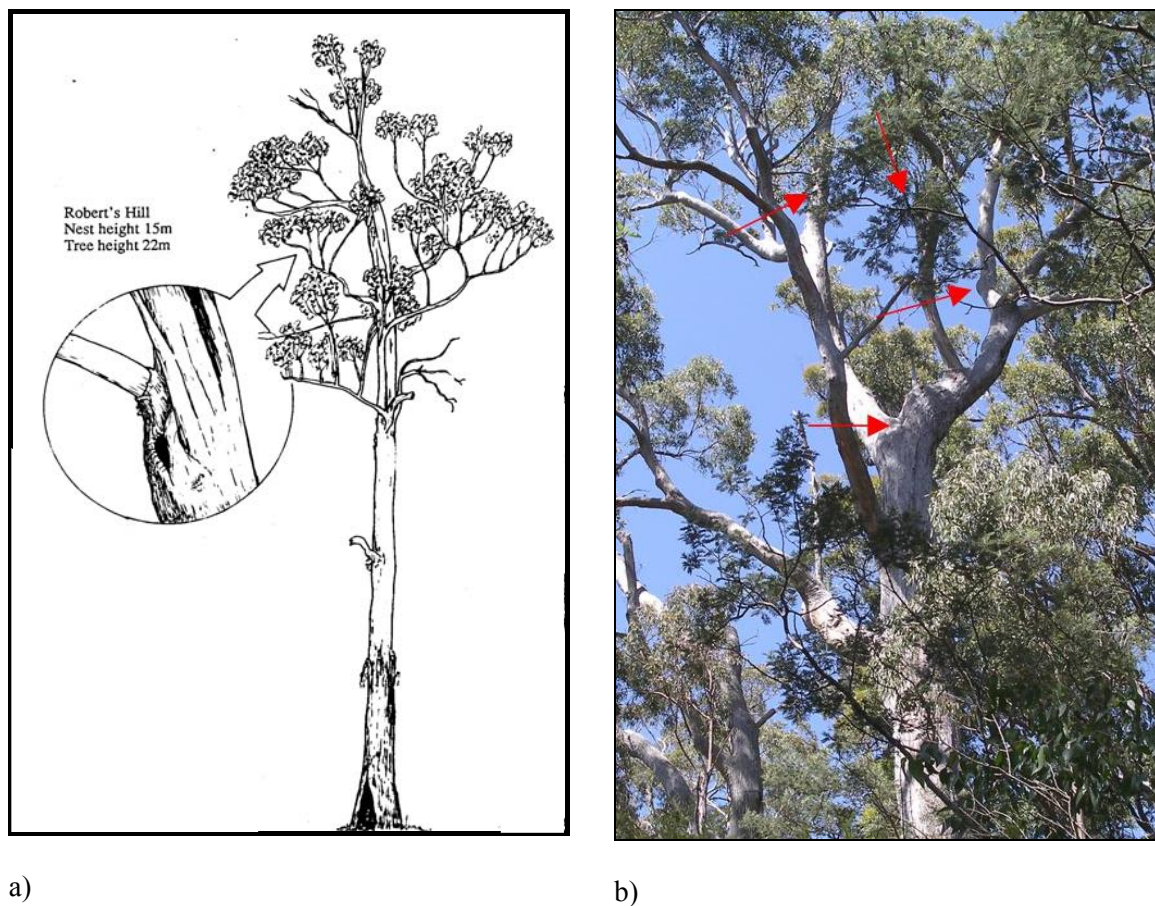


Figure 13 – Old growth forest swift parrot nesting sites a) Robert's Hill near Hobart (Brown 1989), b) North Bruny Island (Photo: M. Webb)

Both Brown (1989) and Brereton's (1996) reports on the species identified habitat loss as the single largest threat to the species, and this continues to be the case in the 21st century

(Swift Parrot Recovery Team 2001; Saunders 2007a) despite the introduction of threatened species legislation and other planning instruments designed to protect such species.

Historic habitat loss (18th & 19th centuries)

Although the loss of habitat as a result of European settlement is not a surprise, the speed and large spatial scales at which it occurred, and the diversity of swift parrot habitats that were impacted upon is significant. Within less than 60 years since the first European settlement in Australia, habitats within each part of the swift parrot's migratory range were being cleared. This was during Australia's exploitative pioneering era, when forests and woodlands were seen as an inexhaustible resource and the government supported progress, growth and development of the land without consideration of environmental effects (Frawley 1994). The loss of habitat extended from their breeding range in south-eastern Tasmania, through their southern wintering habitats in Victoria, New South Wales and eastern South Australia, to northern wintering areas in south-eastern Queensland (Figure 14). The following section focuses on habitat loss in what are considered core areas of the species' range, namely New South Wales, Tasmania and Victoria.

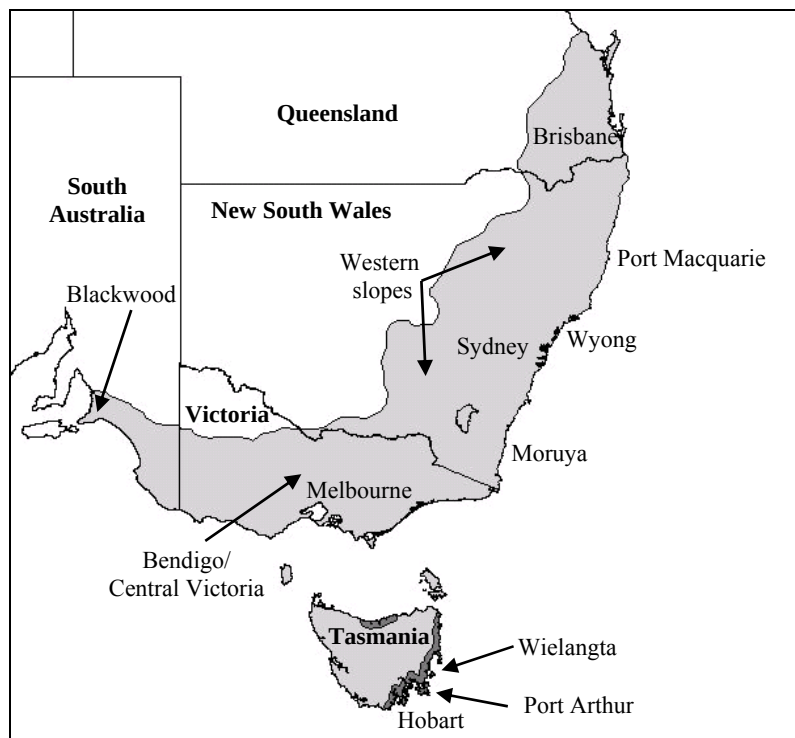


Figure 14 – Key historic localities within the swift parrot range noted in this chapter.

New South Wales (European settlement from 1788)

The rapid loss of swift parrot habitat began almost as soon as Europeans first settled in eastern Australia. The first colony was established in 1788 at Sydney Cove, Port Jackson, within the wintering range of the swift parrot (Figure 14). To early pioneers, areas of native vegetation needed to be cleared to make the land productive (Cubit 1996). As a result, vegetated areas were cleared for agriculture and grazing as well as for timber for purposes such as construction of dwellings and fences, ship repairs, and as a source of fuel for heating and cooking (Carron 1985). One of the artists who painted swift parrots in the late 18th century, Thomas Watling, also did some drawings of the landscape around the colony, providing some insight into the extent and type of clearing of vegetation for the settlement (Figure 15). In general large areas were entirely cleared of native vegetation, however, sometimes isolated old trees were left scattered around the edges of the settlement (Figure 15).

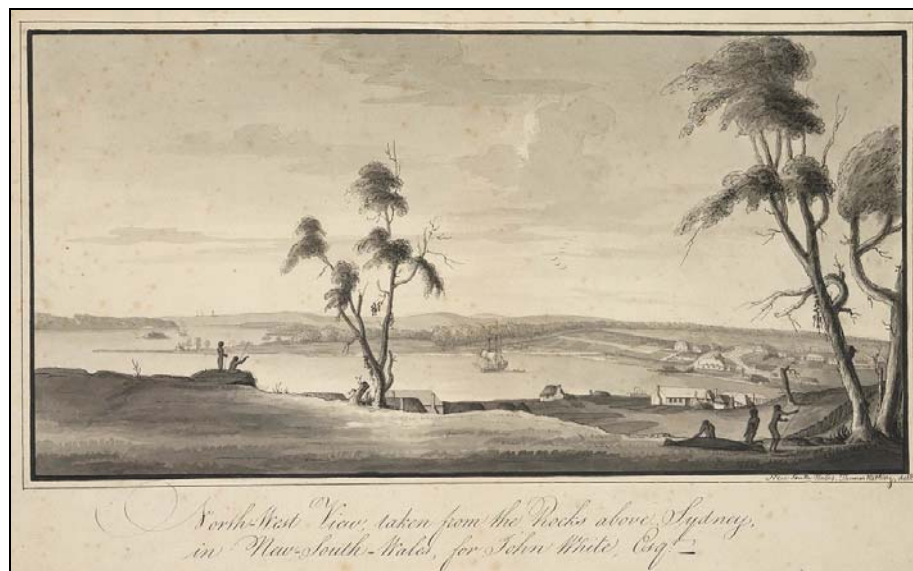


Figure 15 – North-West View taken from the Rocks above Sydney Cove in New South Wales, for John White (1793-1795) by Thomas Watling (Source: State Library of NSW)

From first settlement to the end of the 18th century extensive, indiscriminate cutting of timber trees occurred in a largely wasteful manner (Grant 1989) including areas known to contain habitat suitable for swift parrots. The extent of destruction of forested lands, such as around the Nepean River, South Creek and George's River, prompted Governor Hunter to introduce the first timber regulations in 1795, although in reality they had little effect (Grant 1989). However, these areas were then included on a map of settlement growth

districts in 1810 (Figure 16), and large areas of woodland containing swift parrot forage tree species continued to be cleared, despite further attempts to control such activity (Carron 1985). In 1898 North noted that he:

Seldom met with swift lorikeets at this time, but in former years it was a regular visitor to the county when the gum trees were in flower and it used to be common at Dobroyde, Rooty Hill and Ropes Creek (North 1898) (Figure 16).

With continued incremental loss of remnant vegetation in this area for over 200 years, only increasingly small fragmented patches of endangered ecological communities remain among an otherwise cleared landscape (NSW Scientific Committee 1997; Endangered Species Scientific Subcommittee 2000) (Figure 16).

In 1826, Governor Darling issued an order that selection and settlement of land was to be confined to a defined section of New South Wales. The “Limits of Location” were from Port Macquarie in the north to Moruya in the south and extending inland to the Liverpool Range and Yass (Wadham 1967; Grant 1989). A variety of swift parrot habitats within both coastal and inland areas of the settlement limits were subsequently impacted upon by a variety of residential, agricultural, pastoral and forestry developments. For example, John Gould first observed the species in its winter habitats of the Upper Hunter River district during a severe drought within an area that was extensively grazed by thousands of sheep and cattle (Datta 1997).

Coastal habitats within the specified limits would have been impacted upon concurrently by a number of settlements including Port Macquarie (1821) and Port Stephens (1826) on the north coast (Grant 1989) and Batemans Bay and Moruya (1820s) on the south coast (Eurobodalla Shire Council 2000) (Figure 17). These settlements were established in areas that contain key forage tree species for swift parrots including Forest Red Gum *Eucalyptus tereticornis*, Swamp Mahogany *Eucalyptus robusta*, Spotted Gum *Corymbia maculata*, and Blackbutt *Eucalyptus pilularis* (Saunders 2007a). As a result, within the first 50 years of European settlement, all major coastal habitat types known to be used by the swift parrot in New South Wales had been cleared or altered to some extent.

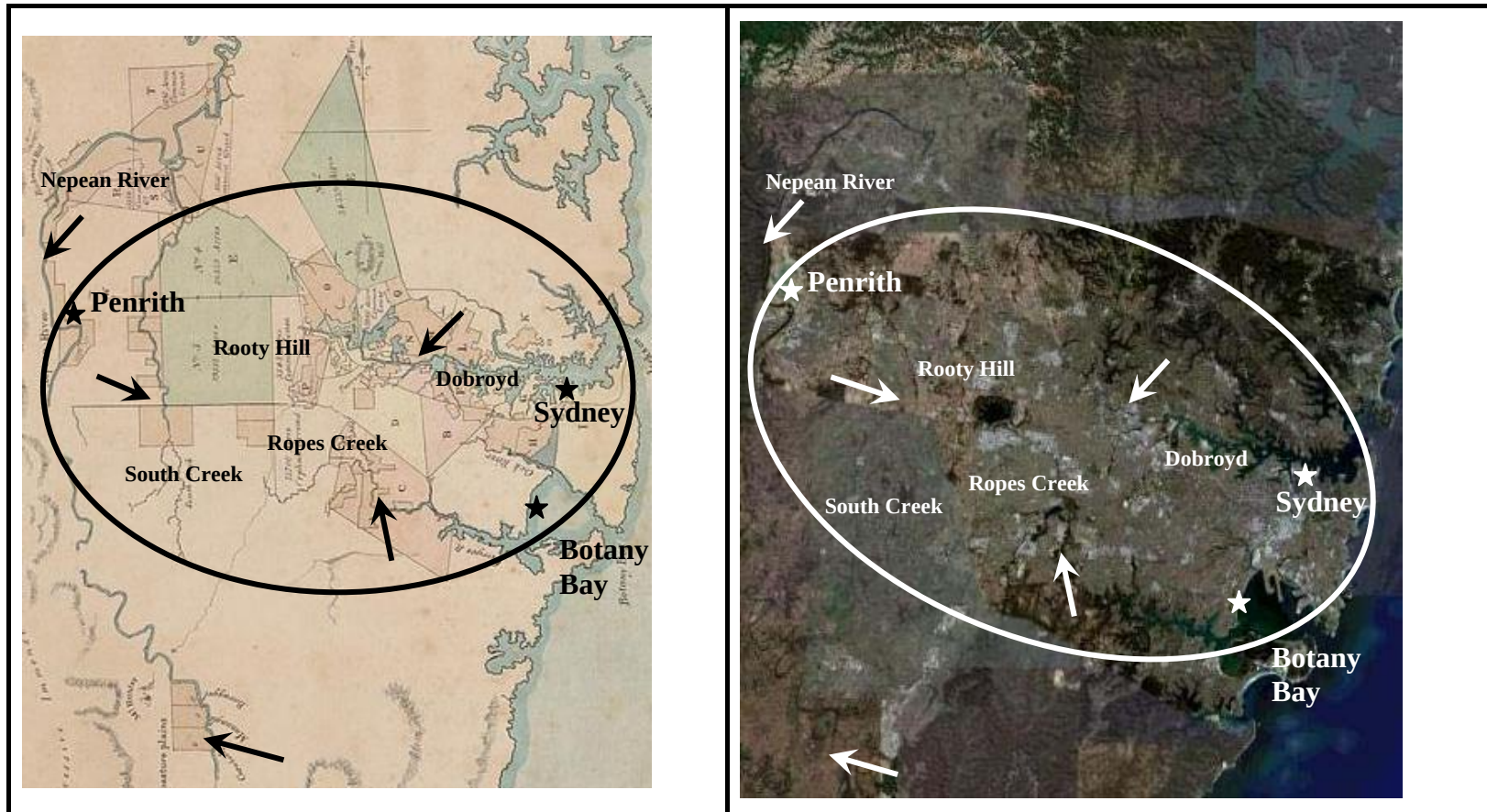


Figure 16 - The Cumberland Plain area of western Sydney in a) 1810, A new plan of the settlements in New South Wales: taken by order of Government, July 20th 1810, by John Booth (1810), reproduced by William Dymock (1870-1899) (Source: National Library of Australia) and b) 2007, Aerial photograph of Sydney showing extensive urban development across areas previously used by swift parrots (remnant habitats are small dark patches, large dark patch near Rooty Hill is Prospect Reservoir) (Google 2007).

Under regulations introduced in 1820 timber-getters needed permission to operate and the quantity they could cut was specified. By 1870 the continuation of largely unregulated cutting of trees was considered a threat to future wood supplies and eventually resulted in establishment of the some of the first forestry reserves in New South Wales (Carron 1985).



Figure 17 - Historic clearing of coastal forests near Tanja (Bega), on the south coast of New South Wales (Source: State Library of NSW)

The Liverpool Plains on the north-western slopes of the Great Dividing Range were discovered by Europeans in 1823 and marked the western boundary of the limits of settlement. The plains are among the most fertile and productive agricultural lands in Australia, and by 1831 squatters were establishing pastoral and agricultural areas (Halliday 2005). Squatters continued to spread across the western slopes of the Great Dividing Range to occupy extensive grazing areas beyond the specified limits (Grant 1989), gradually impacting on various types of grassy woodlands. These woodlands contained swift parrot habitat with forage tree species such as Mugga Ironbark *Eucalyptus sideroxylon*, White Box *Eucalyptus albens*, Grey Box *Eucalyptus microcarpa* and Yellow Box *Eucalyptus melliodora* (Kennedy and Overs 2001; NSW Scientific Committee 2001b; 2002c; 2006; Saunders 2007a). Grazing and clearing of native vegetation continued for much of the remainder of the 19th century with increasingly small patches of native vegetation retained. These patches of native vegetation were largely limited to traveling stock routes and road reserves (NSW Scientific Committee 2001b) (Figure 18).



Figure 18 – Historical clearing of woodlands for agriculture on the western slopes of New South Wales with a narrow strip of trees retained in the background - ‘7ft high wheat crop on "Kia Ora", Grogan - Grogan, Temora area, NSW’ (Unknown photographer 1880-1940) (Source: State Library of NSW).

Tasmania (European settlement from 1803)

As the winter foraging habitats of swift parrots were being increasingly lost in New South Wales, the establishment of Hobart Town in 1803 resulted in additional loss of habitat in the heart of the swift parrot breeding range on the east coast of Tasmania (or van Diemens Land as it was known until 1856). In similar fashion to the expansion of the settlement at Sydney Cove, as soon as Europeans settled in Hobart, clearing of native vegetation occurred (Carron 1985). Timber-getting became an important activity, starting with the eucalypts around the Derwent estuary. This included the harvesting of Tasmanian blue gum *Eucalyptus globulus* and brown-top stringybark *Eucalyptus obliqua*, which are prized for their high quality timber (Carron 1985), and provide important breeding habitat for swift parrots (Saunders 2007a).

The image of Hobart Town in 1868 (Figure 19a) illustrates the development of the Derwent River foreshore and the image of Derwent Park in the 1800s (Figure 19b) provides an example of some clearing on the upper reaches of the Derwent River with Mt Wellington in the background. The Mt Wellington area appears to have also been a popular location for

collecting swift parrots as noted by John Gould (Gould 1848; Datta 1997) and others such as J.W. Mellor who stated:

During a visit to Hobart in November 1906, I found these parrots on the slopes of Mt. Wellington and secured several specimens for my collection. They were feeding on the ground among the grass, apparently eating the seeds of the wild grasses in the timbered country (Mathews 1916, p. 472).

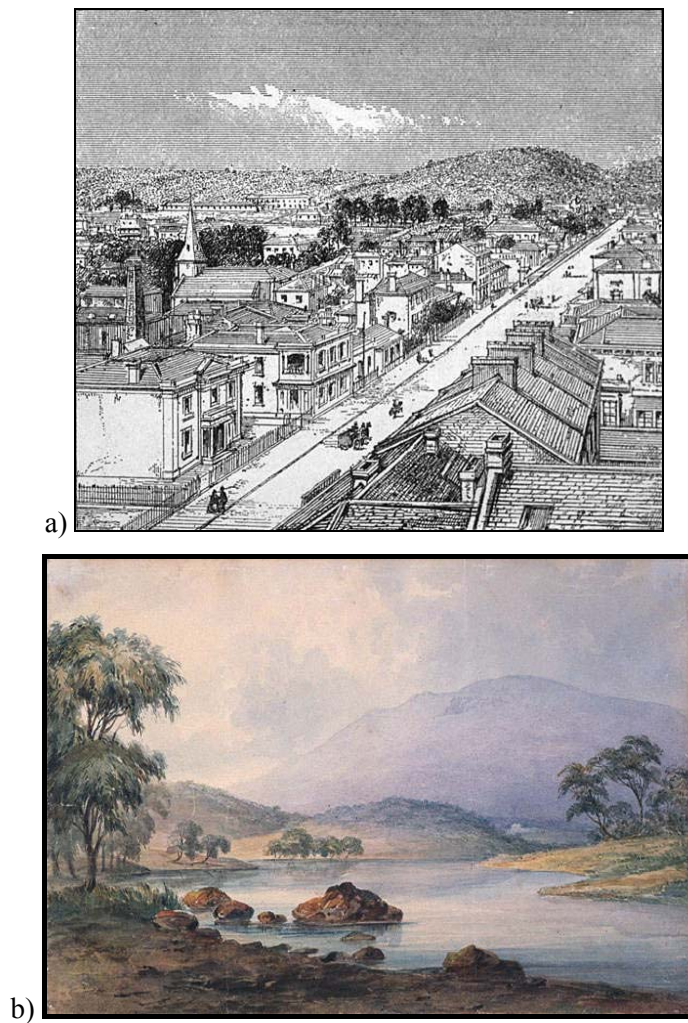


Figure 19 – a) Hobart Town, from the tower of St. David's Church (1859) by Hugh Munro Hull (Source: State Library of Tasmania).

b) At Derwent Park, New Town, V.D.L. (1835-1860) by T.E. Chapman (Source: State Library of Tasmania).

The loss of breeding habitats also occurred in other coastal settlement areas of eastern Tasmania, such as around the Port Arthur penal colony (established in 1830, and where W.B. Gould shot and painted the swift parrot as previously described). This settlement was “hacked from the bush and the first manufactories, such as ship building, blacksmithing, timber and brick making required ongoing use of timber from the surrounding forests” (PAHSMA 2007). However isolated trees and some patches of native vegetation remained in the areas surrounding settlements, which would have continued to provide at least some foraging habitat for swift parrots (Figure 20).

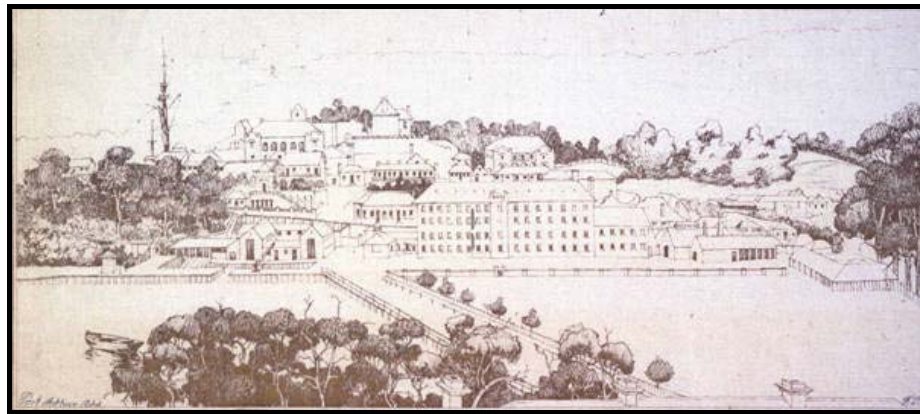


Figure 20 - Port Arthur 1844 by Tasmanian Lands Department (1917) (Source: State Library of Tasmania).

The demands for timber, cleared land for settlement, agriculture and grazing all put pressure on swift parrot breeding habitat. By 1835, virtually all the open grasslands and grassy woodlands of Tasmania had been occupied and given over to the production of wool and wheat. Legislation such as the *Waste Lands Act 1858* was devised to encourage this selection and development of forested areas for agricultural purposes. Although in the 1880s concerns began to be expressed about cumulative impacts on Tasmanian forests from uncontrolled logging, land clearing and frequent and uncontrolled fires, these activities largely continued unchecked to the end of the century (Cubit 1996). For example, George Innes (1896), Franklin District Surveyor, expressed concern over Tasmania’s depleted timber resources:

With regard to the timber industry, one thing is certain – that the wholesale and useless destruction of valuable timber that has taken place in years gone by requires checking, otherwise in a few short years

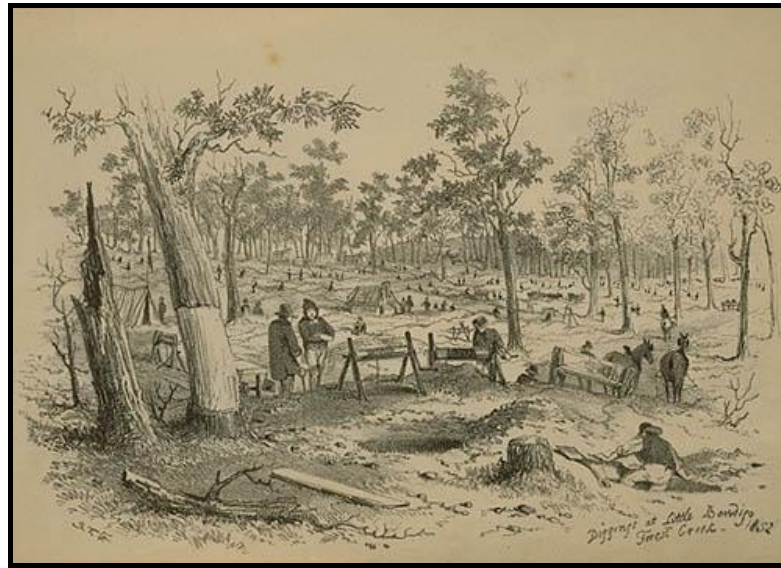
we shall find ourselves running very short of some of the more valuable of our timbers. Our blue-gum is one of these; it will not stand repeated firing of the undergrowth, and is easily destroyed.

“Our blue-gum” refers to the Tasmanian Blue Gum *Eucalyptus globulus*, an essential part of swift parrot breeding habitat (Saunders 2007a). Measures to begin to reduce such destructive practices in Tasmania were not put into place until 1919 when Conservators of forests were appointed and the *Forestry Act 1920* was finally introduced (Cubit 1996).

Victoria (European settlement from 1835)

The settlement of Melbourne in 1835 resulted in loss of native vegetation as it had in New South Wales (Victoria was administered as part of New South Wales until 1851) and Tasmania. Key habitats north of Melbourne were subject to a very different type of clearing, which proved to be perhaps the most devastating loss of swift parrot habitat in the mid 19th century. Within ten years of settlement, Victoria was subject to rapid population increase (Powell 1969), including a core part of the swift parrot wintering range in central Victoria. This was followed by an even greater human population explosion, and corresponding destruction of native forests when gold was discovered in 1851 (Carron 1985) in the heart of swift parrot winter habitat around Bendigo. Within eight years there were half a million people in Victoria (Australian Bureau of Statistics 2006) and the demand for wood for building, mining timbers and firewood, among other uses, was voracious. Although legislation and licensing were eventually put in place, there were no restrictions on tree species, sizes or quantity of timber that could be cut (Carron 1985). The box ironbark forests were extensively damaged during the gold rush period (Environment Conservation Council 2001) (Figure 21), with extensive and indiscriminate clearing of species such as red ironbark *Eucalyptus tricarpa*, mugga ironbark *E. sideroxylon*, grey box *Eucalyptus microcarpa*, yellow gum *Eucalyptus leucoxylon* and yellow box *E. melliodora*. Although there had been many old growth trees in the box ironbark forests of Victoria, over-exploitation in the early decades of settlement almost eliminated large trees (Environment Conservation Council 2001). A gold seeker at Bendigo, Alec Finlay, observed that:

The hills on each side of the gully, which might have been called thickly timbered (less than two months before), are now cleared a considerable distance up for firewood, and trees are barked for miles around for the closing in of chimneys, securing sides of tents and covering the mouths of holes from the wet (Bannear 1992).



a)



b)

Figure 21 – Extensive habitat loss in central Victoria a) Diggings at Little Bendigo, Forest Creek 1852 by S.T. Gill (1855) (Source: National Library of Australia)

b) Mt Alexander 1852 by S.T. Gill (1874) (Source: National Library of Australia)

The extent to which the forests were being exploited, both legally and illegally, continued throughout most of the latter part of the 19th century (Victoria Parliament 1865; Victoria Parliament 1874) and evidence of this remains today with the almost complete absence of old growth trees (Environment Conservation Council 2001). The extent of unnecessary damage to the forests was highlighted in a report by Inspector-General Ribbentrop of the

Indian Forest Service in 1896, which stated that the state forest conservancy and management in Victoria were in an extraordinarily backward state, with inadequate laws, funding, revenue and reserve establishment as well as rampant waste and destruction by fire (Ribbentrop 1896).

Given the extreme and rapid destruction of forests in Victoria, it is not surprising that this was the first state to attempt to curtail the reckless exploitation of the native forests that occurred over the previous century by appointing Conservators of Forests and establishing the 1907 Forestry Act (Carron 1985). However, despite the large spatial and temporal scale of habitat clearance that occurred in the mid 1800s, in the early 1900s Batey noted that swift parrots were:

A frequent visitant. Some two years ago a large party came. Seems to diet extensively on the white waxy scales that abound on the leaves of the yellow box (eucalypt). Those scales have a sugary taste; a small, soft insect is concealed under them (Batey 1907, p. 13).

However, it is unknown whether most birds shifted to other habitats during the Victorian gold rush, or whether a greater number of fatalities occurred during this period.

Ongoing habitat loss (20th & 21st centuries)

In the 20th century new concepts such as ‘wise use’ management of natural resources were introduced, however the first half of this century was dominated by two world wars, post-war reconstruction and an economic depression. As a result, the utilitarian ethos of ‘progress through development’ continued to dominate the management of lands and forests (Frawley 1994). For example, the intensification of rural land settlement continued with little prior economic or environmental analysis, and forests continued to be cut at a level beyond long-term sustainability (Resource Assessment Commission 1990). However, in response to the growing conflict between environmental values and resource development in the 1960s, environmental protection and planning were progressively incorporated into state and federal government legislation (Frawley 1994).

The emphasis on environmental issues continued to grow over the next two decades with environmental strategies developed at national and international levels (IUCN *et al.* 1980; Commonwealth of Australia 1983), and the introduction of numerous pieces of environmental legislation such as the Federal *Environment Protection (Impact of Proposals) Act 1974*; NSW *Environmental Planning and Assessment Act 1979*; Victorian *Environment Protection Act 1979 and Environment Effects Act 1978*; Tasmanian

Environment Protection Act 1973 and *Queensland State Development and Public Works Organisation Act 1971* (Grinlinton 1990; Frawley 1994). In the late 1980s, and throughout the 1990s environmental strategies became focused on Ecologically Sustainable Development principles (Department of the Prime Minister and Cabinet 1990), and legislation was introduced for the protection of native vegetation and threatened species (e.g. *Victorian Flora and Fauna Guarantee Act 1988* (FFG Act), *NSW Threatened Species Conservation Act 1995* (TSC Act), *Federal Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Bates 2006)). This included listing of the swift parrot as a threatened species at national and state levels. Early in the 21st century the impacts from human induced climate change came to the forefront of environmental planning and were given greater recognition with the introduction of the *National Greenhouse and Energy Reporting Act 2007* and ratification of the Kyoto Protocol (Department of Climate Change 2007).

Although there has been an increasing level of awareness and acceptance of the importance of environmental issues in the late 20th and early 21st century, the adequacy of conservation measures remain questionable, with human activities continuing to result in ongoing declines of native species and their habitats (Williams *et al.* 2001; McGrath 2006; Department of the Senate 2008). For example, despite legislative frameworks and recovery plans to protect the swift parrot, various land use practices such as forestry, agriculture, pastoralism, mining and human settlement have continued to impact on this species and its habitat (Saunders 2002a; Marshall 2006; Saunders 2007a).

Although quantification of the extent of habitat loss for the swift parrot is not currently possible due to incomplete vegetation mapping within the species' range, ongoing impacts have been so severe in several habitats that as little as 5% remains in some areas, resulting in their classification as endangered ecological communities (NSW Scientific Committee 1997; 2002c; 2004a; 2004b; 2005). In some areas, most of the clearing of habitat occurred in the 19th century and incremental loss of remaining habitats is the main issue. However in other areas, such as coastal forests within both breeding and wintering areas, valuable habitat continues to be cleared. The cumulative impact of these threats combined with the potential impacts from global warming (Bennett *et al.* 1991; Brereton *et al.* 1995; Intergovernmental Panel on Climate Change 2007), is of great concern for the long term survival of the swift parrot population. The following section focuses on these ongoing threats of the 20th and 21st centuries.

Forestry

Following on from the initial forestry Acts of the early 20th century, various state forestry organisations were becoming more interested in a national outlook, with greater emphasis on the need for special forest legislation, permanent and inalienable reserves, and the creation of permanent management authorities with statutory powers (Carron 1985). Reserves were initially established to ensure future timber supplies, however over time other forest values, such as habitat value for threatened species, became more widely recognized (Frawley 1994).

Years of conflicts and disputes occurred over the values and use of forests, resulting in the Australian government's attempt to resolve the issue by producing the National Forest Policy Statement (Commonwealth of Australia 1992). The statement included the establishment of Regional Forest Agreements (RFAs) which were intended as 20-year plans for the conservation and sustainable management of forests (Commonwealth of Australia 2008). Of the 10 RFAs established, nine have potential implications for swift parrot habitat. Although the RFA process substantially increased the total area of forest in conservation reserves (Commonwealth of Australia 2008), the agreements were based upon forests that had already been impacted by many years of mismanagement, and the logging of old growth forest is still permitted in Tasmania (Bates 2006). It should also be noted that the RFA process generally did not deal with private lands or plantation forests, and was limited in terms of landscape scale conservation given it was implemented on a region by region basis. Therefore only limited swift parrot habitat was protected under the RFA and the old growth forests that continue to be cleared contain important nesting habitat for this species (Saunders 2007a). RFAs and associated licenses include detailed prescriptions for the retention and protection of threatened species habitats within timber harvesting areas, however they have proven to be largely inadequate for the swift parrot (Munks *et al.* 2004; Marshall 2006) and the 'effectiveness' of RFAs in general is currently the subject of a senate inquiry (Department of the Senate 2008).

Swift Parrot habitat within production forests in different states and regions of the swift parrot range are afforded different levels of protection. Within key regions of Victoria, such as the Bendigo Forest Management Area, Swift Parrot Management Areas have been established at 40 priority sites for the species. Forestry operations within Swift Parrot Management Areas are required to retain all trees greater than 80cm Diameter at Breast Height (DBH) as well as two trees per hectare for the remaining three tree size classes (60-80 cm, 40-60 cm and 20-40 cm)(Department of Sustainability and Environment 2003).

However, in other regions of Victoria the required level of habitat retention is less. In NSW protection of potential habitat is not required unless there are records of this rare species at a particular location. However, even when there are records of the species, only 10 trees (with no specification of minimum size) need to be retained for every two hectares of net logging area (NSW Department of Primary Industries 1999). However, of greatest concern are the impacts from timber harvesting practices in Tasmania, where the species is entirely dependant on old growth forest for nesting (Voogdt 2006) and yet this habitat continues to be legally cleared (Australian Government and Tasmanian Government 2005; Marshall 2006) for the establishment of “sustainable harvest” forest plantations (Figure 22). So in the 100 years since forestry Acts were established in eastern Australia, forestry activities continue to have an impact on core areas of swift parrot habitat.

On a more positive note, 23 of the 40 priority sites identified for swift parrots on public land in Victoria were included in the conservation reserve system as part of the Box-Ironbark Investigation in 2002 (Environment Conservation Council 2001; Department of Natural Resrouces and Environment 2002). A further seven priority sites were partially included in the conservation reserve system and the remaining 10 priority sites were retained within production forest (Environment Conservation Council 2001; Department of Natural Resrouces and Environment 2002). A number of important swift parrot sites in state forests on the western slopes of NSW are no longer used for timber harvesting (e.g. Jindalee State Forest) or have been incorporated into the conservation reserve system (e.g. Livingstone and Benambra National Parks created in 2001). This has resulted in the retention of some of the largest and most important habitat remnants in the region.

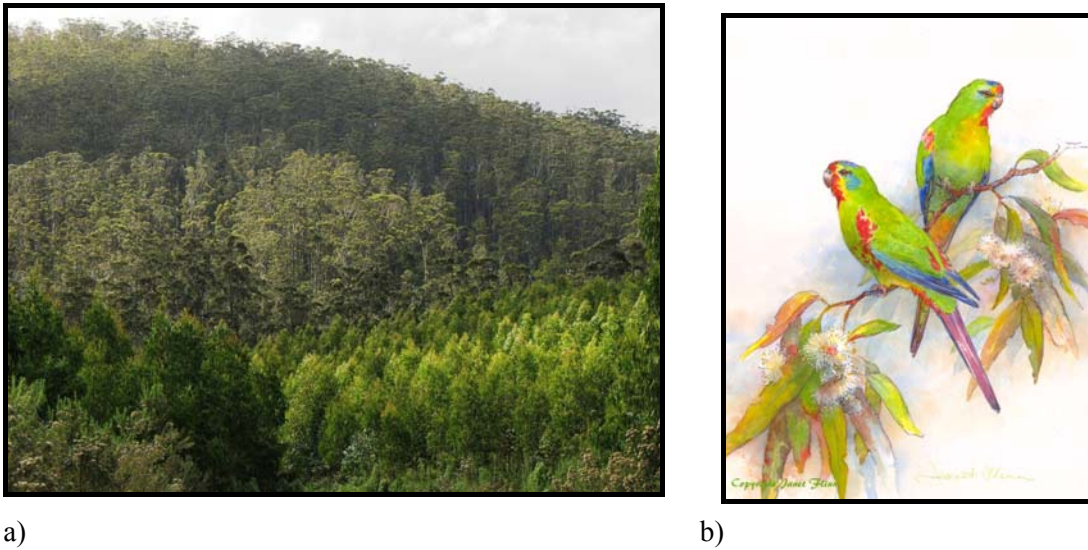


Figure 22 – Ongoing conservation issues for the swift parrot a) Wielangta Forest broad-scale clear felling of old growth swift parrot breeding habitat (background) for conversion to younger “sustainable-harvest” plantation forest (foreground)(2007) (Photo: Debbie Saunders).

b) Swift Parrots (2006) by Janet Flynn. Water colour painting commissioned for fundraising purposes to help conserve swift parrot breeding habitat in Wielangta Forest, Tasmania. (Source: artist Janet Flynn).

Agricultural production

Economic development in south-eastern Australia in the 19th century resulted in land clearing to create much of the current agricultural landscape. This process resulted in the over-clearing of agricultural areas (SOE 06) and left native vegetation confined to small, isolated remnants (Lunt and Spooner 2005) (Figure 23). Many areas continued to be cleared of native vegetation while others suffer incremental loss of vegetation from management of the surrounding landscape or through senescence of old trees and inhibited regeneration of new ones (Gibbons and Boak 2002). These impacts have been so severe in swift parrot habitats such as Inland Grey Box and Grassy White Box Woodland that only 5% to 30% of the original vegetation now remains, and what is left is often degraded (NSW Scientific Committee 2002c; 2006).

The need to address extensive degradation in agricultural landscapes was recognized in the late 1980s with the establishment of Landcare Australia. Landcare groups are comprised of

farmers and other land owners and managers interested in restoring and increasing the sustainability of their land (Landcare Australia 2007). An estimated 700 landcare groups now occur within the swift parrot range, undertaking local scale restoration projects such as the planting, regeneration and protection of native vegetation (Youl *et al.* 2006; Landcare NSW 2007). Despite these efforts to protect and revegetate the landscape, the loss of native vegetation and associated problems of land degradation and biodiversity loss have continued to such an extent that land clearance is now listed as a key threatening process under the federal *EPBC Act 1999* and the *NSW TSC Act 1995* (Endangered Species Scientific Subcommittee 2001; NSW Scientific Committee 2001a).

A National Framework for the Management and Monitoring of Australia's Native Vegetation was also established in 2001, requiring a commitment from all Australian, state and territory governments to reverse the long-term decline in quality and extent of Australia's native vegetation cover, and encouraging the protection, rehabilitation and restoration of native vegetation (Natural Resource Management Ministerial Council 2000). Although the level of commitment within most of the swift parrot range was an improvement on past management practices (Department of Primary Industries Water and Environment 2000; Department of Natural Resources and Environment 2002; Australian State of the Environment Committee 2006; Ministerial Review Committee 2006; Natural Resources and Water 2007), clearing of old growth habitat is still permitted in Tasmania (Australian Government and Tasmanian Government 2005).

In Victoria, the Native Vegetation Management Framework (Department of Natural Resources and Environment 2002) was established to achieve a reversal, across the entire landscape, of the long term decline in the extent and quality of native vegetation. This is now being implemented through Property Vegetation Plans (PVPs) whereby landholders outline the future management of native vegetation on their property (Department of Sustainability and Environment 2006b), and identify how they will offset the negative environmental impacts of proposed clearing by managing other native vegetation for conservation (Ministerial Review Committee 2006). Incentives are also being provided to landowners for conservation management and restoration of native vegetation (Department of Natural Resources and Environment 2002) which have the potential to provide a range of benefits for the long term sustainability of swift parrot habitat. Similar devices have now also been established in other states containing habitat for the swift parrot (Department of Primary Industries Water and Environment 2000; Department of Natural Resources 2006; Ministerial Review Committee 2006; Environment Protection Authority 2007). These planning tools have the ability to integrate natural resource management imperatives to

generate win-win outcomes for biodiversity protection and native vegetation retention. However, whether this will happen depends largely on practical implementation ‘on the ground’ (Bates 2006). How effective these native vegetation reforms are in protecting and enhancing swift parrot habitat in the long term will become apparent over time.

Given many important areas of swift parrot habitat occur on private property, establishing voluntary conservation agreements on these properties ensures that valuable habitat will be managed for conservation in perpetuity. Conservation agreement schemes are available throughout the swift parrot range in association with either the federal, state or local government conservation strategies and provide financial and technical support for land owners in the management of native vegetation (e.g. (Australian Government and Tasmanian Government 2007; Department of Environment and Climate Change 2008; Sunshine Coast Regional Council 2008). Despite the relatively small size of many properties with such agreements, they contribute to protection of landscapes which are often not otherwise protected (Department of Environment and Climate Change 2008) and have resulted in the protection of swift parrot habitat on a number of private properties throughout the species’ range (Saunders 2007a).



Figure 23 - Remnant western slopes habitats a) Mates Gully Traveling Stock Reserve, near Tarcutta, New South Wales (2003) (Photo: Debbie Saunders) and b) Livingstone National Park, surrounded by agricultural land on the western slopes of New South Wales, was previously a state forest (2001) (Photo: Debbie Saunders).

Urban and other built environments

The spread of towns and cities to accommodate Australia's growing population in the 18th and 19th centuries has continued to the present day with ongoing clearing of natural ecosystems (Australian State of the Environment Committee 2006), including habitat for the swift parrot. With much of Australia's urban development undertaken prior to the 1980s (Australian State of the Environment Committee 2006), and prior to the introduction and enforcement of environmental legislation (Frawley 1994), a legacy of extensive urban development surrounding fragmented and degraded natural environments remains (Figure 24). In the 1990s Environmentally Sustainable Development (ESD) principles were incorporated into environmental planning (Australian Government 1992), and more comprehensive legislation for the environment and threatened species were introduced throughout the swift parrot range (e.g. TSC, FFG and EPBC Acts).

This was an improvement on previous environmental law for the protection for threatened species, and intended to promote the ecologically sustainable use of natural resources and the conservation of biodiversity (Chapple 2001; Macintosh 2004). As a result, Environmental Impact Assessment processes for developments included detailed evaluation of the significance of impacts on threatened species and endangered ecological communities at both the state and federal levels (eg (Chapple 2001; Department of Sustainability and Environment 2006a; Department of Environment and Water Resources 2007)). However, after a number of years of EPBC Act implementation, the referral, assessment and approval process has failed to achieve its environmental objectives (Macintosh 2004; Macintosh and Wilkinson 2005). Such environmental legislation has often contributed to the 'death by a thousand cuts' for biodiversity, in favour of economic development (Bates 2006). For example, the cumulative loss of swift parrot habitat continues to occur as a result of native vegetation clearing approvals for urban (e.g. (Commonwealth of Australia 2002; Cowper 2002; Department of Environment Water Heritage and the Arts 2007; Lambert 2007)), industrial (e.g. (Saunders 2002a; Commonwealth of Australia 2004b)) and mining developments (e.g. (Commonwealth of Australia 2004a)). As a result the decline of native species, including the swift parrot, and their habitats has continued in the 21st century (Department of the Senate 2008).

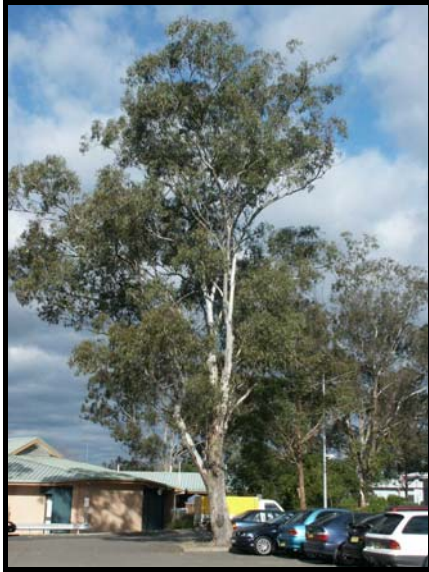
The impacts of spreading urban development on the swift parrot have been most pronounced in coastal areas where 86% of Australia's human population now reside (Natural Resource Management Ministerial Council 2003). Furthermore, these impacts are likely to increase with growing pressure for extensive urban development along the south-

eastern coast of mainland Australia (winter habitat) and on the Tasmanian coastline (breeding habitat) (Australian State of the Environment Committee 2006).

An example of the extent of swift parrot habitat loss in some coastal areas is provided by observations of the species in the Wyong Local Government Area of New South Wales in 2002. During that year swift parrots were concentrated in coastal habitats predominantly consisting of Swamp Mahogany and Forest Red Gum (for further details refer to chapter four), which have both been extensively cleared on the central coast of NSW for residential developments (NSW Scientific Committee 2002b; 2002a; 2004a; 2004b). Indeed, there is so little Forest Red Gum remaining in this area it almost entirely occurs as individual trees scattered within an otherwise urban environment. Up to one third of the swift parrot population (650 birds) is reliant upon this urban environment in some years, roosting and foraging in old trees in residential backyards (pers. obs.) (Figure 24a,b).

In addition to habitat loss, where remaining habitats occur near buildings and other urban structures, ongoing impacts occur from fatal swift parrot collisions with these structures (Figure 24c,d) (Brown 1989; Laubscher 1999; Swift Parrot Recovery Team 2001; Tzaros 2002a). Education programs about collision hazards have been implemented within the swift parrot breeding range involving local schools and community groups (Swift Parrot Recovery Team 2001) and a collision risk management plan has been developed in conjunction with building designers and urban planners so that a more strategic approach can be taken to reduce the threat of collision hazards (Pfennigwerth 2008). An educational video on swift parrot ecology, threats and conservation (Swift Parrot Recovery Team 2008) has also been distributed to interested groups throughout the species range.

a)



b)



c)



d)



Figure 24 - Remnants and individual trees in urban areas are often the only habitat that remains on the central coast of New South Wales

a) Swift parrot foraging habitat at Penrith, on the Cumberland Plain of western Sydney 2005. (Photo: Debbie Saunders)

b) Urban mass roosting site at Charmhaven, Central Coast NSW with evidence of incremental loss of remnant vegetation for further housing (Photo: Debbie Saunders).

c) and d) Swift parrot deaths from fatal collisions in the urban environment (Photos: Chris Tzaros)

Climate change

Anthropogenic climate change is another important conservation issue that has slowly gained recognition and support in policy, legislation and the broader community over the past decade (Allen Consulting Group 2005; Cowie 2007; Intergovernmental Panel on Climate Change 2007; Olsen 2007b). Observational evidence from all continents now show that many natural systems are being affected by regional climate changes, particularly temperature increases (Parmesan and Yohe 2003; Intergovernmental Panel on Climate Change 2007). It has been established that climate change is affecting the phenology, physiology and distribution of numerous organisms, as well as the composition and dynamics of communities (Hughes 2000; Walther *et al.* 2002; Parmesan and Yohe 2003; Parmesan 2006).

For migratory species, the effects of climate change may vary both spatially and temporally in different parts of the migratory cycle, making adaptation particularly complex and challenging (Moller *et al.* 2004). However, species that migrate from a single breeding population to several different overwintering locations (termed ‘diffuse migratory connectivity’) (Webster *et al.* 2002), such as the swift parrot, are generally considered to have a potentially strong adaptive capacity to respond to global warming given their ability to move long distances and use a diversity of areas and/or habitats (Webster and Marra 2004). However there are also pronounced species-specific responses to global warming whereby each migratory species’ adaptive capacity is dependant on the their migratory habits (Bairlein and Huppopp 2004) and the extent to which they are driven by endogenous or environmental mechanisms (Coppack and Both 2002).

The swift parrot exhibits diffuse migratory connectivity and therefore may have potential to adapt to rapid climate change. For example, their ability to respond to extreme and widespread climatic events such as drought (see chapters four and five) indicates a degree of migratory plasticity in relation to variable environmental conditions. However the species also exhibits a number of life history characteristics, and is subject to a number of ecological constraints, that suggest it may actually be quite vulnerable to both direct and indirect impacts from climate change. For example, as a cool climate nesting species, the swift parrot is highly intolerant of excessive heat, and nestlings can, and often do, die from heat exhaustion (Laubscher 1999; Pollard 2000). Therefore conditions within currently suitable nesting habitat may become less optimal for successful breeding and fledging as global warming increases.

Within the breeding area, swift parrots also need a combination of nesting hollows in old growth forest in close proximity to suitable foraging resources (Webb 2008; Webb and Voogdt in prep). As a nectarivore, the swift parrot is dependent on food sources directly influenced by climatic conditions such as rainfall and temperature (Law *et al.* 2000). Therefore global warming is likely to change the phenology of swift parrot foraging habitat and there is a risk that foraging and nesting resources may become spatially separated with potentially serious ramifications. There is also potential for mismatches between the timing of migration and foraging habitat phenology within both breeding and non-breeding habitats. Such mismatches have been found to result in reduced fitness and survival in some migratory birds (Coppack *et al.* 2001; Coppack and Both 2002; Bairlein and Huppopp 2004), although a diverse array of responses (shifts forward and backward, as well as no shifts) have been observed both in Australia and around the world (Lehikoinen *et al.* 2004; Gordo *et al.* 2005; Beaumont *et al.* 2006; Lehikoinen *et al.* 2006; Chambers 2008; Gordo and Sanz 2008).

The only study to examine timing of swift parrot migration (Beaumont *et al.* 2006) found no significant change in arrival date in the breeding grounds. These results may be interpreted in a number of different ways. Firstly, at the time of the study, swift parrots and their habitats may not have been significantly affected by climate change and therefore there were no shifts in the timing of migration to the breeding grounds. Alternatively, the spatially variable nature of swift parrot habitat use (Webb 2008; Webb and Voogdt in prep) and/or the concentration of observers within one part of this breeding range, may have masked some shifts in the timing of migration. However, impacts on the swift parrot from climate change are likely to become more evident over time, with significantly altered habitat availability predicted within both their wintering (Bennett *et al.* 1991) and breeding areas (Brereton *et al.* 1995).

Swift parrot habitat use is negatively correlated with large, aggressive species such as the noisy miner and rainbow lorikeet (see chapter 4), and ongoing habitat loss and fragmentation together with climate change are likely to result in greater abundance of such opportunistic and invasive species (Low 2008). Therefore the extensive physiological demands already on the species to locate a combination of distant and seasonally variable food sources from increasingly fragmented habitats (see chapters three, four and five), may be exacerbated by increased levels of negative inter-specific interactions in future. Furthermore, when affected by a combination of such stressors, the immune system of migratory species may also become depressed to such an extent that their health, and ability to successfully migrate, is reduced (Bairlein and Huppopp 2004; Hoyer *et al.* 2007). The

health and sustainability of forests and woodlands currently inhabited by the swift parrot may also be impacted since this species plays an important role in pollination of the tree species in which it forages (Hingston *et al.* 2004).

The full extent of climate change impacts on the swift parrot are currently speculative, however with our growing knowledge of the species' ecology and habitat use, it is clear that the extent of impacts from climate change will depend on the dynamic cumulative impacts with habitat loss, fragmentation and altered human land use across the landscape as identified for a diversity of other species (Opdam and Wascher 2004; Pimm 2008; Felton *et al. submitted*).

Conclusion

The combination of images and other historical information on swift parrots and their habitats in both colonial and more recent times, provides valuable insights into the large spatial and temporal extents of impacts on the species for over 200 years. It illustrates how swift parrots depend on forests and woodlands that have also been sought after, and extensively cleared and altered by humans since the late 18th century, and the ongoing vulnerability of this species despite recognition of its conservation significance for over ten years (Brown 1989; Brereton 1996; Swift Parrot Recovery Team 2001; Marshall 2006; Saunders 2007a) (for further discussion refer to chapter three).

In order to improve our understanding of ecological limitations for the swift parrot in each phase of their variable migratory cycle, more research is needed on the species' migratory movements, habitat use across their broad winter range on mainland Australia as well as its breeding biology and ecology in Tasmania. To improve conservation of this species there is also an urgent need to protect existing breeding and foraging habitat remnants across the landscape, determine the type and extent of impacts expected as a result of global warming and to incorporate new insights into the species' ecology and vulnerabilities into policy and management frameworks to provide the most effective conservation management in the future.

Chapter 3 - Conservation of the swift parrot - management lessons for a threatened migratory species

Published in Pacific Conservation Biology:

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Conservation of the swift parrot *Lathamus discolor* - management lessons for a threatened migratory species. *Pacific Conservation Biology* (2007): 13(2) 111-119



The swift parrot [*Lathamus discolor*] (1928) by E.E. Gostelow
(Source: National Library of Australia)

The swift parrot...appears to be exceedingly rare in New South Wales,
and more common, though by no means now as plentiful as formerly, in
Tasmania (Mathews 1916)

Abstract

Conserving habitat for wide-ranging fauna provides a challenge because impacts on these species tend to be dismissed based on the assumption that there is sufficient habitat in other areas of its range. This incremental loss of habitat is a serious conservation issue for a diversity of bird species. As knowledge of wide-ranging and migratory bird species increases, it often becomes evident that they select specific sites on a regular basis (i.e., the species exhibit site fidelity). Gaining a better understanding of site fidelity and selective habitat use for wide-ranging species is clearly important but also extremely challenging. In this paper, challenges associated with conservation of the migratory and wide-ranging swift parrot *Lathamus discolor* are discussed as an example of how a recovery program has aimed to address such conservation and management challenges. Despite the small population size (less than 2 500 birds), broad distribution (1 250 000 km²) and often cryptic nature, the implementation of the national recovery program has been successful in the identification and protection of important habitats. This has been made possible by involving large numbers of volunteers who collect long-term sighting and habitat data over large areas, together with more detailed ecological research undertaken through the recovery program. This information is then used to inform the conservation assessment process and to improve habitat conservation throughout the range of the species.

Introduction

Migration is a phenomenon that has major implications for the spatial dynamics and organization of many species and populations. The major driver of migratory behaviour in most species appears to be seasonal variation of food availability (Terrill 1990b). Regular large-scale seasonal movements are common among avifauna around the world, but are rare in parrots with only two obligate migratory parrots in the world, one of which is the swift parrot *Lathamus discolor* (Juniper and Parr 1998). This species only breeds in eucalypt forest and woodlands in the south and east of Tasmania. The population vacates Tasmania during autumn and winter, migrating to a vast area from eastern South Australia to southern Queensland. In winter, the majority of the population frequents eucalypt woodlands in central Victoria, and the south-western slopes and coastal forests of New South Wales. With a population of less than 2500 individuals, the species is listed as endangered under the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999. A national recovery plan outlines the need to identify the extent and quality of foraging habitat throughout the range of the species in order to protect the long term viability of the species (Swift Parrot Recovery Team 2001).

The swift parrot travels up to 2500 kilometres between Tasmania and the Australian mainland during migration. When swift parrots reach the mainland they disperse widely searching for suitable winter food resources such as nectar and lerp (carbohydrate excretions from psyllid insects on leaves) from eucalypts and other plant species. Swift parrots occur in a range of vegetation types from dry open woodlands on the inland slopes of the Great Dividing Range to coastal forests and heaths. Loss of these habitats is a major threat to the swift parrot, which may only survive in the long term if there are networks of protected habitats throughout their range (Swift Parrot Recovery Team 2001).

This paper discusses the challenges of conserving wide-ranging threatened species. The swift parrot recovery program has been implemented for over 10 years and stands as an example of how demonstrable conservation outcomes can be achieved for a threatened, migratory species.

Conservation Challenges of Dispersive and Migratory Fauna

Migrants and other dispersive bird species avoid seasonal extremes by traveling large distances to access resources in more moderate climates (Berthold 1993). Therefore these species must adapt to different seasonal habitats and resources throughout the year (Keast 1980). However, this evolutionary strategy may be limited by resource availability within

the human modified landscape. Habitat specialists that move sequentially among several habitat patches are particularly at risk when essential resources have been reduced or lost disproportionately (Ford *et al.* 2001). Seasonal variation, species detectability, different land ownerships and management practices and cumulative impacts can therefore all have an influence on the long term sustainability of a species and the effectiveness of conservation management.

Seasonal and inter-annual variation

Food availability appears to be the major driver of migratory behaviour in most species (Terrill 1990b) with resources varying at local, regional, State and National scales, both within and between seasons. Limited knowledge about the availability of these resources makes it difficult to predict habitat use and implement sound habitat management for highly mobile species (Clarke *et al.* 1999). Although there has been some research on resources such as nectar and lerp in eucalypts (Porter 1978; Paton 1980; Woinarski *et al.* 1989; Pook *et al.* 1997; Oliver 1998; Wilson and Bennett 1999; Oliver 2000; Mallick *et al.* 2004); there is still much to be learnt about flowering phenology and resource variability across the range of the swift parrot.

Seasonal variation in swift parrot habitat use during migration is demonstrated by records of the species collected by recovery program volunteers over the past 10 years across eastern mainland Australia. The swift parrot population is dependent on resources within a limited geographic area and in specific vegetation types. Over time, all of these resources are important for the long-term sustainability of the population. The loss of one or more seasonal food sources is thought to have contributed to the species' decline (Ford *et al.* 2001; Swift Parrot Recovery Team 2001). An example of the seasonal variation in habitat use by swift parrots is illustrated by comparing spatial and temporal variation in swift parrot records between the 1998 and 2002 migration seasons. In 1998 birds concentrated in central Victoria, whereas in 2002 a large proportion of the population migrated up to 1 000 kilometers further north than recorded in previous years, and was concentrated in small fragments of habitat among coastal urban development (Figure 25a, b). Presumably, the shift in 2002 was due to drought conditions throughout central Victoria and western New South Wales. See chapters four and five for full analyses of the factors affecting the use of known foraging sites and the variable use of habitat patches according to climatic and ecological parameters.

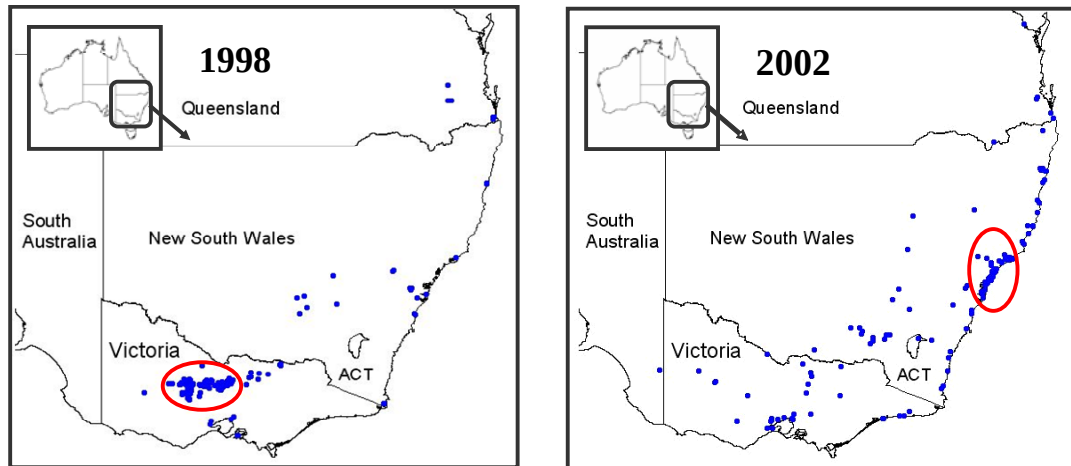


Figure 25 - Large-scale spatial and temporal shifts in habitat use by swift parrots in a) 1998 and b) 2002 sampled in May and August each year.

Detectability of target species

Dispersive species can be difficult to detect because surveys are required to cover large areas at times and locations which may be highly variable. Where dispersive species occur in small groups and/or are cryptic, their detectability is further reduced if the population size is small and they occur across a broad landscape. For example, the ability to detect swift parrots in an area is constrained by their small population size and the large geographic area they occupy. Although this species can be very conspicuous, with loud calling and exuberant flights, they can often exhibit cryptic behaviour such as silently feeding, sitting and preening within the upper foliage of tall trees, particularly in the middle of the day (Higgins 1999). Therefore when they are not detected at a site, it cannot be assumed that they are not present. In the absence of records of the species from wildlife atlas databases (such as the New South Wales Department of Environment and Conservation Wildlife Atlas), the potential suitability of habitat may be used as an indication of the likelihood of the species occurring at the site. This can be difficult where vegetation mapping is inadequate for fine scale habitat assessments. However, habitat modeling at a range of scales may assist in the identification of potential habitat availability (Mackey and Lindenmayer 2001).

Multiple jurisdictions and land ownerships

The issue of conserving fauna within the human modified environment is complex when habitats occur across different land tenures and States. It is challenging to develop a uniform approach to the conservation of a migratory species because various landowners, land managers and government agencies may have different priorities. This may lead to gaps in the conservation effort across the range of a species (Berthold 1993). The swift parrot occurs across multiple jurisdictions and land ownerships including six States/Territories, 28 Catchment Management Authorities (CMAs), over 150 local government areas and thousands of private properties. This complexity makes it challenging to effectively implement conservation measures across the range of the species.

Cumulative impacts

As resources are depleted through anthropogenic habitat loss and modification, it is important that remnant habitats used throughout a species' life cycle are identified and adequately protected (Powell and Bjork 1995). Identification, protection and management of habitat for migratory and other dispersive species is often difficult given they move over vast geographic areas and are usually dependent on the availability of suitable foraging resources that are largely influenced by climatic and environmental conditions (as demonstrated in chapters four and five). In a particular year the majority of the population may be dependent on specific resources within a limited number of regions and be susceptible to cumulative spatial and temporal impacts by human modifications to those resources and habitats.

Cumulative impacts to habitat of the swift parrot occur throughout the species' range. Habitat loss from agricultural, forestry, urban and industrial developments all pose significant threats to this species (Swift Parrot Recovery Team 2001), especially where there is a disproportionate loss of key foraging habitats (Ford et al. 2001). Additional impacts such as human-made structures creating bird collision hazards (e.g., reflective windows, wire mesh fences, vehicles and power lines, as illustrated in chapter two) within or near suitable habitats provide additional survival pressure on the species (Swift Parrot Recovery Team 2001).

The increased number of collisions on the mainland during the drought event of 2002 emphasizes the susceptibility of the population to fatal collisions with human-made objects. When food resources were scarce in drought affected habitats of Central and Northern Victoria and the western slopes of NSW, the majority of the parrot population concentrated in coastal environments of NSW dominated by urban development. With an increasingly

large proportion of the human population (currently more than 86%) residing in coastal areas of Australia (Natural Resource Management Ministerial Council 2003), associated development and impacts from fatal collisions are also likely to increase. During the 2002 migratory season the total number of fatal collisions reported by the general public exceeded the combined total of the previous seven years of the recovery program on mainland Australia (unpub. data). When impacts occur over several breeding and migration seasons, this may have a significant impact on the long-term viability of the species (Swift Parrot Recovery Team 2001).

Other ongoing threats to the swift parrot include increased competition with more aggressive nectarivorous bird species. The fragmentation of habitats and landscapes used by the swift parrot has favoured some of the large aggressive species (i.e., Noisy Miner *Manorina melanocephala*, Red Wattlebird *Anthochaera carunculata* and Noisy Friarbird *Philemon corniculatus*) that have the ability to impact on the swift parrot through competitive exclusion and resource depletion (Ford et al. 1993; Grey et al. 1998) (see chapter 4). Resource competition with the introduced European Honeybee *Apis mellifera* may also pose a threat to the swift parrot with up to 2 000 tonnes of honey being produced each year from potential habitats in the Victorian Box Ironbark woodlands on public land alone (Environment Conservation Council 2001). Other factors that may alter food availability are drought, plant insect damage and fire (Goodman 2001), and potentially rising ground water and salinity affecting tree health.

The varying nature of threats and management in each jurisdiction, and the limited capacity of current legislation to consider cumulative impacts of all developments makes it difficult to address the issue of cumulative impacts. By implementing a national recovery program for the swift parrot across the range of the species, there is the potential to address cumulative impacts.

Overcoming the challenges

Despite the challenges associated with conserving dispersive species, the swift parrot recovery team has had some success in protecting important habitats through collaborative efforts, which have focused on the implementation of the National Swift Parrot Recovery Plan.

National swift parrot recovery program

The swift parrot recovery program commenced in 1995 with the development of the National Swift Parrot Recovery Plan. Prior to the inception of the recovery program, there

was a paucity of knowledge of the ecological requirements of the swift parrot, particularly on the mainland. This plan identified recovery objectives, actions and resource requirements across all states within the swift parrot range. Broad recovery objectives were to change the conservation status of the swift parrot from endangered to vulnerable, and to achieve a demonstrable sustained improvement in the quality of swift parrot habitat to increase carrying capacity. In the decade since, the recovery team has successfully prioritized and implemented recovery actions throughout the range of the species (Tzaros 2002b).

For conservation efforts to be most effective for this migratory species, cooperation was required from all relevant States and Territories. Accordingly, the swift parrot has been listed as threatened in each State and Territory in which it occurs, providing recognition of the population status and the need to implement conservation measures throughout their range. This cooperation also included coordinating volunteers, conducting targeted surveys and ecological research, as well as providing advice in regard to the implementation of conservation measures.

Volunteer participation

Voluntary community participation has been an essential component of numerous wildlife monitoring projects, provided invaluable baseline data for future research (as demonstrated in chapter five) and guided practical habitat conservation management of a diversity of species (as discussed in this chapter). Such participation has resulted in cost effective monitoring at relevant temporal and spatial scales, increased community education and awareness, and local ownership of conservation issues (Saunders 1993; Lunney 1997; Bildstein 1998; Barrett and Davidson 1999; Otley 2001). However, once a volunteer program has been established a key component to maintaining effective volunteer networks in the long term is to provide ongoing support and feedback to members (Weston et al. 2003). The swift parrot recovery program provides an example of how volunteer participation can be implemented over an extended period of time with extensive involvement, education and support of members of the community. The mainland volunteer program commenced in 1996 with a small group of interested community members, and has continued for ten years with over 20 coordinated autumn and winter surveys within the mainland range of the swift parrot. During each survey period, volunteers from across south-eastern Australia conduct bird surveys in their local area, documenting specific survey location details, bird species present, behavioural observations, habitat characteristics and food resource availability. These surveys are

conducted regardless of target species' presence, to enable to the collection of both 'nil' and positive data. This has been done collaboratively with the regent honeyeater recovery program as both species utilize similar habitats and geographic ranges on the mainland (Menkhorst et al. 1999). Survey effort has increased from 185 surveys in 1995 to over 900 surveys in 2004 (Figure 26). This is one of the largest and longest-running community-based surveys of a threatened species in Australia with over 7200 volunteer surveys conducted over ten years. Twice a year volunteers survey potential habitats in their local area on the same weekend to provide a snapshot of how the population is distributed across the landscape, providing invaluable information about the species over large spatial and temporal scales that would not otherwise be possible.

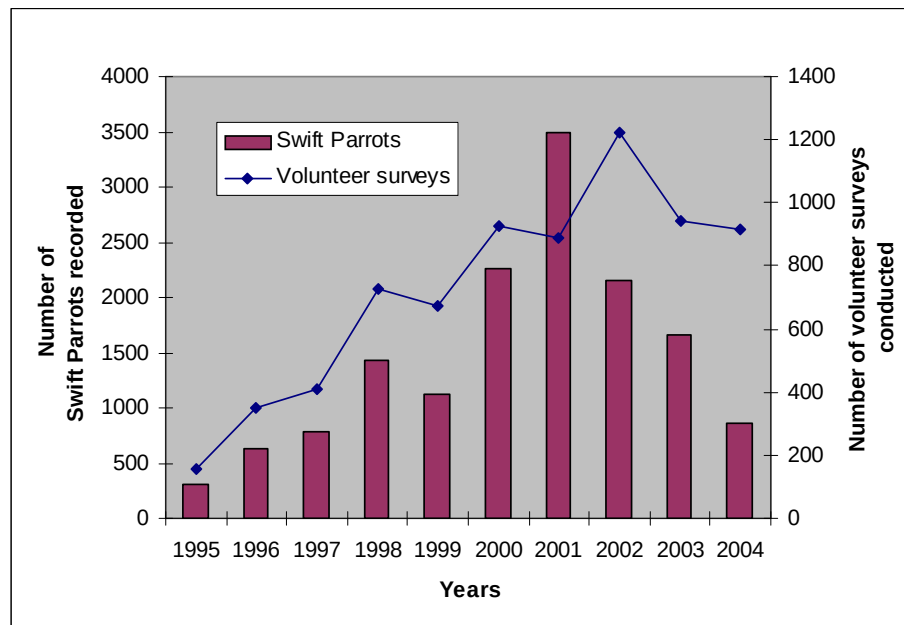


Figure 26 – Results of national volunteer swift parrot surveys on mainland Australia 1995-2004. A total of 14696 swift parrots have been recorded from a total of 7215 surveys. The number of swift parrots recorded and volunteer surveys conducted are the combined totals from the bi-annual surveys each year.

Volunteer and community education workshops have been conducted in regional locations throughout the range of the swift parrot. These workshops promote the recovery effort, foster public interest and involvement, give feedback to volunteers as well as provide the opportunity for personal contact and sharing of knowledge. The program is also promoted among the community through various forms of media, including radio interviews, newspaper articles, television, newsletters and brochures as well as presentations and

regular communications with interested community groups. Collaborative efforts with other threatened species recovery programs, such as the regent honeyeater recovery program, have also been mutually beneficial with sharing of resources, knowledge and responsibility for maintaining enthusiastic and skilled volunteer networks.

Information collected by volunteers has been used extensively throughout the program to identify and map important areas of habitat, as a basis for advice on a broad range of conservation management issues at all levels of government, and to improve our understanding of the ecology of the swift parrot (see chapter five). It has also identified habitats within the ACT (e.g., Grassy Box woodlands and planted trees) and south-east Queensland (e.g., Forest Red Gum *Eucalyptus tereticornis* Forests and urban remnants) that are used on a more regular basis than previously recognized. This has increased the level of interest and participation by volunteers in these areas, further improving our understanding of the species' use of habitats. As a result, the swift parrot is now listed as a threatened species in Queensland and therefore has potentially greater protection than previously afforded.

Long-term volunteer involvement has provided invaluable ecological information about swift parrots on a scale not otherwise possible. This information has been used to guide conservation decisions for the species, highlight the seasonal variation in habitat and resource use, and establish essential baseline data for further ecological research (see chapters four and five).

Ecological research and conservation management

Several studies of the foraging and breeding ecology of swift parrots have been conducted as key actions of the recovery program (Kennedy and Overs 2001; Tzaros 2002b; Brereton *et al.* 2004; Mallick *et al.* 2004; Munks *et al.* 2004; Kennedy and Tzaros 2005). These research projects have focused on identifying, mapping and modeling the extent and quality of habitat. Long-term monitoring of these habitats will determine use and site fidelity (repeated use of a site by the species) by swift parrots and provide a basis for habitat conservation measures. Research on the biology of swift parrots has also improved understanding of the species' physiological requirements (Gartrell *et al.* 2000; Gartrell 2001; Gartrell 2002).

Site fidelity is considered to be important for the long term survival of migrants at both breeding and non-breeding sites (Villard *et al.* 1995). Information obtained through the recovery program demonstrates the importance of site fidelity for the swift parrot population (Kennedy and Tzaros 2005). Over 100 sites have been identified across the

mainland as being used repeatedly by the species in two or more years (Figure 27, also refer to chapters four and five) and used for extended periods of time within seasons. However, this does not necessarily diminish the importance of areas where site fidelity has not yet been established since this may be due to observational limitations and long-term resource availability cycles. For example, many parts of north central Victoria and southern New South Wales have been subject to drought conditions for several years. Also some sites may eventually become regularly used if other sites containing habitat are cleared or altered. The extent of habitat clearance has resulted in several swift parrot habitats being listed under state, territory and commonwealth legislation as endangered ecological communities. This includes Grassy White Box Woodlands, Lower Hunter Spotted Gum Ironbark Forest, Cumberland Plain Woodland, and Swamp Sclerophyll and River-flat Forests. These habitats have been reduced to between six and 30% of their former distribution (NSW Scientific Committee 1997; 2002c; 2004a; 2004b; 2005).

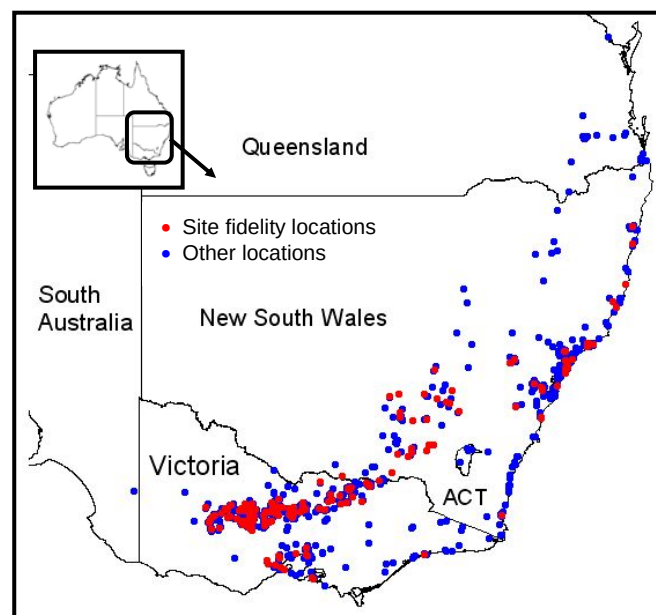


Figure 27 – Swift parrot site fidelity (sites used by the species in more than one year) on mainland Australia 1995-2004. Red circles represent sites that have been used in more than one year (site fidelity) and blue circles represent sites where swift parrots have been recorded on one occasion.

Research and monitoring in Tasmania has provided data on the annual flowering patterns of Tasmanian Blue Gum *Eucalyptus globulus*, which is the primary food source for swift parrots during the breeding season, as well as estimates of swift parrot densities at standard

monitoring sites (Porter 1978; Paton 1980; Woinarski et al. 1989; Pook et al. 1997; Oliver 1998; Wilson and Bennett 1999; Oliver 2000; Mallick et al. 2004). As a result, priority swift parrot foraging habitat has been mapped. A total of 2209 hectares of grassy Tasmanian Blue-gum forest, 606 hectares of shrubby Black Gum *Eucalyptus ovata* forest and 4620 hectares of mixed dry forest, containing some Tasmanian Blue Gum, has been protected. Habitat protection has been achieved through the covenanting and purchase of private properties through the Private Forests Reserves Program (Saunders 2005).

In Victoria, habitat mapping has focused on public land throughout the box-ironbark regions and 40 priority sites have been identified where swift parrots have a high level of site fidelity, or have occurred in large flocks. An additional 121,000 hectares of box-ironbark forests and woodland have been recently added to the State's National Parks & Reserves system, with the majority of the priority sites now within these reserved areas (Environment Conservation Council 2001). This mapping is updated as more information comes to hand. Current work in central Victoria is focusing on mapping habitats on private land and incorporating this with existing public land mapping for a more complete picture of habitat availability and use by swift parrots.

Data collected for the program have also demonstrated that swift parrots utilize coastal and inland habitats within NSW more regularly than previously recognized with swift parrots observed annually in these habitats (as further examined in chapters four and five).

Ecological research in NSW has focused predominantly on public land and the identification of priority sites is currently being undertaken. Surveys on private properties have also commenced with an increasing number of landowners becoming involved in the program and taking an interest in managing swift parrot habitat on their properties.

Once habitats have been identified, there is a need to manage incremental loss of habitat due to developments. Therefore an offset system is being developed and implemented in Tasmania whereby swift parrot habitat removed is replaced by a combination of covenanting, land-management agreements and replanting at an average replacement ratio of 10:1 or greater (M. Holdsworth *pers. comm.*). In NSW, property vegetation planning (PVP) systems are being developed by the State government, which are intended to provide offsets and restrictions to vegetation clearing. The effectiveness of this for protecting swift parrot habitat in NSW is currently unknown.

In production forests and woodlands, forestry prescriptions are intended to reduce the impact of timber harvesting on threatened species. Prescriptions within Victorian forests have been updated to take priority foraging sites into consideration. Within NSW,

recommendations have been made for revision of current forestry prescriptions across the state. However, a review of interim management prescription implementation in production forests of Tasmania found these prescriptions are often not effective in preserving swift parrot habitat (Munks et al. 2004). These prescriptions have therefore been changed to exclude recognised habitat from harvesting. However, there is often not enough habitat information collected prior to harvesting, and therefore prescriptions may be implemented using inadequate data and habitat models.

Given that swift parrots form one part of a larger functioning ecosystem, the recovery plan also acknowledges the need for wider biodiversity conservation strategies that encapsulate a broader range of woodland and forest biota (Swift Parrot Recovery Team 2001). Therefore information on a wide diversity of flora and fauna species has been documented at survey sites, providing information not otherwise available, for use in this and other conservation programs (e.g. NSW flying fox foraging resource project). Support has been given to community funding applications for implementation of on-ground conservation projects for swift parrot habitats. This has resulted in protection of mature habitats, enhancement of degraded areas and a heightened awareness among the community in regard to the importance of threatened species and habitat diversity at the local level.

By implementing a combination of administrative and on-ground approaches to conservation through the recovery plan, there have been conservation achievements throughout the range of the swift parrot.

Ongoing challenges

Although the swift parrot recovery program has achieved many positive conservation outcomes, there are still many threats to the species and its habitat that need to be addressed through a continuing and adaptive recovery effort.

The establishment and maintenance of an effective volunteer network across a broad spatial area has involved a great deal of time, effort and resources, and the ongoing recruitment of volunteers is an integral yet demanding component of this recovery program. Data gathered by this volunteer network require prompt entry into a readily accessible database. With a significant increase in volunteer recruitment, there has been a correspondingly large quantity of data requiring standardisation and input into the database.

The uncertainty of an adequate amount of recovery program funding is a major challenge. Applications for funding need to be submitted annually and at the regional level, despite the long-term, national scale of the project. The regional focus of the latest Natural Resource

Management reforms also presents challenges, with implementation of recovery actions required across 28 CMAs rather than the six States/Territories as was the case during previous nationally centralised funding programs. Given that each CMA is focused on management within their regional boundaries, it is difficult to stimulate sufficient recognition of the importance of habitats for species that occur over broader geographic areas. Using this regional approach, there is also a risk of disproportionate levels of funding being directed to the various regions. Regions where relatively large proportions of the population are known to concentrate should be given priority funding.

Although some key foraging habitats have been identified, these can only be based on the information available at the time, which is often incomplete. Therefore as new information becomes available it is important to update relevant management plans. For example, as the ecological requirements of swift parrots are increasingly understood, important knowledge gaps have also become evident. These include a limited understanding of swift parrot nesting and roosting requirements, migratory movements and large-scale habitat use throughout their winter range. It should be noted however, that once priority habitats are clearly identified, their protection is not guaranteed given that social and economic priorities are often considered to be of greater importance than conservation priorities.

Conclusions for Dispersive Species Conservation

Despite these ongoing and varied challenges, the swift parrot recovery program provides an example of how some of these challenges may be addressed. The following elements are considered to be important for successful implementation of conservation measures for dispersive species such as the swift parrot. This is not intended as an exhaustive list, but rather a snapshot of the mechanisms that have been used effectively for the conservation of this migratory species. These may prove useful to other conservation projects that have a focus on dispersive species:

- Build the capacity of regional and local communities through involvement, education, resourcing and supporting activities.
- Demonstrate site fidelity and dependence of population on specific sites (see chapters four and five).
- Recognise that for many species habitat is not contiguous and, as a result of human influences, is becoming increasingly patchily distributed, isolated and reduced in size and extent.

- Recognise that remnants can still provide important habitat for dispersive species (see chapter four).
- Monitor at an appropriate time scale that enables detection of intra- and inter-seasonal variations in habitat resource availability (as highlighted in chapters four and five).
- Facilitate and encourage close cooperation and healthy working relationships between government and non-government agencies, including CMAs.
- Provide advice based on sound research to guide strategic reserve conservation decisions and legislative assessment processes at all levels of government.
- Secure long-term funding to ensure ongoing implementation and maintenance of the knowledge base.
- Manage all databases from the commencement of the program to ensure all data is accessible and in a useful format to provide a basis for conservation management actions/recommendations.
- Publish the results of research conducted by, or in affiliation with, the recovery program, in a range of publications, including peer-reviewed journals (as for chapters 3, 4 and 5). This demonstrates that the recovery program is achieving pertinent research and communication-based recovery objectives, and provides a sound basis to guide management strategies.
- Implement the program across the entire range of the species.

The future overall objectives of the swift parrot recovery program are to improve the conservation status of the species and long-term sustainability of the population. Specific actions aimed at achieving these objectives include continuing all long-term monitoring components of the program, commencing work to address new knowledge gaps, further developing relationships with CMAs, continuing to involve and support our established volunteer community network, and implementing on-ground habitat conservation measures.

Chapter 4 - Winter habitat use by the endangered, migratory Swift parrot (*Lathamus discolor*) in New South Wales.

Published in Emu - Austral Ornithology:

Saunders, D.L. and Heinsohn, R. (2008). Winter habitat use by the endangered, migratory Swift Parrot (*Lathamus discolor*) in New South Wales. *Emu* **108**, 81-89.



Juvenile swift parrot within in the species' winter range
by Geoffrey Dabb (2005)

The birds, when feeding, utter subdued, but tuneful notes as they move actively amongst the foliage, frequently hanging head downwards nibbling the leaves for scale insects or sipping nectar from the blossoms (Hindwood and Sharland 1964).

Abstract

Migratory birds are dependent on a combination of suitable wintering, migration and breeding habitats. Identification and protection of these habitats is essential for their conservation. The endangered swift parrot (*Lathamus discolor*, Psittacidae) migrates north from Tasmania in search of suitable winter food resources across south-eastern mainland Australia. This five 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 coastal and/or western slopes regions of New South Wales each year, including several habitats that occur in endangered ecological communities. Swift parrot abundance 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

The 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), only limited information is currently available on their habitat use. The few studies that have been undertaken focused on breeding habitats (Legge and Heinsohn 2001; Boland 2004; van Dongen and Yocom 2005) or relatively small areas within the species' wintering range (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 (*Lathamus discolor*, Psittacidae), an endangered austral migrant (population estimate 2,500 birds). It breeds in Tasmania then migrates north across Bass Strait before dispersing across a broad wintering range (approximately 1,250,000 km²) 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 focused 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 region 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 (as identified in chapter 3).

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 north coast (30°S, 154°E) to the south-western slopes (36°S, 146°E) of New South Wales (NSW) (Figure 28). This included five regions; the north, central and south 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.

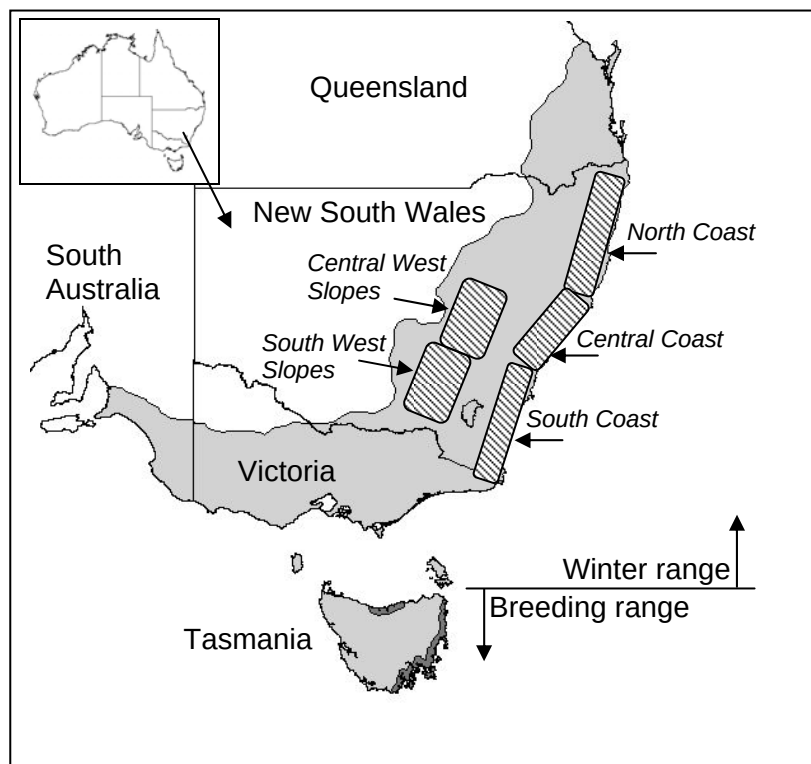


Figure 28 – Study area regions (hatched) extending from Coffs Harbour on the north coast to Culcairn on the south west slopes of the Great Dividing Range in New South Wales, Australia.

Site selection

The aim was to establish known swift parrot foraging sites and to document the variables that determined whether they were used each year. Swift parrots are rare, broadly distributed and often cryptic by nature. Therefore extensive audio and visual searches were initially conducted along access routes from a slow 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. These 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 metre 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. Observations on each foraging individual were limited to a period of 3 minutes. These short observation periods were continued until it was no longer possible to identify individuals due to their rapid movements between trees and amongst each other. Once the original individuals could no longer be identified, three minute foraging observations were made on random individuals. Each study site extended to a radius of 500 metres from the tree in which the birds were first observed foraging. Within this site, a 0.1 hectare (20m x 50m) habitat plot and a 50 metre radius bird survey plot were also established to provide a sample of the surrounding habitats and bird communities.

The 53 sites (35 coastal, 18 western slopes) used in this study were, by necessity, added incrementally throughout the study period (nine sites 2001; 28 sites 2002; three sites 2003; nine sites 2004; 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 2001; 30 surveys 2002; 40 surveys 2003; 49 surveys 2004; 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 focused 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). Any potential bias from the variable survey effort was accounted for by comparing abundance on a per survey basis.

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 to 2000) databases (NSW wildlife atlas and swift parrot recovery program database).

Landscape and habitat types

Potential swift parrot habitats were located within three main landscape types. These were classified as scattered tree (scattered individual trees within a rural or urban environment), remnant vegetation (patches of natural vegetation less than 10 000 hectares surrounded by rural or urban environments) or continuous forest (extensive areas (10 000 hectares or more) of natural vegetation) landscapes. Although the size of remnant vegetation patches varied from less than five hectares to 8400 hectares, suitable habitat within the largest remnants was limited to approximately 10-20% of the total remnant area. We examined associations between these landscape types and swift parrot abundance.

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 and/or nectar 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. Food abundance was estimated by counting the number of trees with lerp and/or flowers within the habitat plot. Flowers were used as a surrogate for nectar as it was not practical to collect detailed nectar production information on the large-scale of this study. The abundance of all bird species seen or heard during a 10 minute 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. stop foraging or fly out of tree). Non-aggressive competitors were those that did not display aggression towards the swift parrot despite occurring in close proximity

(within 50m) 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 modeling approach using Genstat software (Genstat Committee 2007) that 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 in 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 due 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 due to violations of the assumptions inherent in the modeling approach. For example, swift parrot abundance could not be modelled at the site scale due 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 five 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 $\pm$ 48 s.d.) in coastal habitats and up to 60 birds (median = 20 birds $\pm$ 18 s.d.) in western slopes habitats.

Spatial and temporal habitat use

Throughout the study period, the abundance of swift parrots (per survey) in NSW habitats varied significantly between regions and years (region $X^2_2=3.73$, $p=0.005$, all years $X^2_4=393.95$, $p<0.001$). Similarly, the abundance of swift parrots varied significantly during both drought (2002 only, regions $X^2_2=49.08$, $p<0.001$) and non-drought conditions (regions $X^2_2=3.73$, $p=0.005$, non-drought years $X^2_4=393.95$, $p<0.001$) (Figure 29).

Variation in swift parrot abundance was most pronounced during the 2002 drought (Figure 29a). In this year, the mean swift parrot abundance was 21.7 times greater in the central coast region and 7.5 times greater in the north coast region when compared to other years (Figure 29b). An indication of the large proportion of the population using these foraging habitats in 2002 is provided by an incidental observation of mass roosting by 650 swift parrots (one third of the estimated population) near foraging sites on the central coast (Saunders *personal observation*). Further evidence of this influx of birds is provided by volunteer data that was collected concurrently throughout the species range which detected a large influx of swift parrots into coastal habitats of NSW and a correspondingly large decrease in Victoria (see Chapter 5). The south western slopes supported swift parrots during both drought and non-drought years (Figure 29b).

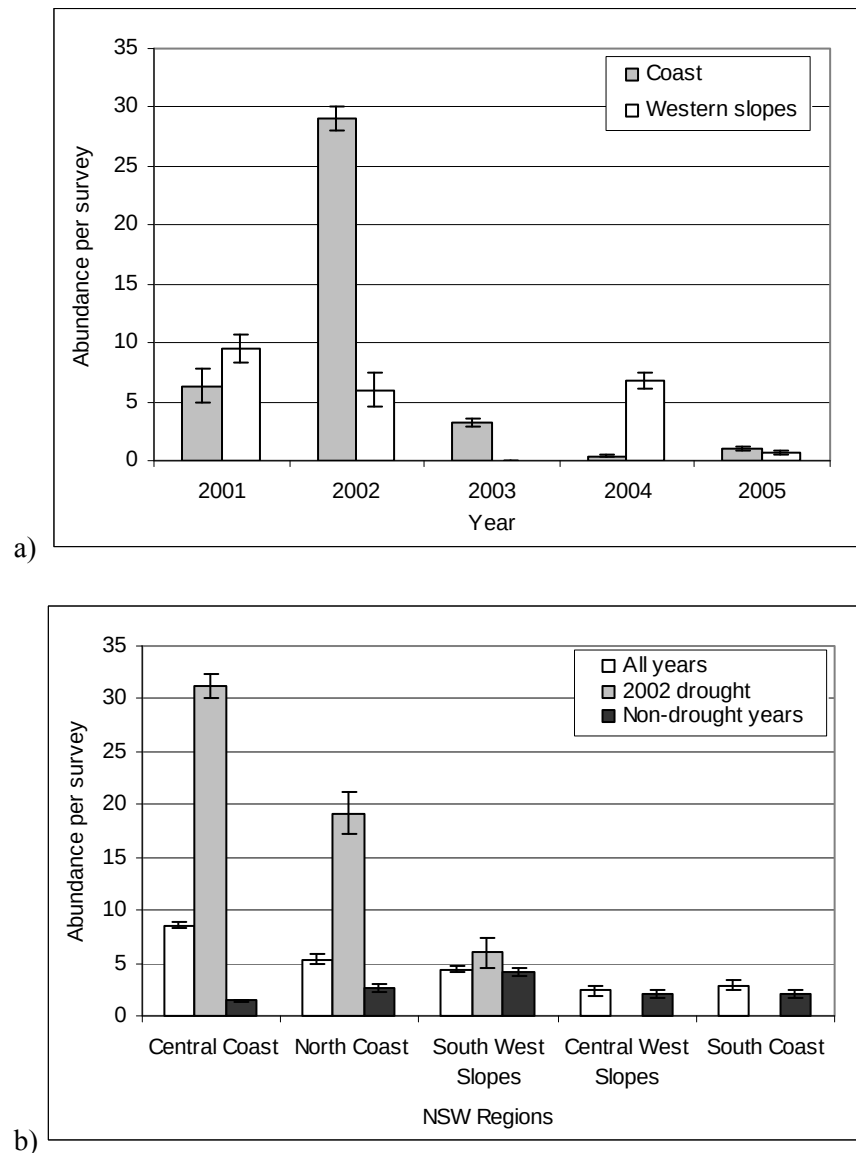


Figure 29 – Predicted temporal (a, b) and spatial (b) variation ($\pm$ s.e.) in mean swift parrot abundance (per survey) within five regions of New South Wales 2001-2005.

Site fidelity

During the five year study period, swift parrots were recorded using 21% of the study sites repeatedly between years (not necessarily consecutive), despite sites being surveyed only once each year and the potential to miss birds. However, when swift parrot records prior to this study were included (1968-present), there was evidence of long-term repeated use with 53% of sites (37% coastal, 83% western slopes) used in multiple years (Figure 30).

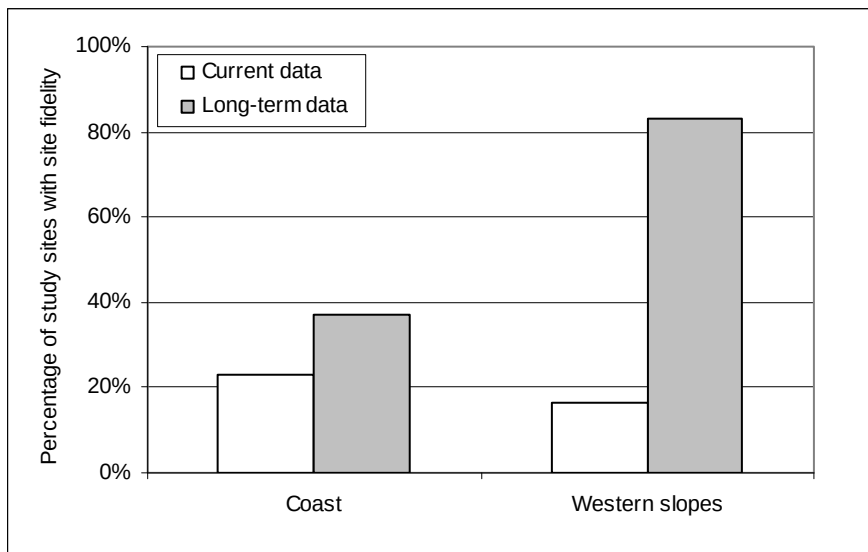


Figure 30 – Percentage of study sites repeatedly used by swift parrots in coastal and western slopes habitats of NSW based on both current (this study) and long-term (NSW Wildlife Atlas and swift parrot recovery program database) records.

Landscape and habitat types

Swift parrot foraging sites were located within scattered tree, remnant vegetation and continuous forest landscapes. In coastal habitats, the majority of sites were in scattered trees (69% versus 17% in remnant vegetation and 14% in continuous forests). However, mean abundance was significantly greater in remnant vegetation ($X^2_2=142.22$, $p<0.001$) than in the other landscape types (Figure 31). Within western slopes habitats, the majority of sites were in remnant vegetation (89%) with all remaining sites in scattered trees. Mean swift parrot abundance did not differ significantly between the remnant vegetation and scattered tree landscapes for western slopes habitats ($X^2_2=0.48$, $p=0.49$).

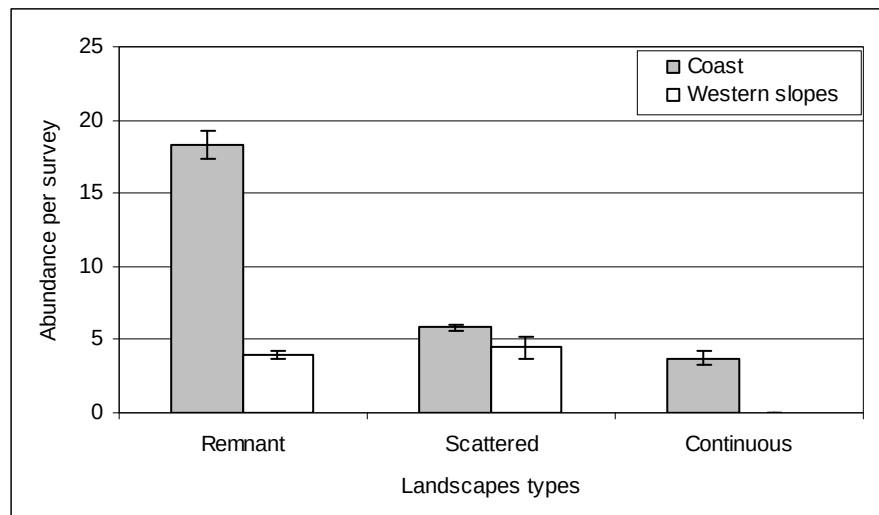


Figure 31 – Predicted swift parrot abundance ($\pm$ s.e.) (per survey) within different landscape types in coastal and western slopes areas of NSW.

Swift parrots were observed foraging on lerp and nectar 11,306 times over the five 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 forage tree species (seven coastal, four western slopes), consuming lerp from all, and nectar from eight of these (Table 1). Seven of these tree species have been so extensively cleared they now occur within endangered ecological communities, 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 34% of all western slopes foraging observations (Table 1).

Table 1 – Forage tree species, regions, landscape types, food types and number of forages by swift parrots in wintering habitats of NSW.* = occurs within an endangered ecological community (NSW Scientific Committee 1997, 1998, 2000, 2002a,b,c, 2004a,b, 2005, 2006).

Forage tree species	NSW regions	Landscape types	Number of forages		
Coastal			Lerp	Nectar	Total
*Forest Red Gum (<i>Eucalyptus tereticornis</i>)	central, north coasts	scattered, remnant	841	3040	3881
*Swamp Mahogany (<i>Eucalyptus robusta</i>)	central, north coasts	scattered, remnant	1441	738	2179
Blackbutt (<i>Eucalyptus pilularis</i>)	central, north coasts	scattered, remnant, continuous	831	278	1109
*Spotted Gum (<i>Corymbia maculata</i>)	south, central, north coasts	scattered, remnant, continuous	175	234	409
*Coastal Grey Box (<i>Eucalyptus mollucana</i>)	central, north coasts	scattered, remnant	111	12	123
Red Bloodwood (<i>Corymbia gummifera</i>)	north coast	scattered	130	0	130
Rough-barked Angophora (<i>Angophora subvelutina</i>)	north coast	remnant	116	0	116
Total coastal forages			3645	4302	7947
Western slopes					
Mugga Ironbark (<i>Eucalyptus sideroxylon</i>)	south, central western slopes	remnant	847	619	1466
*White Box (<i>Eucalyptus albens</i>)	south, central western slopes	scattered, remnant	301	845	1146
*Grey Box (<i>Eucalyptus microcarpa</i>)	south western slopes	remnant	503	8	511
*Yellow Box (<i>Eucalyptus melliodora</i>)	south, central western slopes	remnant	236	0	236
Total western forages			1887	1472	3359
Total forages			5532	5774	11306

Site use associations

Variables significantly affecting the occurrence of swift parrots at known foraging sites included the abundance of trees with flowers and/or lerp and non-aggressive competitors (Table 2). They were more likely to occur at both coastal and western slopes sites as flower abundance increased (Figure 32a). However, in coastal areas, the positive influence of flowering trees was only significant when it interacted with the number of trees with lerp and non-aggressive competitors (Table 2). Similarly, the number of lerp trees had a significant positive influence on swift parrot occurrence in coastal habitats (Figure 32b). Within both coastal and western slopes habitats, swift parrots were significantly more likely to occur as the number of non-aggressive competitor species increased (Figure 32c).

There were no significant interactions affecting swift parrot occurrence on the western slopes. All other variables failed to improve the models significantly (coast $0.06 \leq X^2_1 \leq 2.75$, $0.097 \leq p \leq 0.808$, western slopes $0.05 \leq X^2_1 \leq 2.78$, $0.096 \leq p \leq 0.824$).

Table 2 – Significant terms and interactions associated with swift parrot occurrence in known coastal and western slopes foraging habitats. “Effect” indicates an overall increase (↑) or decrease (↓) in the likelihood of swift parrot occurrence.

Coastal model	d.f.	X ²	p	effect
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	d.f.	X ²	p	effect
Flowering trees	1	6.94	0.008	↑
Non-aggressors	1	14.64	<0.001	↑

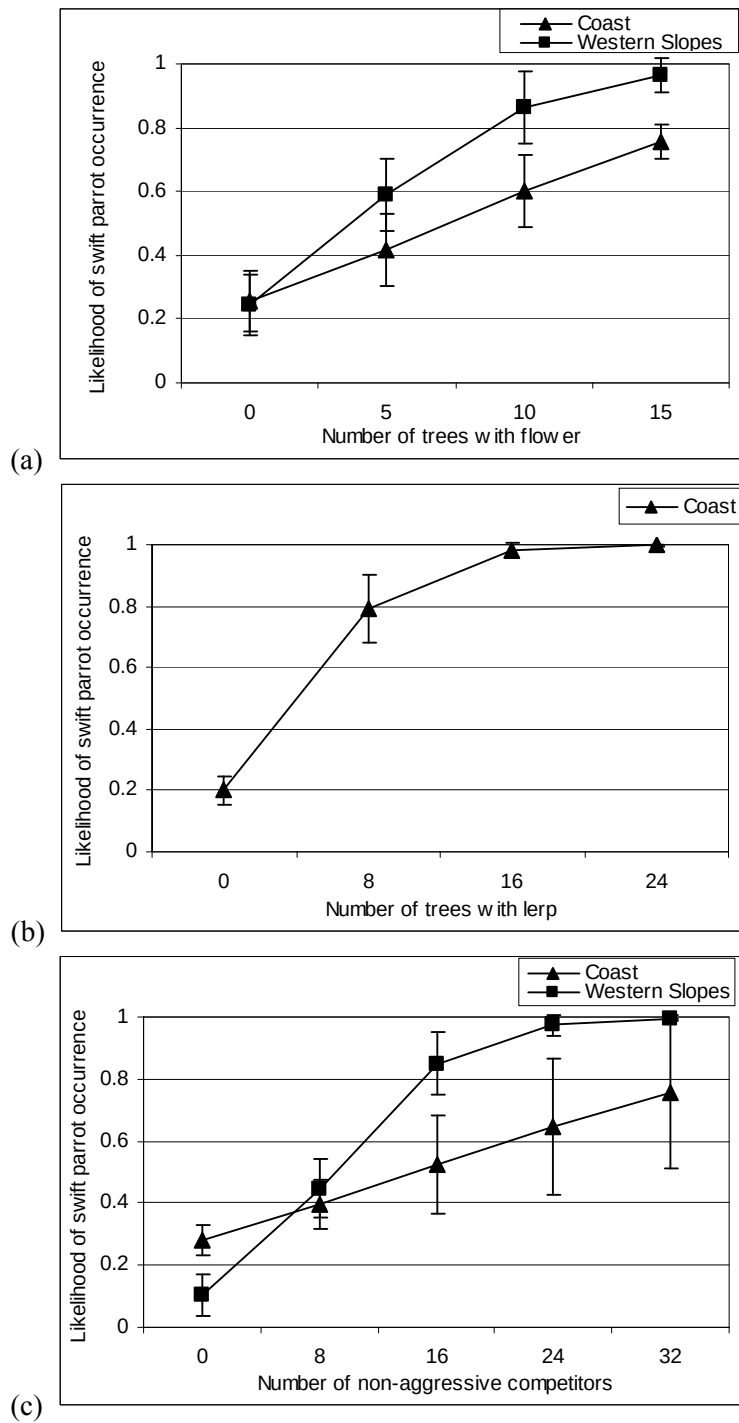


Figure 32 - Predicted likelihood of swift parrot occurrence ($\pm$ s.e.) in relation to the number of trees with (a) flowers and (b) lerp and (c) the abundance of non-aggressive competitor species in coastal and western slopes habitats of NSW. Note: (b) does not include western slopes data because trees with lerp did not significantly contribute to the model.

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 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 ($0 \leq X^2_1 2.94, 0.086 \leq p \leq 0.971$).

Table 3 – Aggressive and non-aggressive competitor bird species recorded at swift parrot foraging sites.

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

The Little Lorikeet 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 also had a significant positive association with swift parrots. Similarly, the Red Wattlebird, Dusky Woodswallow and Fuscous Honeyeater 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 in coastal habitats and the Noisy Miner within western slopes habitats (Table 4).

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.

Bird common names	d.f.	X ²	p	Effect
Coastal				
Little Lorikeet	1	15.1	<0.001	↑
Noisy Friarbird	1	15.0	<0.001	↑
Rainbow Lorikeet	1	16.4	<0.001	↓
Western slopes				
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	↓

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 five year study led to sufficient encounter rates (2149 swift parrots at 53 sites) to enable analysis of the factors determining their use of known 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 habitat use

The abundance of swift parrots at our NSW study sites fluctuated markedly between years and regions. This is consistent with previous studies in central Victoria (Mac Nally and Horrocks 2000; Kennedy and Tzaros 2005), indicating that variable patterns of habitat use occur throughout the wintering range of this species. Such variable patterns in habitat use 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 habitat use in this study occurred on the central and north 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 multiple years. Such site fidelity was evident within all coastal and western slopes regions over the five year study 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), however this may have been due to the small spatial (single region) and temporal (two 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 land bird species within wintering and migration habitats around the world, and is thought to reduce the energy expenditure required for locating and consuming sufficient food for the wintering period, return migration and subsequent breeding (Purchase 1985; Terrill 1990b; Ganusevich *et al.* 2004; Markovets and Yosef 2005). The 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 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 the majority of 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, however 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 due to the agricultural land use that dominates the area. This emphasises the importance of protecting and enhancing the remaining fragmented vegetation in these regions for the swift parrot, as well as a diversity of other species (Reid 1999; Gibbons and Boak 2002; Manning et al. 2006a; Manning et al. 2006b).

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 documented two further tree species of potential importance, Coastal Grey Box and Rough-barked Angophora, 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 known forage tree species (Forest Red Gum, Blackbutt, White Box and Yellow Box). 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 both lerp and nectar in both the north and central coast 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 a number of 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.

Foraging site use

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 austral migration system of Australia. 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 food sources for 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 both these food sources. Previous studies primarily focused 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; Ford and Paton 1985; Pyke 1985; McFarland 1986b; McFarland 1986a; Ford 1991; Timewell and Mac Nally 2004) have had mixed success. This is possibly because honeyeaters also consume alternative carbohydrate resources such as lerp, manna or honeydew (Clark 1964; Paton 1980; Woinarski 1984; Paton 1985; Pyke 1985; Woinarski et al. 1989) or because birds may be more dispersed when there are widespread sources of nectar available (Ford and Paton 1985). In this study, lerp and nectar comprised similar proportions of the foraging observations, emphasising the importance of both food types, although it is not clear why lerp had a greater influence in coastal habitats.

The diversity of bird species, and more specifically competitor bird 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 eighteen competitors we recorded (regularly enough for inclusion in the analyses) only seven were associated with swift parrots. Five of these were positively, and two negatively, associated with swift parrots. 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 of these species are known to impact negatively 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; Grey et al. 1998; French et al. 2003; Shukuroglou and McCarthy 2006).

In summary, this study provides valuable insights into the spatial and temporal variability in winter foraging habitat use 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. multiple states) would provide a more complete understanding of the ecological requirements of the population (see chapter five). 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 (Wilkelski et al. 2006). This study also focused on readily accessible public land, however additional habitat on private land should be included for a more complete picture of habitat use. Given that lerp were consumed 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 inter-specific associations with Swift parrots, suggesting that further behavioural research in this regard may yield valuable information about these associations

Chapter 5 - Austral migration and dynamic winter habitat use in endangered swift parrots

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Swift parrots in flight
by Nevil Lazarus (2002)

It is a migratory species, passing the summer and breeding-season only in the more southern parts of the Australian continent and Van Diemen's Land, and retiring northward for the remainder of the year (Gould 1848).

Abstract

Migratory birds spend a large proportion of their lives within their wintering habitats. However, the spatial and temporal dynamics of winter habitat use for most species are poorly understood. In this study we document patterns of winter habitat use in an endangered austral migrant, the swift parrot (*Lathamus discolor*, Psittacidae), a species that migrates north from its breeding range in Tasmania each year to winter habitats throughout south-eastern mainland Australia. Data on habitat use across a broad geographic range were collected by up to 300 volunteers in both autumn and winter for seven years (1998-2004). Despite the small population size (2500 birds), broad winter distribution (1 250 000 km²) and often cryptic nature of swift parrots, they were detected in 19% of 4140 surveys and were observed to use the same locations repeatedly. Four regions in central Victoria were used most consistently, although the birds also visited other regions each year. During drought, swift parrot abundance and distribution was significantly correlated with rainfall, whereby most of the population either concentrated in a few regions or migrated longer distances (up to 1000km) to drought refuges in wetter coastal areas. However, swift parrot abundance was not associated with specific climate variables during years of average to high rainfall throughout most of their range. Instead they appeared to prefer particular regions. This study provides the first demonstration of large-scale drought related movements by a migratory population throughout their winter range. It also demonstrates the dynamic spatial and temporal patterns of winter habitat use, including repeated use of sites, by an austral migrant. Importantly it emphasises that conservation measures need to be implemented throughout the distribution of migratory species, including drought refuge habitats and areas outside conservation reserves.

Introduction

Migratory birds depend on encountering suitable conditions in ecologically disparate locations throughout their migratory cycle (Newton 2004). Events in one phase of their annual cycle, such as on the wintering grounds, may affect subsequent cycle phases, such as migration capabilities or population dynamics on the breeding grounds and vice versa (Webster and Marra 2004). The inextricable links between different phases, termed migratory connectivity, influence the ecology and evolution of migratory species and have important implications for their conservation (Webster *et al.* 2002).

Knowledge of migratory systems is predominantly based on extensive research within the Palaearctic-African and Nearctic-Neotropic migratory systems (Dorst 1962; Moreau 1972; Keast and Morton 1980; Biebach *et al.* 1991; Biebach 1995; Martin and Finch 1995; Greenberg and Marra 2004; Rubenstein and Hobson 2004). Within these systems, migrants breed in the northern hemisphere and migrate south for the boreal winter. During the wintering period, some migratory species have been found to return to the same location each year, whereas other species appear to undertake facultative migration to two or more sites both within and between years due to the spatial and temporal occurrence of food supplies (Gauthreaux 1982; Terrill and Ohmart 1984; Terrill 1990a; Newton 2004). Despite recognition of these variable wintering strategies, there is still only limited information on the spatio-temporal dynamics of winter habitat use by terrestrial migratory bird species (Berthold *et al.* 2004; Meyburg *et al.* 2004b; Paxton *et al.* 2007).

There is a particular paucity of information on migrants within austral migration systems, where birds breed, migrate and winter entirely within the southern hemisphere (Chan 2001; Griffioen and Clarke 2002; Chesser 2004). Most information on austral migrants in Africa (Underhill *et al.* 1992; Berruti *et al.* 1994) and Australia (Chan 2001; Griffioen and Clarke 2002; Dingle 2004; Beaumont *et al.* 2006) has been obtained through the use of large scale bird atlas and volunteer survey projects. Such projects provide a valuable resource, with data collected at a number of spatial and temporal scales not otherwise available for highly mobile and migratory species (Underhill *et al.* 1991; Weston *et al.* 2003). However, this has not been the case in South America where basic distribution information is still lacking for many migratory species (Jahn *et al.* 2004). Bird banding projects have also contributed important information on austral migrants in Africa (Underhill *et al.* 1991; Harrison 1995), and to a lesser extent in South America (McNeil 1982), however similar projects in Australia have had relatively little success with low recapture rates of most migratory birds (Purchase 1985; Garnett *et al.* 1991; Griffioen and Clarke 2002).

Although the Australian continent experiences temperatures that are less extreme than those in the northern hemisphere, it experiences highly variable annual climatic conditions, including major periods of drought, due to the El Nino Southern Oscillation (ENSO) (Bureau of Meteorology 2007a). Such climatic variability influences the spatial and temporal distribution of food sources (Nix 1976) and may explain why a large number of Australian birds exhibit some form of migratory behaviour (Chan 2001; Griffioen and Clarke 2002; Dingle 2004). Studies of terrestrial migrants in Australia initially focused on the movements of honeyeaters (Hindwood 1948; Watson 1955; Hindwood 1956; Hindwood and Sharland 1964; Keast 1968). Since then, studies have diversified to include movement patterns and migration systems of a variety of species (Chan and Sutton 1993; Chan 2001; Griffioen and Clarke 2002; Roshier and Reid 2003; Dingle 2004), migrant breeding biology and ecology (Legge and Heinsohn 2001; Clarke *et al.* 2003; Boland 2004; Brereton *et al.* 2004; Manning *et al.* 2006b) and migration dates (Farmer *et al.* 2004; Beaumont *et al.* 2006). However, studies on winter ecology, habitat use and conservation management have been limited to three species of parrot, all of which are threatened. This includes the swift parrot *Lathamus discolor* (Mac Nally and Horrocks 2000; Kennedy and Overs 2001; Kennedy and Tzaros 2005) and orange-bellied parrot *Neophema chrysogaster*, which are both obligate migrants (Loyn *et al.* 1986; Drechsler *et al.* 1998), as well as the partial migrant/nomadic superb parrot *Polytelis swainsonii* (Manning *et al.* 2006b; Manning *et al.* 2007). Parrot migration is a rare phenomenon around the world (Juniper and Parr 1998), with only a small number of migratory parrot species in Australia (e.g. above species and the blue-winged parrot *Neophema pulchella*) (Juniper and Parr 1998; Barrett *et al.* 2003), the Americas (e.g. mealy parrot *Amazona farinose* and burrowing parrot *Cyanoliseus patagonus*) (Bjork 2004; Masello *et al.* 2006), Africa (e.g. brown-necked parrot *Poicephalus robustus*) (Symes and Perrin 2003) and possibly Asia (e.g. Lord Derby's parakeet *Psittacula derbiana* and long-tailed parakeet *Psittacula longicauda*) (Juniper and Parr 1998). However, fundamental knowledge about most terrestrial migratory species, including migratory parrots, is still lacking, making conservation at relevant spatial and temporal scales challenging (as discussed in chapter three).

The need for basic knowledge is most pressing for migratory species that have already suffered from substantial anthropogenic impacts and have had their populations reduced to such an extent that they are now threatened with extinction. One such species is the swift parrot, an endangered austral migrant that breeds in Tasmania and migrates north across Bass Strait to winter over a vast area of south-eastern Australia (Figure 33). Their total population is small (<2500 birds) and individuals migrate up to 2500 km north of their

breeding grounds. Swift parrots usually arrive in their breeding grounds in August/September (Brown 1989; Beaumont *et al.* 2006) where they nest in hollows of old growth trees and remain until their chicks have fledged in November/December (Brown 1989). Post-breeding dispersal then occurs across Tasmania prior to northward migration to winter habitats in March/April (Brown 1989; Swift Parrot Recovery Team 2001). Swift parrots forage on nectar and lerp in the canopy of temperate forests and woodlands (Swift Parrot Recovery Team 2001). Their use of winter foraging habitats is influenced by the maturity of suitable habitats (Kennedy and Overs 2001; Kennedy and Tzaros 2005), food availability and competition with other species (see chapter four). Although swift parrots migrate annually, their patterns of habitat use, migration pathways and specific first arrival and last departure dates within their winter range have not previously been examined. The complexity of habitat use and variable movements by this species is highlighted by a previous attempt to examine overall movement patterns of this species, which proved unsuccessful (Griffioen and Clarke 2002).

This study is the first to demonstrate large-scale drought related movements by a migratory population throughout their winter range. It also demonstrates variable spatial and temporal patterns in habitat use, and repeated use of sites by austral migrants throughout their wintering range. We demonstrate dynamic winter habitat use by swift parrots using extensive, site specific volunteer survey data, and relate the occurrence of swift parrots to highly variable rainfall patterns. Our study provides novel insights into the austral migration system and highlights the need for conservation measures to be implemented at relevant spatial and temporal scales for both the swift parrot and other austral migrants.

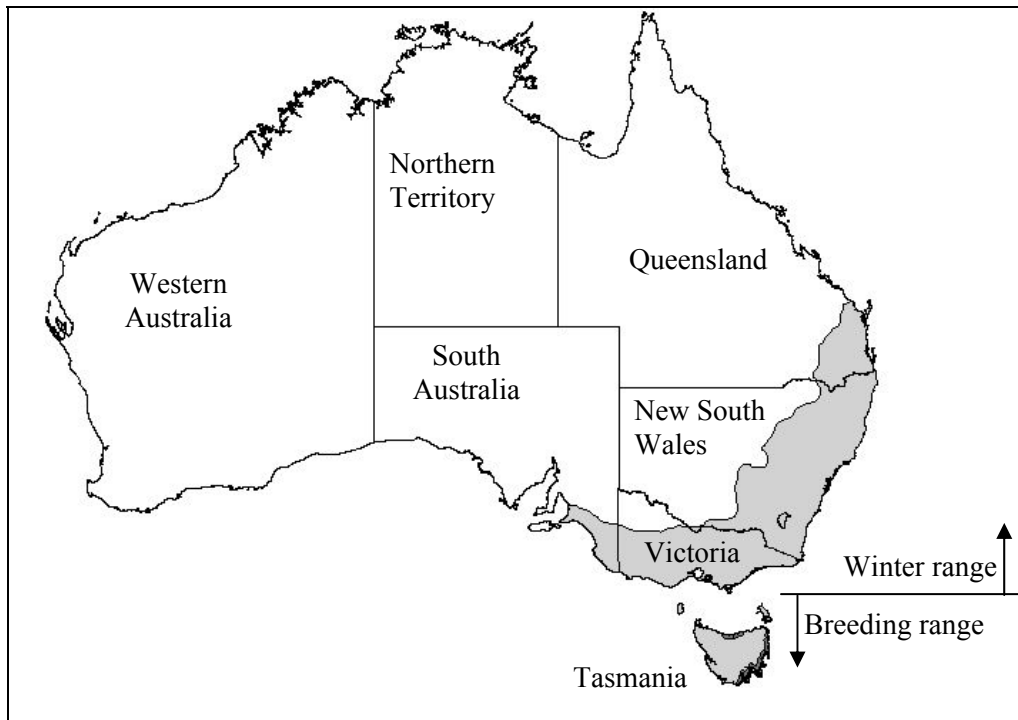


Figure 33 – Distribution of the swift parrot in south eastern Australia

Methods

The study area included temperate woodland and forest habitats across the winter range of the swift parrot, including five Australian states and territories (Victoria, New South Wales, Australian Capital Territory, Queensland, South Australia) between 25°1'S 152°14'E and 37°6'S 145°24'E (Figure 33). Winter habitats occurred across a diversity of landscapes ranging from remnant vegetation within agricultural, urban and industrial areas, to more extensive forested areas managed for conservation or for timber harvesting. Habitat types included box ironbark and grassy woodlands in inland areas and a variety of forests in coastal areas. Important feed tree species within inland habitats include Red Ironbark *Eucalyptus tricarpa*, Yellow Gum *Eucalyptus leucoxylon*, Grey Box *Eucalyptus microcarpa*, and White Box *Eucalyptus albens*, and within coastal habitats Swamp Mahogany *Eucalyptus robusta*, Forest Red Gum *Eucalyptus tereticornis* and Spotted Gum *Corymbia maculata* (Mac Nally and Horrocks 2000; Kennedy and Overs 2001; Swift Parrot Recovery Team 2001; Kennedy and Tzaros 2005) (see also chapter four).

Volunteer survey data

From 1998 to 2004, up to 300 volunteers surveyed a diversity of regions, locations, sites and potential habitats throughout the swift parrots' winter range during defined national survey periods. The surveys were for one week either side of a nominated weekend in

autumn (third weekend in May) and winter (first weekend in August) each year.

Volunteers were coordinated to survey sites within one or more regions and locations during each survey period to maximize survey coverage throughout the species' winter range. Regions were predominantly based on broad geographical areas with similar habitat types in each state. The only exception to this was for central Victoria where large concentrations of swift parrots regularly occurred. Thus four smaller regions were defined to enable trends within this area to be examined. The use of more standardized regions, such as Interim Biogeographic Regionalisation of Australia (IBRA) and Catchment Management regions, was not possible due to the large number of regions involved (18 and 27 respectively) and the small number of swift parrot records in each sub-region. The use of such regions which would mask the variability within Victorian habitats (ie be a single region instead of four) and would have too few records within NSW for analytic purposes. Within each region, a number of locations were defined as recognizable areas such as state forests, national parks or private properties. Similarly, within each location there were one or more sites, which were defined as specific areas where surveys were conducted and coordinates were provided. The surveys provided landscape-scale snapshots of swift parrot occurrence, abundance and habitat use at a large number of sites throughout their wintering range each year. All observations of birds simply flying overhead were excluded.

Surveys were conducted using the national recovery program survey form (<http://www.birdsaustralia.com.au/birds/swift.html>) and were undertaken regardless of the presence/absence of the target species. The forms included details on the locations and sites surveyed as well as site coordinates and the occurrence and abundance of the target species. To minimise false positive errors from misidentification, reported sightings of swift parrots were confirmed by the survey coordinator by discussing details with the observers and/or getting more experienced observers to visit the site and confirm their presence. However, we were unable to account for false negative errors whereby the species was not detected despite being present. Such errors may occur for a variety of reasons, from cryptic behaviour of the target species to the inherent variability in experience of individual observers. Further potential limitations of this data include limited access to some potential survey areas, adverse weather conditions during the survey periods and survey effort being focused in areas surrounding human habitation. The extent to which repeated surveys were conducted at sites between seasons and years also varied. In addition, the data were based on two seasonal snapshots (autumn and winter) within the 'wintering' period each year. Therefore examination of variable arrival and departure dates

was not possible and some regions may have been used more often, or by larger flocks of swift parrots, outside of these survey periods.

Climate data

Monthly rainfall and maximum temperature data for each site were extracted from spatially interpolated (modelled) climate surfaces developed in the ANUCLIM software package (McMahon *et al.* 1995; Australian Greenhouse Office 2002). All site coordinates and extracted climate data had a spatial resolution of approximately one kilometer (Australian Greenhouse Office 2002; Australian Greenhouse Office 2005). Regional rainfall conditions were classified into four categories in relation to the mean monthly rainfall (derived from 16 years of climate data from 1990-2005). These categories included wet (greater than 120% of mean rainfall), average (80-120% of mean rainfall), dry (60-79% of mean rainfall) and drought (less than 60% of mean rainfall) conditions. Mean climate data for each site were calculated for a number of different time periods (1, 3, 6 and 12 months) prior to each survey for exploratory purposes given the variability and uncertainty associated with eucalypt, and hence food, phenology (Pook *et al.* 1997; Law *et al.* 2000; Keatley *et al.* 2002).

Analyses

All statistical analyses were conducted using Genstat statistical software (Genstat Committee 2007). Generalized linear mixed models (GLMM) were used to examine both the variation in swift parrot habitat use throughout their winter range, and correlations between habitat use and climate variables. First, large-scale trends in swift parrot occurrence (i.e. presence or absence, modeled using a binomial distribution and logit link function) and abundance (poisson distribution and logarithmic link function) were examined throughout the species' winter range (herein referred to as the "habitat use models"). The initial models included the explanatory variables "season" (autumn and winter), "year" (1998-2004) and "region" (refer to Table 5), as well as their interactions. Two additional terms "site" and "location" were included in the models as random terms to avoid pseudo-replication from repeated surveys in the same place. Best linear unbiased predictions (BLUPs) of occurrence and abundance were then derived for each site in each year. These predictions were then mapped and smoothed using kernel density estimation in ARCVIEW (ESRI 2005) to illustrate significant trends.

Second, the dependence of swift parrot abundance (poisson distribution and logarithmic link function) on climate variables was examined throughout the species winter range (herein referred to as the "climate models"). Models were developed for all years

combined as well as for each year to enable examination of overall as well as inter-annual effects. Terms in the climate models included “year”, “region”, rainfall (“rain”) and maximum temperature (“maxtemp”). Interactions were not included in the climate models due to potential over-parameterisation caused by including too many variables. Climate models were developed for each of the four time periods (1, 3, 6 and 12 months) prior to surveys to determine which period most clearly explained the observed trends (overall and inter-annual) in swift parrot habitat use. Significant trends are illustrated for the time period that most clearly explained the observed trends in swift parrot habitat use.

In all habitat use and climate models, terms that did not significantly contribute to the models were dropped. Model terms were also added in varying order to confirm consistency of effects. Due to the unequal survey effort and detection rates across regions, those that had less than 20 surveys over the study period, or less than a 5% detection rate, were excluded from the analyses, however all regions are listed in Table 5 to provide an indication of survey coverage. Within each of the eight regions included in the analyses, variable numbers of surveys were conducted at both new and existing sites each year depending on volunteer availability.

Table 5 – Number of regional surveys within the wintering range of the swift parrot 1998–2004, including the number of surveys with swift parrots present, the number of years when swift parrots occurred and the number of years when large concentrations of swift parrots were recorded. *= insufficient data for inclusion in analyses.

States/regions	Number of surveys (with swift parrots present)	Swift parrot occurrence (# years)	Large swift parrot concentrations (# years)
Victoria			
Maryborough (MA)	461 (251)	7	5
Rushworth (RU)	370 (127)	6	4
St Arnaud (ST)	194 (85)	6	3
Bendigo (BE)	309 (65)	5	3
North east (NE)	214 (58)	6	1
Southern (SO)	204 (23)	3	0
Western (WV)*	14 (3)	2	0
Northern (NV)*	5 (1)	1	0
Eastern (EV)*	17 (0)	0	0
New South Wales/Australian Capital Territory			
Coast (CO)	1254 (106)	6	1
Western slopes (WS)	748 (55)	7	0
Tablelands (TA)*	95 (3)	2	0
Queensland/South Australia			
South east Queensland (SQ)*	253 (7)	4	0
Eastern South Australia (SA)*	2 (2)	1	0
Total	4140 (786)		

Results

Swift parrots were detected in 19% of the 4140 surveys (at 3308 sites) carried out over 14 regions and seven years. However, analyses were limited to eight regions with sufficient data (3754 surveys, 2991 sites) (Table 5). Within these regions, swift parrots were detected in 20% of surveys (mean proportion 0.20 ± 0.007 s.e.) and abundance during individual surveys varied from 0 to 220 birds (mean 3.41 ± 0.21 s.e.). The regional mean monthly rainfall varied from 35.90 to 108.97mm with maximum temperatures varying from 9.2 to 23.5 °C. Most of the regions that could not be included in the analyses (northern and western Victoria, tablelands of NSW, south east Queensland and eastern South Australia) were used by small numbers of swift parrots in at least one year during the study period (Table 5).

Variable winter habitat use

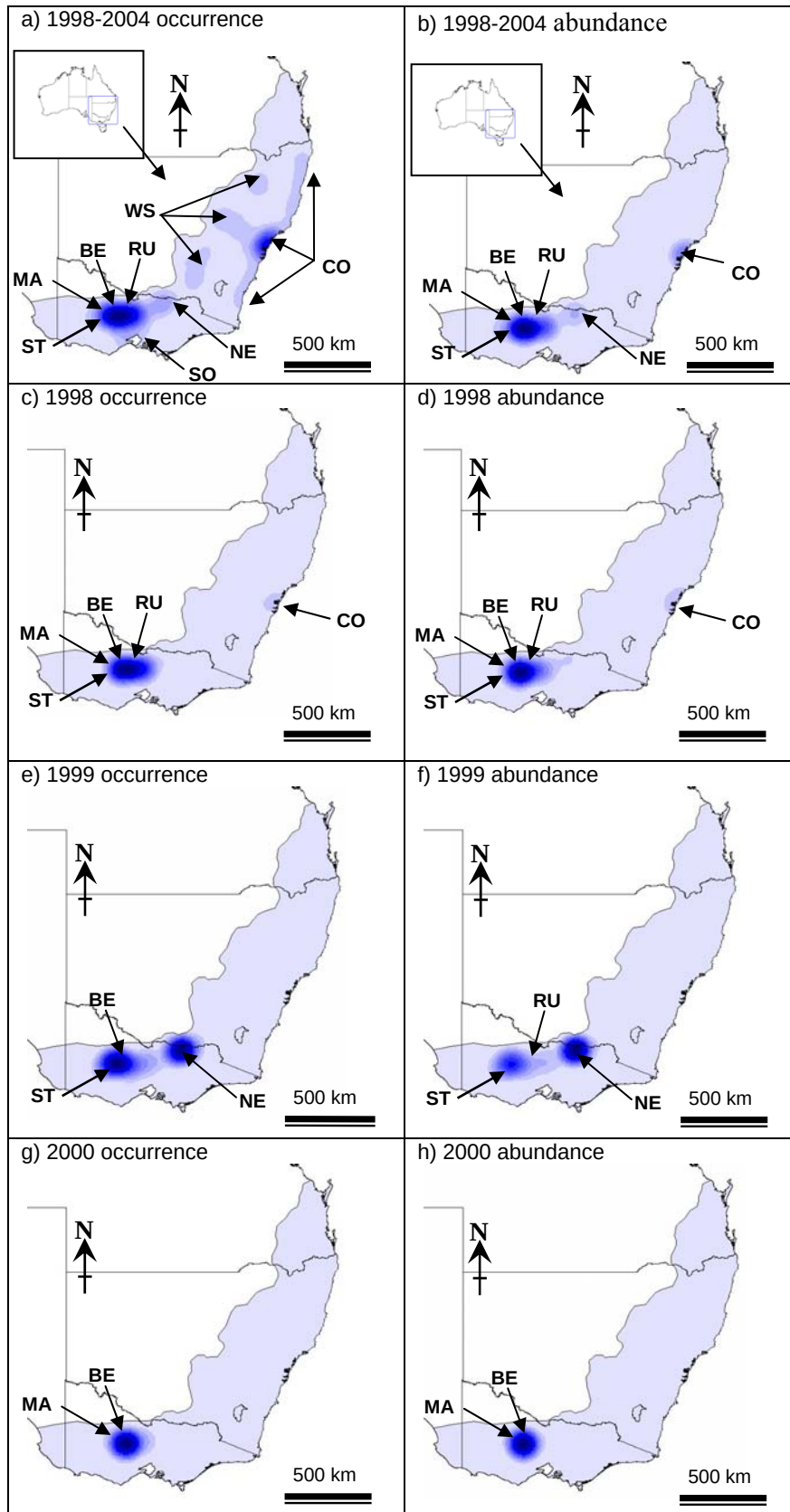
Swift parrots occurred regularly within both Victoria and NSW regions. However, the likelihood of occurrence (ranging from 0 to 0.78) and abundance (ranging from 0 to 9.7 birds) per survey varied significantly between years and regions, and for the interaction between year and region (Table 6). Similar numbers of swift parrots repeatedly used the same locations over the study period, as indicated by a high within-term correlation for the random term “location” in the abundance model ($r = 0.86$).

Table 6 – Habitat use models: terms and interactions for swift parrot occurrence and abundance in relation to regions and years (1998-2004).

Occurrence	Wald statistic	d.f.	P
year	79.04	6	<0.001
region	169.71	7	<0.001
year.region	366.24	42	<0.001
Abundance			
year	53.27	6	<0.001
region	128.07	7	<0.001
year.region	355.49	42	<0.001

The four central Victorian regions (Maryborough, Rushworth, St Arnaud and Bendigo) supported large flocks of swift parrots most consistently, although annual expansions and contractions between these regions also occurred (Figure 34). Large flocks were also recorded in the north-east region of Victoria during 1999 (Figure 34e,f), and to a lesser extent in 2001 (Figure 34i,j). In general, the regions with the greatest likelihood of swift parrot occurrence also supported the greatest abundance (Figure 34). Exceptions to this were noted for 1999 and 2002. For example, in 1999 (Figure 34e,f) although swift parrots were more likely to occur in the Bendigo region than in the Rushworth region of Victoria, larger flocks were recorded in the latter region.

The most notable large-scale variation in habitat use by the swift parrot occurred in 2002 when most of the swift parrot population migrated over 1000 km further north-east than in other years (Figure 34k,l). This large influx of swift parrots into coastal habitats of NSW corresponded with a large decrease in the Victorian regions (Figure 34, Figure 36e).



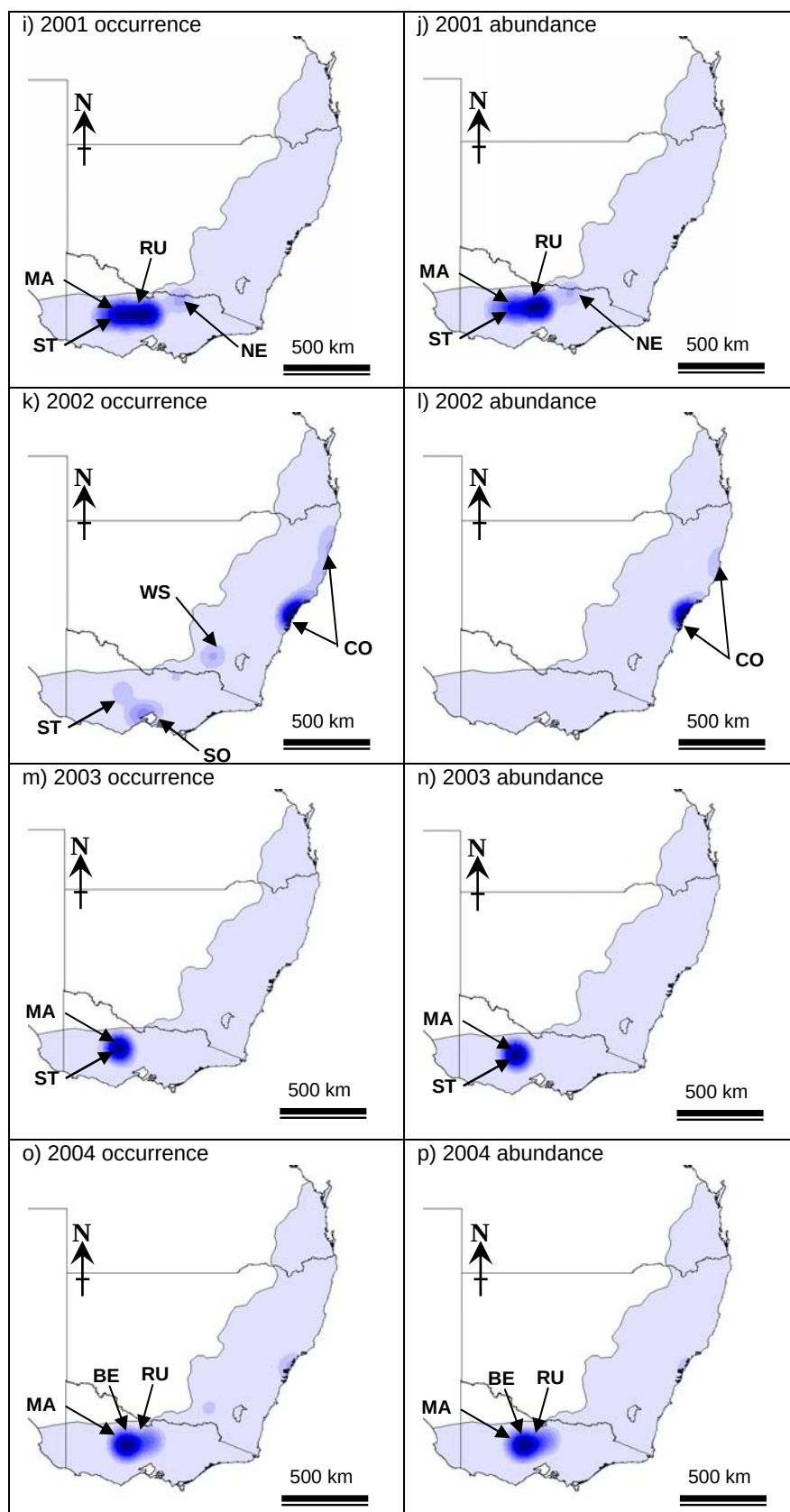


Figure 34 - Spatial and temporal variability of swift parrot occurrence and abundance.

Regions where swift parrots were most likely to occur and where their abundance was greatest are indicated for each year as well as for the overall study period. Shading represents the predicted likelihood of swift parrot occurrence (ranging from 0 to 0.78; maps on left) and abundance (ranging from 0 to 9.7 birds; maps on right) per survey on a continuous scale ranging from low (light shading) to high (dark shading) occurrence/abundance. Scales are approximate. Due to the potential for false negative data, predicted occurrence and abundance values of zero were included as low occurrence/abundance. See Table 5 for a list of regions.

Seasonal habitat use

Overall there were no significant seasonal effects in either of the habitat use models (occurrence $p=0.088$, abundance $p=0.932$). Examples of minor seasonal variation in swift parrot occurrence and abundance are shown in Figure 35.

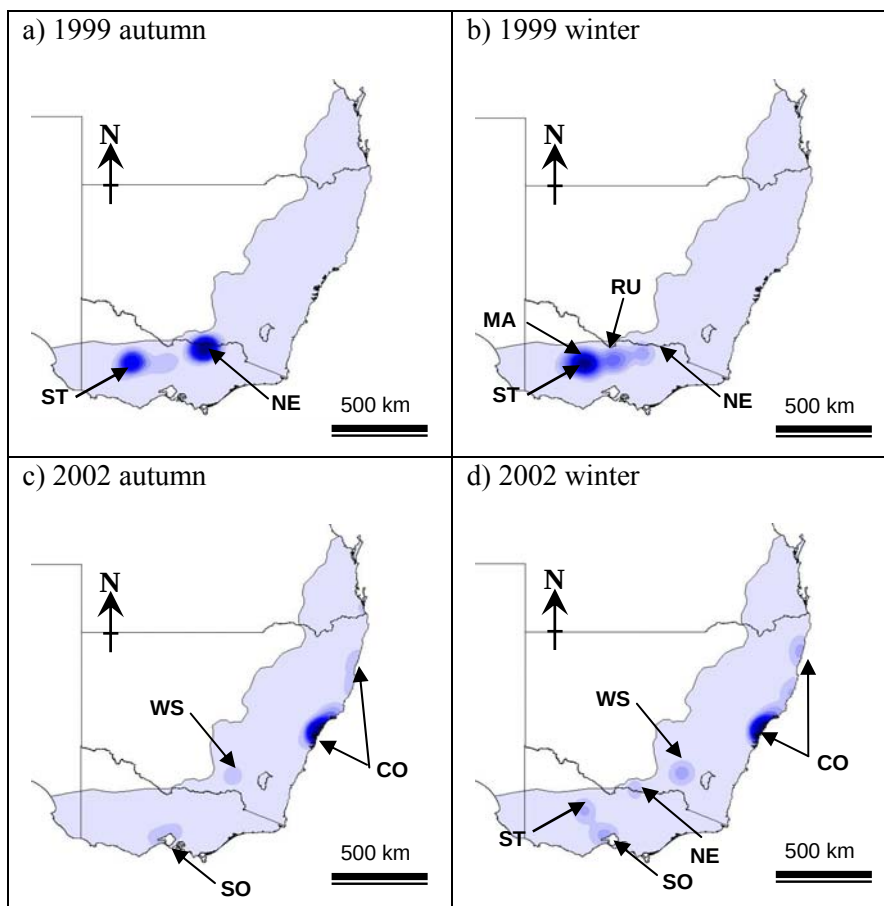


Figure 35 – Seasonal (autumn/winter) variation in winter habitat use by swift parrots in 1999 and 2002. The shading follows that of Figure 34.

Climate and habitat use

The climate models using the month prior to surveys (Figure 36) provided the clearest ecological explanation of observed trends in variable habitat use. These results are discussed in further detail below. The effect of some terms varied when the different time periods (1, 3, 6 and 12 months) were used in the climate models, although overall trends were consistent. For example, in each of the four models for 2002 (when the largest shift in habitat use occurred, Figure 34), the term “region” did not significantly affect swift parrot abundance (Table 7), whereas it did in every other year (Table 8). Rainfall was significant in both the 1 and 3 month models and temperature was significant in both the 3 and 6 month models. However in the 12 month model none of the terms were significant (Table 7). Similar variability in significance of the rainfall and maximum temperature terms also occurred in the remaining years for each of the models.

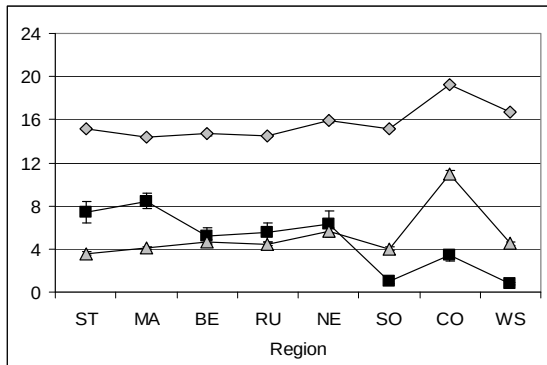
Initially all years were combined in a climate model to examine the overall effects on swift parrot abundance, however due to the dominant effect of inter-annual variability (Table 8), trends in habitat use were sometimes obscured (Figure 36). Therefore, models were also developed separately for each year (Table 8).

Although dry to drought conditions were prevalent throughout Victorian regions in 2001, 2002 and 2004 (Table 9, Figure 36e,f,h), the effect on swift parrot abundance was complex and depended on the extent of drought conditions in more northern parts of the species’ winter range (such as the NSW coast). That is, when dry to drought conditions dominated throughout the species’ winter range (2001 and 2004), large flocks of swift parrots concentrated in a small number of Victorian regions (Figure 36e,h). Although the general response of swift parrots was similar in these two years, the correlations between swift parrot abundance and rainfall differed (negative in 2001, non-significant in 2004) (Table 8). This was simply due to the relative levels of rainfall between the regions of Victoria (typically dryer) and NSW (typically wetter). That is, in 2001 there was a negative correlation since dry conditions in coastal NSW (76% of mean regional rainfall) were still relatively wetter than the drought conditions in Victorian habitats (38-51% of mean regional rainfall) (Table 9). Whereas in 2004, the non-significant correlation was due to moderately low levels of rainfall in most regions of Victoria (77-83% mean regional rainfall) and NSW (35-80% mean regional rainfall)(Table 9).

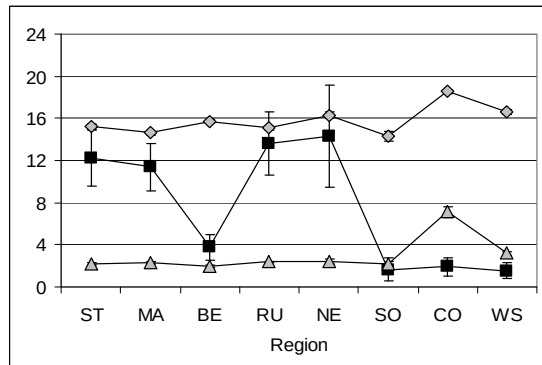
Alternatively, in 2002 when drought conditions in Victoria (31-44% mean regional rainfall) coincided with wet conditions in coastal NSW (162% mean regional rainfall), large flocks of swift parrots concentrated approximately 1000km further north in this coastal region,

resulting in a positive correlation (Table 8, Table 9). Although wet conditions also occurred in coastal NSW in other years (Table 9, Figure 36), a large influx of swift parrots into this region only occurred when there were extensive drought conditions elsewhere in their range.

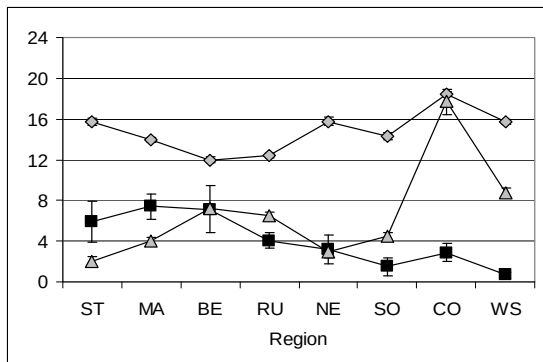
During the remaining five years when average to high rainfall occurred in most regions throughout their winter range (Table 9), swift parrots were significantly influenced by regional differences but not by climatic conditions. In these years, concentrated flocks of swift parrots tended to occur in different combinations of two to four Victorian regions, with smaller flocks occurring in the remaining regions (Figure 34, Figure 36). In 2000 there was also a weak, negative correlation between maximum temperature and swift parrot abundance (Table 8, Figure 36d). In southern Victoria and on the western slopes of NSW small numbers of swift parrots were recorded in most years (Figure 36).



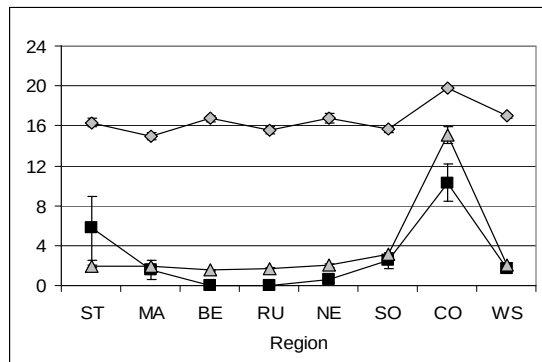
a) all years (1998-2004)



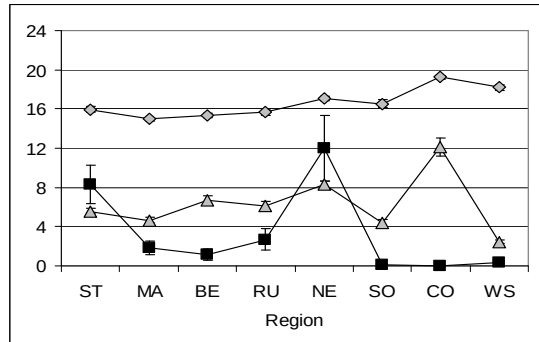
e) 2001



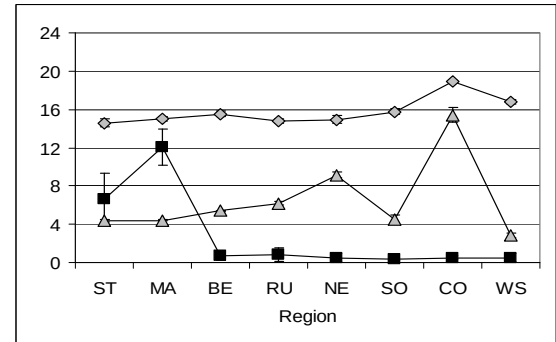
b) 1998



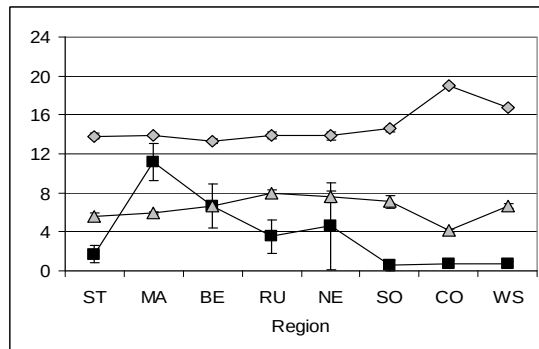
f) 2002



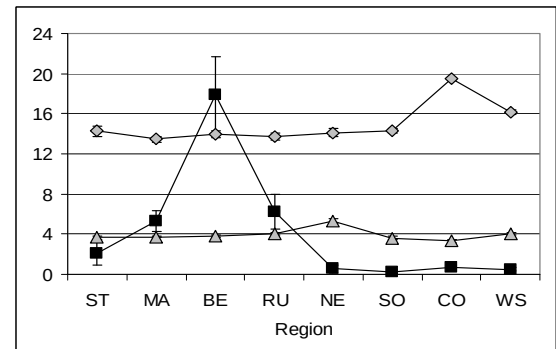
c) 1999



g) 2003



d) 2000



h) 2004

Figure 36 – Mean swift parrot abundance per survey ($\pm$ s.e.) compared with monthly rainfall ($\pm$ s.e.) and maximum temperature ($\pm$ s.e.) according to region and year (1998-2004). ■ = mean swift parrot abundance/survey, ♦ = maximum temperature ($^{\circ}$ C), ▲ = mean rainfall/10 (mm). Abbreviations for regions are given in Table 5.

Table 7 – Effect of major climatic variables and region on swift parrot abundance in 2002 for the one, three, six and twelve month climate models.

2002 models	Fixed term	Wald statistic	d.f.	p	effect
1 month	max temp	1.96	1	0.162	n.s.
	rainfall	20.35	1	<0.001	positive
	region	6.18	7	0.8	n.s.
3 month	max temp	32.12	1	<0.001	positive
	rainfall	5.69	1	0.017	positive
	region	7.94	7	0.338	n.s.
6 month	max temp	33.23	1	<0.001	positive
	rainfall	0.79	1	0.375	n.s.
	region	6.9	7	0.439	n.s.
12 month	max temp	3.21	1	0.073	n.s.
	rainfall	0.63	1	0.427	n.s.
	region	7.63	7	0.367	n.s.

Table 8 – Effect of major climatic variables and region on swift parrot abundance in the one month climate models (1998-2004).

Year/s	Fixed term	Wald statistic	d.f.	p	effect
All years (1998-2004)	max temp	20.09	1	<0.001	positive
	rainfall	236.02	1	<0.001	positive
	region	223.51	7	<0.001	
	year	593.38	6	<0.001	
1998	max temp	1.59	1	0.208	n.s.
	rainfall	0.92	1	0.339	n.s.
	region	37.77	7	<0.001	
1999	max temp	3.08	1	0.079	n.s.
	rainfall	0.02	1	0.889	n.s.
	region	29.72	7	<0.001	
2000	max temp	4.59	1	0.032	negative
	rainfall	1.56	1	0.212	n.s.
	region	20.13	7	0.005	
2001	max temp	3.81	1	0.051	n.s.
	rainfall	25.56	1	<0.001	negative
	region	22.47	7	0.002	
2002	max temp	1.96	1	0.162	n.s.
	rainfall	20.35	1	<0.001	positive
	region	6.18	7	0.8	n.s.
2003	max temp	0.15	1	0.703	n.s.
	rainfall	0.01	1	0.913	n.s.
	region	99.7	7	<0.001	
2004	max temp	1.17	1	0.278	n.s.
	rainfall	0.05	1	0.826	n.s.
	region	73.06	7	<0.001	

Table 9 – Percentage of mean monthly rainfall experienced in each region and year.

Region	St Arnaud	Mary- borough	Bendigo	Rushworth	North East Victoria	Southern Victoria	Coastal NSW	Western Slopes of NSW
Mean rainfall (mm)	45.27	44.98	49.45	50.98	64.01	41.97	93.17	50.02
Year	Percentage of 16 year mean rainfall (%)							
1998	43	90	145	128	46	106	190	176
1999	124	103	136	119	130	103	130	49
2000	124	132	134	156	119	169	44	133
2001	49	51	40	46	38	51	76	63
2002	43	44	31	34	31	73	162	42
2003	97	98	109	121	143	106	165	56
2004	81	83	77	80	83	86	35	80

Discussion

Although the importance of spatial and temporal variation in habitat use has been recognised within the most studied (Palearctic and Nearctic) migration systems of the world (Terrill 1990a; Newton 2004), few studies have examined the extent of variability and the underlying causes (Bairlein and Coppack 2006). Using landscape-scale volunteer survey data, this study provides the first demonstration of large-scale drought related movements by a migratory population throughout their winter range. It also demonstrates the dynamic spatial and temporal patterns of winter habitat use, including repeated use of sites, by a small, terrestrial migratory bird.

Swift parrots varied markedly in their spatial and temporal use of winter habitats. Although four central Victorian regions were used most regularly by large flocks of swift parrots, this occurred to different extents and in different combinations each year. When climate conditions were similar throughout the range of the swift parrot, variation in their abundance was best described by their preference for particular areas, with large flocks concentrated in two to four regions and smaller flocks occurring elsewhere. This suggests that where sufficient habitat is available in each region, swift parrots are able to tolerate a moderately variable range of climatic conditions.

However, when strong ENSO results in severe drought (Bureau of Meteorology 2006), swift parrots become more vulnerable since they either have to concentrate in large flocks in a small number of regions or, if drought is unevenly spread across their range, migrate substantially longer distances to drought refuges. For example, in 2001 when there was drought throughout the swift parrot range, they concentrated in large flocks in several Victorian regions. When faced with uncertainty about the location of food sources during widespread drought, the strategy of concentrating in large flocks may enable individuals to acquire important information about surrounding resources and conditions from the behaviour of con-specifics (Dall *et al.* 2005; Hancock and Milner-Gulland 2006), increasing their likelihood of finding sufficient resources.

Most swift parrots were observed to use a different wintering strategy during 2002 when one of the most severe droughts prevailed across much of south eastern Australia (Nicholls 2004). Under these conditions swift parrot abundance was correlated with rainfall, and most of the population migrated approximately 1000km further north east and concentrated in small, fragmented patches of drought refuge habitat within suburban areas of coastal NSW (see also chapter four). Although a large number of swift parrots were able to migrate the extra distance and locate coastal drought refuges, the birds probably had to

contend with additional stressors associated with these environments. Possible stressors include the extra physiological demands of having to migrate substantially longer distances; increased mortality from collisions with human made structures surrounding remnant habitats (see chapters two and three) and increased competition and aggression for limited resources from a variety of nectarivorous birds (as demonstrated in chapter four) (Keast 1968; Ford 1979; Paton 1980; Ford and Paton 1985; 1986; Kennedy and Tzaros 2005).

The variable southern hemisphere climate has also been found to correspond to variable habitat phenology (Law *et al.* 2000; Keatley *et al.* 2002; Keatley *et al.* 2004), food availability (Nix 1976; Eby 1991; Ford 1991; Jaksic and Lazo 1999; Lima *et al.* 1999; Jaksic and Lima 2003; Farias and Jaksic 2007) and movements within and between habitats (Nix 1976; Ford 1979; Chan 2001; Roshier *et al.* 2001; Ziembicki and Woinarski 2007) for a diversity of other migratory species. Therefore the dynamic responses to variable climate conditions, as demonstrated for swift parrots, are also likely to occur within other austral migration systems of the world. For example, in South America extreme ENSO drought and rain cycles have been related to large fluctuations in the abundance and diversity of migratory birds in some areas (Jaksic and Lazo 1999).

Despite variable spatial and temporal habitat use, swift parrots were also found to use the same locations repeatedly throughout their winter range and over multiple years, emphasizing the importance of protecting these locations. Similar dynamic habitat use patterns have also been demonstrated for larger migrants using satellite tracking techniques (Berthold *et al.* 2004; Meyburg *et al.* 2004a; Meyburg *et al.* 2004b; Phillips *et al.* 2005; Lindberg *et al.* 2007). Such patterns may reflect a combination of basic migration decision rules where birds initially undertake obligate (endogenous) migration to fly north for the austral winter, initially returning to preferred sites, and facultative (exogenous) migration to other sites if conditions are found to be unfavourable (Terrill 1990a). The importance of repeatedly used habitats has been demonstrated for a variety of species within both the Palearctic (e.g. (Berthold *et al.* 2002; Markovets and Yosef 2005; Belda *et al.* 2007)) and Nearctic migratory systems (e.g. (Hestbeck *et al.* 1991; Warkentin and Hernandez 1996)) and may convey advantages for migrants such as improved knowledge of spatial, daily and seasonal variation in resources in particular areas, and enhanced ability to avoid predation (Gauthreaux 1982; Warkentin and Hernandez 1996; Latta and Faaborg 2002; Hancock and Milner-Gulland 2006).

Although variable inter-annual and drought-related movements by the swift parrot population highlight their adaptability to the highly variable Australian environment, they

also emphasize their potential vulnerability to resource bottlenecks. That is, with the cumulative effects of naturally variable food resources (Law *et al.* 2000) and ongoing habitat loss throughout their range (Swift Parrot Recovery Team 2001; Munks *et al.* 2004) (see chapters two and three), there is an increasing risk of critical food shortages at some point in the annual cycle of the swift parrot. For example, although some important swift parrot habitats are now included in conservation reserves (Environment Conservation Council 2001), most habitats throughout the species' winter and breeding ranges (including old-growth nesting and drought refuge habitats) occur outside the reserve system and continue to be lost or impacted upon. This is despite legislation and environmental impact assessment processes intended to protect them (Swift Parrot Recovery Team 2001; Munks *et al.* 2004; Marshall 2006) (see chapters two and three). Furthermore, with global warming predicted to increase drought frequency and intensity (Nicholls 2004; Intergovernmental Panel on Climate Change 2007), alter habitat productivity and migratory phenology (Hughes 2000; Keatley *et al.* 2002; Howden *et al.* 2003; Bairlein and Huppopp 2004; Beaumont *et al.* 2006) and substantially reduce habitat suitability for a diversity of species (Bennett *et al.* 1991), the current and ongoing stresses on migratory populations are likely to be exacerbated, providing challenges for effective conservation management.

For conservation of migrants and their habitats information is required at relevant spatial and temporal scales (Bairlein 2003). This study demonstrates the efficacy of volunteer surveys as a means of acquiring such large spatial and temporal scale information and as a tool for studying avian migration. Data from the swift parrot monitoring program have not only provided the most extensive and valuable information on swift parrots across their wintering range, but also increased our understanding of their variable habitat use, and informed conservation management of the species, as discussed in chapter three. Such monitoring programs are particularly important within austral migration systems where there are only limited observers scattered over large areas (Keast 1968; Underhill *et al.* 1992; Griffioen and Clarke 2002; Latta *et al.* 2005), socio-economic constraints that limit environmental research capacity (Abaza *et al.* 2004; Latta *et al.* 2005) and where alternative methods such as bird banding have failed to provide sufficient information (Griffioen and Clarke 2002). However, monitoring programs need to be implemented throughout the species' range (breeding, migration and wintering areas) to gain a more complete understanding of limitations within each phase of the annual cycle.

Chapter 6 - Conclusion and further research



Adult swift parrot during southward migration (2004) (Photo: Geoffrey Dabb)

No one of the Australian birds will be more deeply imprinted upon my memory than the Swift Lorikeet...(Gould 1848)

This thesis provides a greater understanding of swift parrot habitat use at various spatial and temporal scales throughout their winter range. The first section introduced the species (Chapter 1), critically evaluated both the historical factors leading to the decline of swift parrots (Chapter 2) and the information already obtained by the recovery program (Chapter 3). This included what was known about its habitats, the major impacts on the species, and important knowledge gaps. This provided the necessary context for the second section of the thesis, which addressed the species' variable spatial and temporal use of habitats across New South Wales (Chapter 4) and throughout their broad winter range (Chapter 5). Below I reiterate the key findings of this research, and then outline further research needed to enhance our capacity to conserve this unique and fascinating species.

Key findings

- Swift parrots have lost much of their habitat since European settlement in 1788. This occurred at an extraordinary speed and to a large extent in all parts of the species' broad distribution. Within 60 years of settlement, habitats throughout the range of the species in south-eastern Australia were being cleared. Although the most extensive habitat loss in some areas occurred during colonial times, habitats continue to be lost or altered as a result of various land management practices and climate change. Consequently the swift parrot is now an endangered species and the subject of an ongoing national recovery program. This thesis contributes important knowledge to that program.
- The immense challenges associated with studying and protecting the swift parrot across the vast landscape of south-eastern Australia were identified together with the major achievements of the national recovery program to date. Key gaps in our knowledge were identified. These included the need for a better understanding of swift parrot habitat use at various spatial and temporal scales, as addressed in this thesis.
- Targeted volunteer surveys provided extensive data on the species, its habitats and co-inhabitants that would not otherwise have been possible to collect from across a vast landscape and over an extended period of time. Despite the challenges associated with finding the swift parrot, volunteers detected them in 19% of their 4140 surveys over seven years.
- Dynamic spatial and temporal patterns of winter habitat use by the swift parrot were demonstrated at the site, region, state and winter range (multi-state) levels. Swift parrots used the same locations throughout their winter range repeatedly between years. For

example in NSW over half of all foraging sites studied were used repeatedly, highlighting their likely importance for conservation.

- Swift parrots used four regions in central Victoria most consistently, although they also visited other regions each year.
- A diversity of winter foraging habitats in coastal and/or western slopes regions of New South Wales were used by the species each year, including several endangered ecological communities.
- These habitats occurred in a variety of landscapes from scattered trees and remnant vegetation to continuous forests, many of which are outside conservation reserves.
- Swift parrots undertake large-scale (up to 1000km) drought related movements throughout their winter range. That is, swift parrot abundance fluctuated significantly between years and regions, with coastal areas providing important refuge habitats during drought. This is the first time such movements have been demonstrated for a terrestrial migratory bird population throughout their winter habitats.
- During drought conditions, swift parrot movements were determined by rainfall, whereby most of the population either concentrated in a few regions or migrated longer distances (up to 1000km) to wetter coastal areas. In years of average to high rainfall their movements were more closely associated with regional habitats.
- The occurrence of swift parrots at foraging sites was primarily associated with the abundance of lerp, nectar, and non-aggressive competitors such as little lorikeets, fuscous honeyeaters and dusky woodswallows. Although nectar is a well recognised and important component of the swift parrot diet, the importance of lerp as a food source was highlighted.
- Conservation measures to protect and enhance habitats of the swift parrot need to be implemented throughout the distribution of this migratory species, including habitats that provide refuge from drought and occur outside conservation reserves.

Further research

The above findings provide valuable insights into the use of winter habitats by swift parrots. However, for the level of understanding necessary to fully protect this endangered austral migrant, the following further research is recommended:

Migration and movements

Although this research provides important information on the large-scale movements made by swift parrots, many key aspects of their movements remain unknown. For example, it is unknown whether swift parrots migrate nocturnally or diurnally; where their migration pathways are; whether they use stop-over habitats during migration; how the birds are able to locate suitable foraging sites in variable climatic conditions; at what height they fly during migration and whether they are threatened by wind farms; and whether some birds fly direct to distant habitats. Only when individual tracking devices are small enough to be used on swift parrots will it be possible to elucidate this critical information on individual migratory strategies and movements.

Breeding success and population biology

There is an urgent need to identify and follow the behaviour of individual birds within their breeding habitat. This includes research on whether the same birds breed together each year and whether they re-use the same nesting sites. Breeding success and age-related mortality (return rates), in conjunction with better estimates of population size, could then be used in population viability analyses (PVA). Genetic profiles are also essential for determining the genetic viability of the remaining population, particularly the level of inbreeding. Samples could be obtained from new and existing sources (museum specimens, injured birds, blood/feather samples from nestlings). Stable isotope/trace elements research may also be of use for establishing broad scale movements of individual birds in the absence of satellite tracking.

Climate change

Given the sensitivity of the swift parrot to extreme climatic conditions (Laubscher 1999) that are predicted to occur more frequently with global warming (Intergovernmental Panel on Climate Change 2007), a robust and long-term climate and migration monitoring program needs to be established in conjunction with breeding and migration ecology research and the national swift parrot volunteer survey network. There is also a need to

develop temporally dynamic bioclimatic models for the swift parrot that account for their variable spatial and temporal use of habitats.

This further research would provide information on movements, breeding success, sources of mortality, population size and the impact of global warming on the species, enabling a better understanding of the entire migratory cycle. This will enable the implementation of more dynamic and effective management strategies for this endangered species in the future.

In conclusion, given the extent of historical loss of habitats outlined in chapter two, it seems remarkable that any swift parrots have survived to this day. My research suggests that there is hope for the maintenance of a viable population, largely due to the apparent ability of swift parrots to utilize small patches of remaining habitat over a vast landscape. However, it is imperative that existing habitats are protected for the small remaining population to remain viable. Although many challenges remain for both research and conservation of this endangered migrant, my thesis has addressed some significant knowledge gaps and provides a basis for future research. By submitting my research for publication as I progressed through my thesis, I aimed to ensure that it is accessible for conservation management practitioners and researchers alike.

My thesis research has taken me on some of the most wonderful and unexpected journeys, both in Australia and around the world. Importantly it has also expanded my capacity to think critically, and inspired me to continue researching the amazing phenomenon of migration within the unique Australian environment.

Swift parrots - adaptable yet vulnerable

Complex yet simple

Challenging yet rewarding

Dedication, cooperation and enthusiasm

Hope despite endangerment

References

- Abaza, H., Bisset, R. and Sadler, B. (2004). 'Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach'. (United Nations Environment Programme (UNEP)).
- Allen Consulting Group (2005). 'Climate Change Risk and Vulnerability. Promoting an efficient adaptation response in Australia'. (Australian Greenhouse Office, Department of the Environment and Heritage: Canberra).
- Australian Bureau of Statistics (2006). 'Australian Historical Population Statistics, Table 1. Population by sex, state and territories, 31 December, 1788 onwards. Cat. no. 3105.0.65.001.' (Commonwealth of Australia: Canberra).
- Australian Government (1992). 'National Strategy for Ecologically Sustainable Development.' (Commonwealth of Australia: Canberra) Available at <http://www.environment.gov.au/esd/national/nsesd/index.html>, accessed 17 July 2008.
- Australian Government and Tasmanian Government (2005). 'Tasmanian Community Forest Agreement'. (Commonwealth of Australia: Canberra).
- Australian Government and Tasmanian Government (2007). 'Tasmanian Forest Conservation Fund.' (Commonwealth of Australia: Canberra) Available at <http://www.environment.gov.au/land/forestpolicy/fcf/index.html>, accessed 1 August 2008.
- Australian Greenhouse Office (2002). 'National Carbon Accounting System. Greenhouse gas emissions from land use change in Australia. An Integrated Application of the National Carbon Accounting System.' (Commonwealth of Australia: Canberra).
- Australian Greenhouse Office (2005). 'National Carbon Accounting System. Greenhouse gas emissions from land use change in Australia. Results of the National Carbon Accounting System 1988-2003.' (Commonwealth of Australia: Canberra).
- Australian State of the Environment Committee (2006). 'Australian State of the Environment 2006'. (Commonwealth of Australia: Canberra).
- Bairlein, F. (2003). The study of bird migrations - some future perspectives. *Bird Study* **50**, 243-253.
- Bairlein, F. and Coppack, T. (2006). Migration in the life-history of birds. *Journal of Ornithology* **147**, 121-121.
- Bairlein, F. and Huppopp, O. (2004). Migratory fuelling and global climate change. In 'Birds and Climate Change'. (Eds A. Moller, W. Fiedler and P. Berthold) pp. 33-47. (Academic Press)
- Bannear, D. (1992). 'Goldrush: the journal of Alexander Finlay while at the Victorian gold diggings, May 1852. IN ??? Coppice Regrowth in Victoria's Box-Ironbark Forests.' (St Mark's Press: Sydney) Available at <http://www.egold.net.au/biogs/EG00147b.htm> accessed 10 September 2007.

- Barrett, G. and Davidson, I. (1999). Community monitoring of woodland habitats - the Birds of Farms Survey. In 'Temperate eucalypt woodlands in Australia: biology, conservation, management and restoration.' (Eds R. Hobbs and C. Yates) pp. 382-399. (Surrey Beatty and Sons: Chipping Norton)
- Barrett, G., Silcocks, A., Barry, S., Cunningham, R. and Poulter, R. (2003). 'The new atlas of Australian birds.' (Royal Australasian Ornithologists Union: Melbourne).
- Bates, G. (2006). 'Environmental Law in Australia.' (LexisNexis Butterworths: Chatswood).
- Batey, I. (1907). On fifteen thousand acres: its bird-life sixty years ago. *The Emu* **7**, 1-17.
- Beaumont, L. J., McAllan, I. A. W. and Hughes, L. (2006). A matter of timing: changes in the first date of arrival and last date of departure of Australian migratory birds. *Global Change Biology* **12**, 1339-1354.
- Belda, E. J., Barba, E. and Monros, J. S. (2007). Resident and transient dynamics, site fidelity and survival in wintering Blackcaps *Sylvia atricapilla*: evidence from capture-recapture analyses. *Ibis* **149**, 396-404.
- Bennett, S., Brereton, R., Mansergh, I., Berwick, S., Sandiford, K. and Wellington, C. (1991). 'The potential effect of enhanced greenhouse climate change on selected Victorian fauna.' (Department of Conservation and Environment: Melbourne).
- Berruti, A., Harrison, J. and Navarro, R. (1994). Seasonal migration of terrestrial birds along the southern and eastern coasts of Southern Africa. *Ostrich* **65**, 54-65.
- Berthold, P. (1993). 'Bird Migration, a general survey.' (Oxford University Press: Oxford).
- Berthold, P. (2001). History of bird migration studies. In 'Bird Migration, a general survey.' (Ed. P. Berthold) pp. 11-13. (Oxford University Press: New York)
- Berthold, P., Kaatz, M. and Querner, U. (2004). Long-term satellite tracking of white stork (*Ciconia ciconia*) migration: constancy versus variability. *Journal of Ornithology* **145**, 356-359.
- Berthold, P., von der Bossche, W., Jakubiec, Z., Kaatz, C., Kaatz, M. and Querner, U. (2002). Long-term satellite tracking sheds light upon variable migration strategies of White Storks (*Ciconia ciconia*). *Journal Fur Ornithologie* **143**, 489-493.
- Biebach, H. (1995). Stopover of Migrants Flying across the Mediterranean-Sea and the Sahara. *Israel Journal of Zoology* **41**, 387-392.
- Biebach, H., Friedrich, W., Heine, G., Jenni, L., Jennieiermann, S. and Schmidl, D. (1991). The Daily Pattern of Autumn Bird Migration in the Northern Sahara. *Ibis* **133**, 414-422.
- Bildstein, K. L. (1998). Long-term counts of migrating raptors: A role for volunteers in wildlife research. *Journal of Wildlife Management* **62**, 435-445.

- Bjork, R. D. (2004). 'Delineating pattern and process in tropical lowlands: Mealy Parrot migration dynamics as a guide for regional conservation planning'. Doctor of Philosophy thesis. Wildlife Science, Oregon State University.
- Blakston, W. A. (c. 1880). 'The illustrated book of canaries and cage-birds, British and foreign.' (Cassell and Company Limited: London).
- Boland, C. R. J. (2004). Breeding biology of Rainbow Bee-Eaters (*Merops ornatus*): A migratory, colonial, cooperative bird. *Auk* **121**, 811-823.
- Boyd, B. (2004). '50 years of swift parrot observations'. (Unpublished notes).
- Brereton, R. (1996). 'The Swift Parrot Recovery Plan 1997 - 1999'. (Tasmanian Parks and Wildlife Service: Hobart).
- Brereton, R. (1997). 'Management prescriptions for the Swift Parrot in production forests.' (Report to the Tasmanian Regional Forest Agreement Environment and Heritage Technical Committee.).
- Brereton, R., Bennett, S. and Mansergh, I. (1995). Enhanced greenhouse climate change and its potential effect on selected fauna of south-eastern Australia: a trend analysis. *Biological Conservation* **72**, 339-354.
- Brereton, R., Mallick, S. and Kennedy, S. (2004). Foraging preferences of Swift Parrots on Tasmanian Blue-gum: tree size, flowering frequency and flowering intensity. *Emu* **104**, 377-383.
- Brown, P. B. (1989). 'The Swift Parrot *Lathamus discolor* White: A report on its ecology, distribution and status, including management considerations. Technical Report.' (Department of Lands, Parks and Wildlife.).
- Bureau of Meteorology (2002). 'Rainfall Deficiencies worsen following a dry October, November 01.' (Commonwealth of Australia: Melbourne) Available at http://www.bom.gov.au/announcements/media_releases/climate/drought/, accessed 23 June 2006.
- Bureau of Meteorology (2006). 'Living with drought.' (Commonwealth of Australia: Melbourne) Available at <http://www.bom.gov.au/climate/drought/>, accessed 23 June 2006.
- Bureau of Meteorology (2007a). 'Australia - climate of our continent.' (Commonwealth of Australia: Melbourne) Available at <http://www.bom.gov.au/lam/climate/levelthree/ausclim/zones.htm>, accessed 23 June 2007.
- Bureau of Meteorology (2007b). 'Rainfall deficiency percentile maps of Australia, March to October, for selected years from 1938 to 2004.' (Commonwealth of Australia: Melbourne) Available at http://www.bom.gov.au/announcements/media_releases/climate/drought/, accessed 2 October 2007.
- Butler, A. G. (1909?). 'Foreign Birds for Cage and Aviary. Part II - The Larger Foreign Birds.' (Arthur G. Butler: London).
- Carron, L. T. (1985). 'A history of forestry in Australia.' (Australian National University Press: Canberra).

- Chambers, L. E. (2008). Trends in timing of migration of south-western Australian birds and their relationship to climate. *Emu* **108**, 1-14.
- Chan, K. (2001). Partial migration in Australian landbirds: a review. *Emu* **101**, 281-292.
- Chan, K. and Sutton, P. (1993). Migratory behaviour of silvereyes returning to Tasmania from southern Victoria. *Corella* **17**, 41-42.
- Chapple, S. (2001). The EPBC Act: one year later. *Environmental Planning and Law Journal (EPLJ)* **18**, 523-539.
- Chesser, R. T. (2004). Seasonal distribution and ecology of South American austral migrant flycatchers. In 'Birds of two worlds. The ecology and evolution of migration.' (Eds R. Greenberg and P. P. Marra) pp. 168-181. (Smithsonian Institution: Washington, D.C.)
- Christidis, L. and Boles, W. (1994). 'The taxonomy and species of birds of Australia and its Territories.' (Royal Australasian Ornithologists Union.).
- Clark, L. (1964). Predation by birds in relation to the population density of *Cardiaspina albitextura* (Psyllidae). *Australian Journal of Zoology* **12**, 349 - 361.
- Clarke, M. F., Schipper, C., Boulton, R. and Ewen, J. (2003). The social organization and breeding behaviour of the Yellow-faced Honeyeater *Lichenostomus chrysops*- a migratory passerine from the Southern Hemisphere. *Ibis* **145**, 611-623.
- Cole, C. F. (1919). Notes upon the food of the Swift Parrot (*Lathamus discolor*). *Emu* **19**, 128.
- Commonwealth of Australia (1983). 'A National Conservation Strategy for Australia: Living resource conservation for sustainable development.' (Australian Government Publishing Service: Canberra).
- Commonwealth of Australia (1992). 'National Forest Policy Statement'. (Commonwealth of Australia: Canberra).
- Commonwealth of Australia (2002). 'Environment Protection and Biodiversity Conservation Act 1999. Mirvac Homes subdivision, The Entrance Rd, Bateau Bay (EPBC 2002/711). Decision that action is not a controlled action.' (Australian Government: Canberra) Available at http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=referral_detail&proposal_id=711, accessed 30 July 2008.
- Commonwealth of Australia (2004a). 'Environment Protection and Biodiversity Conservation Act 1999. Decision to approve the taking of an action. To construct and operate the expansion of the Carshalton Mine Complex at Bendigo, Victoria (EPBC 2003/974).' (Australian Government: Canberra) Available at http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=referral_detail&proposal_id=974, accessed 30 July 2008.
- Commonwealth of Australia (2004b). 'Environment Protection and Biodiversity Conservation Act 1999. Decision to approve the taking of an action. To develop the

- Hunter Economic Zone Industrial Estate, Hunter Valley, New South Wales (EPBC 2004/1417).' (Commonwealth of Australia: Canberra).
- Commonwealth of Australia (2008). 'Regional Forest Agreements.' (Commonwealth of Australia: Canberra) Available at <http://www.daff.gov.au/rfa>, accessed 11 July 2008.
- Coppack, T. and Both, C. (2002). Predicting life-cycle adaptation of migratory birds to global climate change. *Ardea* **90**, 369-378.
- Coppack, T., Pulido, F. and Berthold, P. (2001). Photoperiodic response to early hatching in a migratory bird species. *Oecologia* **128**, 181-186.
- Cowie, J. (2007). 'Climate change: biological and human aspects.' (Cambridge University Press: Cambridge).
- Cowper, P. (2002). 'Referral of proposed action. Mirvac Homes 91 lot subdivision, The Entrance Rd, Bateau Bay.' (Andrews Neil Environmental Pty Ltd: Gosford) Available at http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=referral_detail&proposal_id=711, accessed 30 July 2008.
- Cubit, S. (1996). 'Recollections from the forest. 75 years of forest service in Tasmania.' (Forestry Tasmania: Hobart).
- Dall, S. R. X., Giraldeau, L.-A., Olsson, O., McNamara, J. M. and Stephens, D. W. (2005). Information and its use by animals in evolutionary ecology. *Trends in Ecology & Evolution* **20**, 187-193.
- Datta, A. (1997). 'John Gould in Australia: letters and drawings with a catalogue of manuscripts, correspondence and drawings relating to the birds and mammals of Australia held in The Natural History Museum, London.' (Melbourne University Press and The Miegunyah Press: Carlton South).
- Department of Climate Change (2007). 'The Australian Government's Initial Report under the Kyoto Protocol. Australia's National Greenhouse Accounts Report to facilitate the calculation of the assigned amount of Australia pursuant to Article 3, paragraphs 7 and 8 of the Kyoto Protocol.' (Australian Government: Canberra).
- Department of Environment and Climate Change (2008). 'Conservation Agreements.' (NSW Government: Sydney) Available at <http://www.environment.nsw.gov.au/cpp/ConservationAgreements.htm>, accessed 17 July 2008.
- Department of Environment and Water Resources (2007). 'EPBC Act - Environment Assessment Process'. (Australian Government: Canberra).
- Department of Environment Water Heritage and the Arts (2007). 'Environment Protection and Biodiversity Conservation Act 1999. Rezoning and residential development at Avery's Village, Avery's Lane, Hedon Gretta, NSW (EPBC 2007/3880). Referral decision - not controlled action if undertaken in a particular matter.' (Australian Government: Canberra) Available at http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=current_referral_detail&proposal_id=3880, accessed 30 July 2008.

Department of Natural Resources (2006). 'Compliance under the Native Vegetation Act 2003'. (NSW Government: Sydney).

Department of Natural Resources and Environment (2002). 'Victoria's Native Vegetation Management - a Framework for Action'. (Victorian Government: Melbourne).

Department of Natural Resources and Environment (2002). 'Government response to Environment Conservation Council Box-Ironbark Forests and Woodlands Investigation'. (Department of Natural Resources and Environment: Melbourne).

Department of Primary Industries Water and Environment (2000). 'Threatened Species Strategy for Tasmania'. (Tasmanian Government: Hobart).

Department of Sustainability and Environment (2003). 'Habitat Tree Prescriptions for Bendigo Forest Management Area'. (Department of Sustainability and Environment: Bendigo).

Department of Sustainability and Environment (2006a). 'Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978'. (Victorian Government: Melbourne).

Department of Sustainability and Environment (2006b). 'Native Vegetation - sustaining a living landscape'. (Victorian Government: Melbourne).

Department of the Prime Minister and Cabinet (1990). 'Ecologically sustainable development: a Commonwealth discussion paper, June 1990.' (Australian Government Publishing Service: Canberra).

Department of the Senate (2008). 'Inquiry into the operation of the Environment Protection and Biodiversity Conservation Act 1999'. (Commonwealth of Australia: Canberra).

Dingle, H. (2004). The Australo-Papuan bird migration system: another consequence of Wallace's Line. *Emu* **104**, 95-108.

Dorst, J. (1962). 'The migrations of birds.' (Heinemann: London).

Dow, D. (1977). Indiscriminate interspecific aggression leading to almost sole occupancy of space by a single species of bird. *Emu* **77**, 115 - 121.

Drechsler, M., Burgman, M. A. and Menkhorst, P. W. (1998). Uncertainty in population dynamics and its consequences for the management of the orange-bellied parrot *Neophema chrysogaster*. *Biological Conservation* **84**, 269-281.

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.

Endangered Species Scientific Subcommittee (2000). 'Commonwealth Listing Advice on Cumberland Plain Woodlands.' (Department of the Environment and Heritage) Available at

<http://www.deh.gov.au/biodiversity/threatened/communities/>, accessed 30 January 2006.

Endangered Species Scientific Subcommittee (2001). 'Commonwealth Listing Advice on Land Clearance.' (Department of the Environment and Heritage:

- Canberra) Available at <http://www.environment.gov.au/biodiversity/threatened/ktp/clearing.html>, accessed 10 July 2008.
- Endangered Species Scientific Subcommittee (2005). 'Commonwealth Listing Advice on Grassy White Box Woodlands.' (Department of the Environment and Heritage) Available at <http://www.deh.gov.au/biodiversity/threatened/communities/grassy-white-box.html>, accessed 30 January 2006.
- Environment Conservation Council (2001). 'Box-Ironbark Forests and Woodlands Investigation'. (Environment Conservation Council: Melbourne).
- Environment Protection Authority (2007). 'Nature Assist - Nature refuges incentives and assistance.' (The State of Queensland: Brisbane) Available at http://www.epa.qld.gov.au/nature_conservation/nature_refuges/natureassist/, accessed 17 July 2008.
- ESRI (2005). 'ArcView 9.1, Geographic Information System and mapping software.' (ESRI: California).
- Eurobodalla Shire Council (2000). 'Eurobodalla State of the Environment Report. History of human settlement.' (Eurobodalla Shire Council: Moruya) Available at <http://www.esc.nsw.gov.au/plans/documents/archive/1999/SOE/SOERd/TheReport/Eurobodalla/Themes/human.htm#his>, accessed 8 September 2007.
- Farias, A. A. and Jaksic, F. M. (2007). El Nino events, the lean versus fat scenario, and long-term guild dynamics of vertebrate predators in a South American semiarid ecosystem. *Austral Ecology* **32**, 225-238.
- Farmer, D., Catterall, C. P. and Piper, S. D. (2004). Abundance patterns across months and locations, and their differences between migrant and resident landbirds in lowland subtropical eucalypt forest. *Emu* **104**, 283-296.
- Felton, A., Fischer, J., Lindenmayer, D. B., *et al.* (submitted). Climate change, conservation and management: An assessment of the peer-reviewed scientific journal literature. *Basic and Applied Ecology*.
- Forbes, W. A. (1879). On the systematic position of the genus *Lathamus* of Lesson. *Proceedings of the scientific meetings of the Zoological Society of London for the year 1879*, 166-174.
- Ford, H., Davis, W. E., Debus, S., Ley, A., Recher, H. and Williams, B. (1993). Foraging and Aggressive Behaviour of the Regent Honeyeater *Xanthomyza phrygia* in Northern New South Wales. *Emu* **93**, 277-281.
- Ford, H. A. (1979). Interspecific competition in Australian honeyeaters - depletion of common resources. *Australian Journal of Ecology* **4**, 145-164.
- Ford, H. A. (1991). Coping with an erratic nectar source - eastern spinebills *Acanthorhynchus tenuirostris* at New England National Park. *Emu* **91**, 53-56.
- Ford, H. A., Barrett, G. W., Saunders, D. A. and Recher, H. F. (2001). Why have birds in the woodlands of Southern Australia declined? *Biological Conservation* **97**, 71-88.

- Ford, H. A. and Paton, D. C. (1985). Habitat Selection in Australian Honeyeaters, with Special Reference to Nectar Productivity. In 'Habitat Selection in Birds'. (Ed. M. L. Cody) pp. 367-388. (Academic Press: Orlando)
- Ford, H. A. and Paton, D. C. (Eds) (1986). 'The Dynamic Partnership: Birds and Plants in Southern Australia.' (Government Printer: Adelaide).
- Forshaw, J. (2002). Swift Parrot *Lathamus discolor* (Shaw). In 'Australian Parrots.' pp. 500-509. (Lansdowne Press: Melbourne)
- Forsman, J. T., Monkkonen, M., Helle, P. and Inkeroinen, J. (1998). Heterospecific attraction and food resources in migrants' breeding patch selection in northern boreal forest. *Oecologia* **115**, 278-286.
- Frawley, K. (1994). Evolving visions: environmental management and nature conservation in Australia. In 'Australian Environmental History'. (Ed. S. Dovers) pp. 55-78. (Oxford University Press: Melbourne)
- French, K., Paterson, I., Miller, J. and Turner, R. J. (2003). Nectarivorous bird assemblages in Box–Ironbark woodlands in the Capertee Valley, New South Wales. *Emu* **103**, 345-356.
- Ganusevich, S. A., Maechtle, T. L., Seegar, W. S., Yates, M. A., McGrady, M. J., Fuller, M., Schueck, L., Dayton, J. and Henny, C. J. (2004). Autumn migration and wintering areas of Peregrine Falcons *Falco peregrinus* nesting on the Kola Peninsula, northern Russia. *Ibis* **146**, 291-297.
- Garnett, S. T., Sutton, P., Lowe, K. and Gray, S. (1991). Land bird movements across north-east Bass Strait, Autumn 1988. *Corella* **15**, 1-7.
- Gartrell, B. D. (2002). Assessment of the reproductive state in male swift parrots (*Lathamus discolor*) by testicular aspiration and cytology. *Journal of Avian Medicine and Surgery* **16**, 211-217.
- Gartrell, B. D., Jones, S. M., Brereton, R. N. and Astheimer, L. B. (2000). Morphological adaptations to nectarivory of the alimentary tract of the Swift Parrot *Lathamus discolor*. *Emu* **100**, 274-279.
- Gartrell, B. D. a. J., S M (2001). Eucalyptus pollen grain emptying by two Australian nectarivorous psittacines. *Journal of Avian Biology* **32(3)**, 224-230.
- Gauthreaux, S. A. (1982). The ecology and evolution of avian migration systems. In 'Avian biology'. (Eds D. S. Farner and J. R. King) pp. 93-168. (Academic Press: London)
- Genstat Committee (2007). 'GenStat Release 9.0.' (VSN International Ltd: Hemel Hempstead).
- Gibbons, P. and Boak, M. (2002). The value of paddock trees for regional conservation in an agricultural landscape. *Ecological Management and Restoration* **3**, 205-210.
- Goodman, R. (2001). 'Beekeepers' use of honey and pollen flora resources in Victoria'. (Rural Industries Research and Development Corporation: Knoxfield, Victoria).

Google (2007). 'GoogleEarth with images from NASA DigitalGlobe and TerraMetrics.'

Gordo, O., Brotons, L., Ferrer, X. and Comas, P. (2005). Do changes in climate patterns in wintering areas affect the timing of the spring arrival of trans-Saharan migrant birds? *Global Change Biology* **11**, 12-21.

Gordo, O. and Sanz, J. J. (2008). The relative importance of conditions in wintering and passage areas on spring arrival dates: the case of long-distance Iberian migrants. *Journal of Ornithology* **149**, 199-210.

Gould, J. (1848). 'Birds of Australia (Volume V).' (Gould, J.: London).

Gould, J. (1972). 'Handbook to the Birds of Australia (second edition, first edition 1865).' (Lansdowne Press: London).

Gould, W. B. (1840s). Birds. In 'Ballarat Fine Art Gallery Collection'. (Ballarat Fine Art Gallery).

Grant, T. C. (1989). 'History of forestry in New South Wales 1788 to 1988.' (Star Printery: Erskinville).

Greenberg, R. and Marra, P. P. (Eds) (2004). 'Birds of two worlds. The ecology and evolution of migration. ' (Smithsonian Institution: Washington, D.C.).

Grey, M. J., Clarke, M. F. and Loyn, R. H. (1997). Initial changes in the avian communities of remnant eucalypt woodlands following a reduction in the abundance of noisy miners, *Manorina melanocephala*. *Wildlife Research* **24**, 631-648.

Grey, M. J., Clarke, M. F. and Loyn, R. H. (1998). Influence of the Noisy Miner *Manorina melanocephala* on avian diversity and abundance in remnant Grey Box woodland. *Pacific Conservation Biology* **4**, 55-69.

Griffioen, P. A. and Clarke, M. F. (2002). Large-scale bird-movement patterns evident in eastern Australian atlas data. *Emu* **102**, 99-125.

Grinlinton, D. (1990). The Environmental Era and the Emergence of Environmental Law in Australia – a survey of Environmental Legislation and Litigation 1967-1987". *Environmental Planning and Law Journal (EPLJ)* **7**, 74.

Halliday, K. (Ed.) (2005). 'Liverpool Plains Shire Heritage Community Advisory Committee, Community Based Shire Wide Heritage Study Documents 2004-05. ' (Liverpool Plains Shire Council and NSW Heritage Office: Liverpool Plains Shire Council).

Hancock, P. A. and Milner-Gulland, E. J. (2006). Optimal movement strategies for social foragers in unpredictable environments. *Ecology* **87**, 2094-2102.

Harman, I. (1981). 'Australian parrots in bush and aviary.' (Inkata Press: Melbourne).

Harrison, J. (1995). The atlas of southern African birds. *Birding in South Africa* **47**, 42-45.

- Hestbeck, J. B., Nichols, J. D. and Malecki, R. A. (1991). Estimates of Movement and Site Fidelity Using Mark Resight Data of Wintering Canada Geese. *Ecology* **72**, 523-533.
- Higgins, P. J. (Ed.) (1999). 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 4. Parrots to Dollarbirds.' (Oxford University Press: Melbourne).
- Hindwood, K. A. (1937). Parrot at sea. *Emu* **37**, 67-68.
- Hindwood, K. A. (1948). Migration of two species of honeyeaters. *Emu* **47**, 391-393.
- Hindwood, K. A. (1956). The migration of the White-naped and Yellow-faced Honeyeaters. *Emu* **56**, 421-425.
- Hindwood, K. A. (1965). John Hunter: A naturalist and artist of the first fleet. *The Emu* **65**, 83-95.
- Hindwood, K. A. and Sharland, M. (1964). The swift parrot. *Emu* **63**, 310-326.
- Hingston, A. B., Potts, B. M. and McQuillan, P. B. (2004). The swift parrot *Lathamus discolor* (Psittacidae), social bees (Apidae), and native insects as pollinators of *Eucalyptus globulus* ssp. *globulus* (Myrtaceae). *Australian Journal of Botany* **52**, 371-379.
- Howden, M., Hughes, L., Dunlop, M., Zethoven, I., Hilbert, D. and Chilcott, C. (2003). 'Climate Change Impacts On Biodiversity In Australia.' (Commonwealth of Australia: Canberra).
- Hoye, B., Klaassen, M. and Nolet, B. A. (2007). Ecophysiology of bird migration in the face of current global hazards: climate change and avian flu. *Comparative Biochemistry and Physiology Part A*, S127-128.
- Hughes, L. (2000). Biological consequences of global warming: is the signal already apparent? *Trends in Ecology & Evolution* **15**, 56-61.
- Hunter, J. (1788-1790). [Swift parrot (*Lathamus discolor*) and Yellow pittosporum (*Pittosporum revolutum*)]. In 'Birds & flowers of New South Wales drawn on the spot in 1788, '89 & '90'. (Ed. J. Hunter) Vol.
- Innes, E. G. (1896). Reports of District Surveyors. Survey District of Franklin. In '1896, Session II. Parliament of Tasmania, Department of Lands and Surveys: Report of Surveyor-General and Secretary for Lands for 1895. Parliamentary Paper No. 47. Appendix B.' Vol. VIII, pp. 15-16. (Government Printer: Hobart).
- Intergovernmental Panel on Climate Change (2007). 'Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for Policymakers.' Working Group II Contribution to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, (IPCC: Geneva).
- IUCN (2004). '2004 IUCN Red List of Threatened Species.' Available at www.iucnredlist.org, accessed Downloaded on 21 March 2006.
- IUCN, UNEP and WWF (1980). 'World Conservation Strategy. Living resource conservation for sustainable development.' (International Union for the Conservation of Nature: Gland Switzerland).

- Jahn, A. E., Levey, D. J. and Smith, K. G. (2004). Reflections across hemispheres: a system-wide approach to new world bird migration. *The Auk* **121**, 1005-1013.
- Jaksic, F. M. and Lazo, I. (1999). Response of a bird assemblage in semiarid Chile to the 1997-1998 El Nino. *The Wilson Bulletin* **111**, 527.
- Jaksic, F. M. and Lima, M. (2003). Myths and facts on ratadas: Bamboo blooms, rainfall peaks and rodent outbreaks in South America. *Austral Ecology* **28**, 237-251.
- Juniper, T. and Parr, M. (1998). 'Parrots - a guide to parrots of the world.' (Pica Press: Sussex).
- Keast, A. and Morton, E. (Eds) (1980). 'Migrant birds in the Neotropics. Ecology, behaviour, distribution and conservation. ' The symposia of the National Zoological Park. (Smithsonian Institution: Washington D.C.).
- Keast, J. A. (1968). Seasonal movements in the Australian honeyeaters (Meliphagidae) and their ecological significance. *Emu* **67**, 159-209.
- Keast, J. A. (1980). Migratory Parulidae: What can species co-occurrence in the north reveal about ecological plasticity and wintering patterns? In 'Migrant birds in the Neotropics. Ecology, behaviour, distribution and conservation.' (Eds J. A. Keast and E. S. Morton) pp. 457-475. (Smithsonian Institution Press: Washington, D.C.)
- Keatley, M. R., Fletcher, T. D., Hudson, I. L. and Ades, P. K. (2002). Phenological studies in Australia: Potential application in historical and future climate analysis. *International Journal of Climatology* **22**, 1769-1780.
- Keatley, M. R., Hudson, I. L. and T.D., F. (2004). Long-term flowering synchrony of box-ironbark eucalypts. *Australian Journal of Botany* **52**, 47-54.
- Kennedy, S. and Tzaros, C. (2005). Foraging ecology of the Swift Parrot *Lathamus discolor* in the Box-Ironbark forests and woodlands of Victoria. *Pacific Conservation Biology* **11**, 158-173.
- Kennedy, S. J. and Overs, A. E. (2001). Foraging ecology and habitat use of the swift parrot on the south-western slopes of New South Wales. *Corella* **25**, 68-74.
- Lambert, T. (2007). 'Referral of proposed action. Avery Village Residential Development, Hedon Greta, NSW.' (RPS Harper Somers O'Sullivan: Newcastle).
- Lamont, D. A. (1996). 'The changing status of the rainbow lorikeet *Trichoglossus haematodus* (Linnaeus 1771) in south-western Australia: its potential for range extension.' Master of Science thesis. University of New England, Armidale.
- Landcare Australia (2007). 'Annual Report 2006/07'. (Landcare Australia Ltd: Chatswood).
- Landcare NSW (2007). 'A brief history of Landcare support in NSW.' Available at <http://www.landcarensw.org/History.htm>, accessed 8 September 2007.
- Latta, S. C. and Faaborg, J. (2002). Demographic and population responses of cape may warblers wintering in multiple habitats. *Ecology* **83**, 2502-2515.
- Latta, S. C., Ralph, C. J. and Geupel, G. R. (2005). Strategies for the conservation monitoring of resident landbirds and wintering neotropical migrants in the Americas. *Ornitologia Neotropical* **16**, 163-174.

- Laubscher, C. (1999). 'The Swift Parakeet. The Parrot Society UK Special Edition.' (Principal Colour Ltd: U.K.).
- 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.
- Legge, S. and Heinsohn, R. (2001). Kingfishers in paradise: the breeding biology of *Tanyptera sylvia* at the Iron Range National Park, Cape York. *Australian Journal of Zoology* **49**, 85-98.
- Lehikoinen, A., Kilpi, M. and Ost, M. (2006). Winter climate affects subsequent breeding success of common eiders. *Global Change Biology* **12**, 1355-1365.
- Lehikoinen, E. S., Sparks, T. H., Zalakevicius, M., Moller, A., Fiedler, W. and Berthold, P. (2004). Arrival and Departure Dates. In 'Advances in Ecological Research' pp. 1-31. (Academic Press)
- Lendon, A. (1979). 'Australian parrots in field and aviary.' (Angus and Robertson: Sydney).
- Levaillant, F. (1989). 'Histoire Naturelle des Perroquets (revised edition of c. 1803 publication).' (Brian Chester and Imprime: Sydney).
- Lima, M., Keymer, J. E. and Jaksic, F. M. (1999). El Nino-southern oscillation-driven rainfall variability and delayed density dependence cause rodent outbreaks in western South America: Linking demography and population dynamics. *American Naturalist* **153**, 476-491.
- Lindberg, M. S., Ward, D. H., Tibbitts, T. L. and Roser, J. (2007). Winter movement dynamics of black brant. *Journal of Wildlife Management* **71**, 534-540.
- Low, T. (2008). Warming, invasive pests and birds. In 'The State of Australia's Birds 2007. Birds in a changing climate.' (Ed. P. Olsen) pp. 18-19. (Birds Australia: Melbourne)
- Loyn, R. H. (1985). Birds in fragmented forests in Gippsland, Victoria. In 'Birds of Eucalypt Forests and Woodlands: Ecology, Conservation and Management'. (Eds J. A. Keast, H. A. Recher, H. A. Ford and D. A. Saunders) pp. 323-331. (RAOU and Surrey Beatty and Sons: Sydney)
- Loyn, R. H., Lane, B. A., Chandler, C. and Carr, G. W. (1986). Ecology of Orange-Bellied Parrots *Neophema chrysogaster* at Their Main Remnant Wintering Site. *Emu* **86**, 195-206.
- Lunney, D., Esson, C., Moon, C., Ellis, M. and Matthews, A. (1997). A community-based survey of the Koala *Phascolarctos cinereus*, in the Eden region of south-eastern New South Wales. *Wildlife Research* **24**, 111-128.
- Lunt, I. D. and Spooner, P. G. (2005). Using historical ecology to understand patterns of biodiversity in fragmented agricultural landscapes. *Journal of Biogeography* **32**, 1859-1873.
- Mac Nally, R. and Horrocks, G. (2000). Landscape-scale conservation of an endangered migrant: the Swift Parrot (*Lathamus discolor*) in its winter range. *Biological Conservation* **92**, 335-343.

- Macintosh, A. (2004). Why the Environment Protection and Biodiversity Conservation Act's referral, assessment and approval process is failing to achieve its environmental objectives. *Environmental Planning and Law Journal (EPLJ)* **21**, 288-311.
- Macintosh, A. and Wilkinson, D. (2005). 'Environment Protection and Biodiversity Conservation Act: A five year assessment. Discussion Paper 81.' (The Australia Institute: Canberra).
- Mackey, B. G. and Lindenmayer, D. B. (2001). Towards a hierarchical framework for modelling the spatial distribution of animals. *Journal of Biogeography* **28**, 1147-1166.
- Mallick, S., James, D., Brereton, R. and Plowright, S. (2004). Blue Gums *Eucalyptus globulus* in north-west Tasmania: an important food resource for the endangered Swift Parrot *Lathamus discolor*. *Victorian Naturalist* **121**, 36-46.
- Manning, A., Fischer, J. and Lindenmayer, D. (2006a). Scattered trees are keystone structures - implications for conservation. *Biological Conservation* **132**, 311-321.
- Manning, A., Lindenmayer, D., Barry, S. and Nix, H. A. (2006b). Multi-scale site and landscape effects on the vulnerable superb parrot of south-eastern Australia during the breeding season. *Landscape Ecology* **21**, 1119-1133.
- Manning, A., Lindenmayer, D. B., Barry, S. C. and Nix, H. A. (2007). Large-scale spatial and temporal dynamics of the vulnerable and highly mobile superb parrot. *Journal of Biogeography* **34**, 289-304.
- Markovets, M. and Yosef, R. (2005). Phenology, duration and site fidelity of wintering bluethroat (*Luscinia svecica*) at Eilat, Israel. *Journal of Arid Environments* **61**, 93-100.
- Marshall, J. (2006). 'Brown v Forestry Tasmania Summary (No 4) FCA 1729, 19 December 2006'. (Federal Court of Australia: Hobart).
- Martin, T. E. and Finch, D. M. E. (1995). 'Ecology and Management of Neotropical Migratory Birds. A synthesis and review of critical issues.' (Oxford University Press: New York).
- Masello, J. F., Pagnossin, M. L., Sommer, C. and Quillfeldt, P. (2006). Population size, provisioning frequency, flock size and foraging range at the largest known colony of Psittaciformes: the Burrowing Parrots of the north-eastern Patagonian coastal cliffs. *Emu* **106**, 69-79.
- Mathews, G. M. (1916). 'The birds of Australia.' (Witherby & Co: London).
- Mazell, P. (1789). Red-shouldered Parrakeet. In (Ed. A. Phillip), 'The voyage of Governor Phillip to Botany Bay'. (John Stockdale: London).
- McFarland, D. C. (1986a). The organisation of a honeyeater community in an unpredictable environment. *Australian Journal of Ecology* **11**, 107-120.
- McFarland, D. C. (1986b). Seasonal changes in the abundance and body condition of honeyeaters (Meliphagidae) in response to inflorescence and nectar availability in the New England National Park, New South Wales. *Australian Journal of Ecology* **11**.

- McGrath, C. (2006). 'Review of the EPBC Act. Paper prepared for the 2006 Australian State of the Environment Committee.' (Department of the Environment and Heritage: Canberra) Available at <http://www.deh.gov.au/soe/2006/emerging/epbcact/index.html>, accessed 4 July 2008.
- McMahon, J. P., Hutchinson, M. F., Nix, H. A. and Ord, K. D. (1995). 'ANUCLIM User's Guide.' (Australian National University: Canberra).
- McNeil, R. (1982). Winter resident repeats and returns of Austral and Boreal migrant birds banded in Venezuela. *Journal of Field Ornithology* **53**, 125-132.
- Mehlman, D. W., Mabey, S. E., Ewert, D. N., Duncan, C., Abel, B., Cimprich, D., Sutter, R. D. and Woodrey, M. (2005). Conserving stopover sites for forest-dwelling migratory landbirds. *The Auk* **122**, 1281.
- Menkhorst, P., Schedvin, N. and Geering, D. (1999). 'Regent Honeyeater (*Xanthomyza phrygia*) Recovery Plan 1999-2003'. (Department of Natural Resources and Environment).
- Meyburg, B. U., Gallardo, M., Meyburg, C. and Dimitrova, E. (2004a). Migrations and sojourn in Africa of Egyptian vultures (*Neophron percnopterus*) tracked by satellite. *Journal of Ornithology* **145**, 273-280.
- Meyburg, B. U., Meyburg, C., Belka, T., Sreibr, O. and Vrana, J. (2004b). Migration, wintering and breeding of a lesser spotted eagle (*Aquila pomarina*) from Slovakia tracked by satellite. *Journal of Ornithology* **145**, 1-7.
- Ministerial Review Committee (2006). 'Consolidated Report to the Ministers for Natural Resources and the Environment. NSW Native Vegetation Reforms.' (Ministerial Review Committee: Canberra).
- Moller, A. P., Berthold, P., Fiedler, W., Moller, A., Fiedler, W. and Berthold, P. (2004). The Challenge of Future Research on Climate Change and Avian Biology. In 'Advances in Ecological Research' pp. 237-245. (Academic Press)
- Monkkonen, M., Forsman, J. T. and Thomson, R. L. (2004). Qualitative geographical variation in interspecific interactions. *Ecography* **27**, 112-118.
- Moreau, R. E. (1972). 'The Palaearctic-African Bird Migration Systems.' (Academic Press: London).
- Munks, S., Richards, K., Meggs, J. and Brereton, R. (2004). The importance of adaptive management in 'off-reserve' conservation for forest fauna: implementing, monitoring and upgrading Swift Parrot *Lathamus discolor* conservation measures in Tasmania. In 'Conservation of Australia's Forest Fauna'. (Ed. D. Lunney) pp. 688-698. (Royal Zoological Society: Mosman)
- National Library of Australia (2006). 'National Treasures. George Raper, First Fleet Artist.' Available at <http://nationaltreasures.nla.gov.au/ExhibitionChecklist.pdf/Treasures/item/nla.int-ex6-s31>, accessed 1 September 2007.
- Natural Resource Management Ministerial Council (2000). 'National Framework for the Management and Monitoring of Australia's Vegetation'. (Australian Government: Canberra).

- Natural Resource Management Ministerial Council (2003). 'Framework for a national cooperative approach to Integrated Coastal Zone Management.' (Natural Resource Management Ministerial Council: Canberra).
- Natural Resources and Water (2007). 'Vegetation management framework - fact sheet.' (The State of Queensland: Brisbane).
- Newton, I. (2004). Population limitation in migrants - review. *Ibis* **146**, 197-226.
- Nicholls, N. (2004). The changing nature of Australian droughts. *Climatic Change* **63**, 323-336.
- Nix, H. A. (1976). Environmental control of breeding, post-breeding dispersal and migration of birds in the Australian region. In '16th International Ornithological Congress'. Canberra, Australia. (Eds H. J. Frith and J. H. Calaby) pp. 272-305. (Australian Academy of Science, Canberra)
- North, A. J. (1898). Birds of the County of Cumberland. *Handbook of the Australian Association for the Advancement of Science*, 68-116.
- NSW Department of Primary Industries (1999). 'Integrated Forest Operations Approval for Upper North East, Lower North East and Eden regions. Forestry and National Park Estate Act 1998.' (NSW Department of Primary Industries).
- NSW Scientific Committee (1997). 'Cumberland Plain Woodland - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 30 January 2006.
- NSW Scientific Committee (1998). 'Shale sandstone transition forest in the Sydney Basin Bioregion - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 9 November 2006.
- NSW Scientific Committee (2000). 'Bega dry grass forest in the South East Corner Bioregion - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 30 January 2006.
- NSW Scientific Committee (2001a). 'Clearing of native vegetation - key threatening process.' (NSW Department of Environment and Conservation) Available at <http://www.environment.nsw.gov.au/determinations/ClearingNativeVegKTPListing.htm>, accessed 23 July 2008.
- NSW Scientific Committee (2001b). 'Native vegetation on cracking clay soils of the Liverpool Plains - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 8 September 2007.
- NSW Scientific Committee (2002a). 'Hunter lowland redgum forest in the Sydney Basin and NSW North Coast bioregions - endangered ecological community

listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 9 November 2006.

NSW Scientific Committee (2002b). 'Shale gravel transition forest in the Sydney Basin Bioregion - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 30 January 2006.

NSW Scientific Committee (2002c). 'White Box, Yellow Box, Blakely's Red Gum Woodland - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 30 January 2006.

NSW Scientific Committee (2004a). 'River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 30 January 2006.

NSW Scientific Committee (2004b). 'Swamp sclerophyll forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 30 January 2006.

NSW Scientific Committee (2005). 'Lower Hunter Spotted Gum - Ironbark Forest in the Sydney Basin Bioregion - endangered ecological community listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 30 January 2006.

NSW Scientific Committee (2006). 'Inland Grey Box Woodland in the Riverina , New South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions - endangered ecological community preliminary listing.' (NSW Department of Environment and Conservation) Available at <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Final+determinations>, accessed 9 November 2006.

Oliver, D. L. (1998). The importance of insects and lerp in the diet of juvenile Regent Honeyeaters, *Xanthomyza phrygia*: implications for the conservation of an endangered woodland bird. *Wildlife Research* **25**, 409-417.

Oliver, D. L. (2000). Foraging behaviour and resource selection of the Regent Honeyeater *Xanthomyza phrygia* in northern New South Wales. *Emu* **100**, 12-30.

Olsen, P. (2007a). Parrot Pie. *Wingspan* **17**, 36-37.

Olsen, P. (Ed.) (2007b). 'The State of Australia's Birds 2007. Birds in a changing climate.' Supplement to *Wingspan* 14 (4) (Birds Australia: Melbourne).

- Opdam, P. and Wascher, D. (2004). Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation* **117**, 285-297.
- Otley, H. (2001). The use of a community-based survey to determine the distribution of the Platypus *Ornithorhynchus anatinus* in the Huon River Catchment, southern Tasmania. *Australian Zoologist* **31** (4), 632-641.
- PAHSMA (2007). 'Port Arthur Historic Site.' (Port Arthur Historic Site Management Authority) Available at <http://www.portarthur.org.au/>, accessed 4 September 2007.
- Parmesan, C. (2006). Ecological and Evolutionary Responses to Recent Climate Change. *Annual Review of Ecology, Evolution, and Systematics* **37**, 637-669.
- Parmesan, C. and Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature* **421**, 37-42.
- Paton, D. C. (1980). The importance of manna, honeydew and lerp in the diets of honeyeaters. *Emu* **80**, 213-226.
- Paton, D. C. (1985). Food supply, population structure, and behaviour of New Holland Honeyeaters *Phylidonyris novaehollandiae* in woodland near Horsham, Victoria. In 'Birds of eucalypt forests and woodlands: ecology, conservation, management.' (Eds A. Keast, H. F. Recher, H. Ford and D. Saunders) pp. 219-230. (RAOU and Surrey Beatty & Sons: Sydney)
- Paxton, K. L., Van Riper, C., Theimer, T. C. and Paxton, E. H. (2007). Spatial and temporal migration patterns of Wilson's Warbler (*Wilsonia pusilla*) in the southwest as revealed by stable isotopes. *The Auk* **124**, 162-175.
- Pfennigwerth, S. (2008). 'Minimising the swift parrot collision threat. Guidelines and recommendations for parrot-safe building design.' (WWF-Australia: Ultimo).
- Phillip, A. (1789). 'The Voyage of Governor Phillip to Botany Bay.' (John Stockdale: London).
- Phillips, R. A., Silk, J. R. D., Croxall, J. P., Afanasyev, V. and Bennett, V. J. (2005). Summer distribution and migration of non-breeding albatrosses: Individual consistencies and implications for conservation. *Ecology* **86**, 2386-2396.
- Pimm, S. L. (2008). Biodiversity: Climate Change or Habitat Loss - Which Will Kill More Species. *Current Biology* **18**, R117-R119.
- Pollard, M. (2000). 'Keeping Swift Parrots.' (Marcus Pollard: Hobart) Available at <http://www.finchsociety.org/cfa/parrot/swift/swift.htm>, accessed 18 July 2008.
- Pook, E. W., Gill, A. M. and Moore, P. H. (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. *Australian Journal of Botany* **45**, 737-755.
- Port Jackson Painter (1788-1797). Red-shouldered parrot. In 'Watling Drawing - No. 131'. (Natural History Museum).
- Porter, J. W. (1978). Relationships between flowering and honey production of red ironbark *Eucalyptus sideroxylon* and climate in the Bendigo district of Victoria. *Australian Journal of Agricultural Research* **29**, 815-829.

- Powell, G. V. N. and Bjork, R. (1995). Implications of intratropical migration on reserve design: a case study using *Pharomachrus mocinno*. *Conservation Biology* **9**, 354-362.
- Powell, J. M. (1969). The squatting occupation of Victoria, 1834-60. *Australian Geographical Studies* **7**, 9-27.
- Purchase, D. (1985). Bird-banding and the migration of Yellow-faced and White-naped Honeyeaters through the Australian Capital Territory. *Corella* **9**, 59-62.
- Pyke, G. (1983). Seasonal pattern of abundance of honeyeaters and their resources in heathland areas near Sydney. *Australian Journal of Ecology* **8**, 217-233.
- Pyke, G. (1985). The relationships between abundances of honeyeaters and their food resources in open forest areas near Sydney. In 'Birds of eucalypt forests and woodlands: ecology, conservation, management'. (Eds A. Keast, H. F. Recher, H. Ford and D. Saunders) pp. 65-77. (Surrey Beatty & Sons in association with the Royal Australasian Ornithologists: Chipping Norton)
- Raper, G. ([1789]). Parroquet and flower of Port Jackson. In 'Raper Drawing - No. 51'. (Natural History Museum).
- Raper, G. (c. 1789). [Swift parrot (*Lathamus discolor*)]. In 'Raper, George, 1769-1797. Ducie collection of First Fleet art.' (National Library of Australia).
- Reid, J. (1999). 'Threatened and declining birds in the New South Wales sheep-wheat belt: Diagnosis, characteristics and management.' (NSW National Parks and Wildlife Service: Queanbeyan).
- Resource Assessment Commission (1990). 'Australia's Forest and Timber Resources. Background paper No. 1.' (Resource Assessment Commission: Canberra).
- Ribbentrop, B. (1896). 'Report on the state forests of Victoria.' (Government Printer: Melbourne).
- Roshier, D. A. and Reid, J. R. (2003). On animal distributions in dynamic landscapes. *Ecography* **26**, 539-544.
- Roshier, D. A., Robertson, A. I., Kingsford, R. T. and Green, D. G. (2001). Continental-scale interactions with temporary resources may explain the paradox of large populations of desert waterbirds in Australia. *Landscape Ecology* **16**, 547-556.
- Rubenstein, D. R. and Hobson, K. A. (2004). From birds to butterflies: animal movement patterns and stable isotopes. *Trends in Ecology & Evolution* **19**, 256-263.
- Saunders, D. A. (1993). A community-based observer scheme to assess avian responses to habitat reduction and fragmentation in south-western Australia. *Biological Conservation* **64**, 203-218.
- Saunders, D. L. (2002a). 'Assessment of Swift Parrot Sites near Cessnock, Lower Hunter Valley Region, NSW – including the Hunter Employment Zone'. (National Swift Parrot Recovery Team: Queanbeyan).
- Saunders, D. L. (2002b). 'Incident report form - swift parrot trapping.' 26 June 2002 (Department of Environment and Heritage).

- Saunders, D. L. (2005). 'National Swift Parrot Recovery Program Achievements 1995-2004.' (A report prepared for the Commonwealth Department of Environment and Heritage, Natural Heritage Trust Endangered Species Program: Canberra).
- Saunders, D. L. (Ed.) (2007a). 'Draft National Recovery Plan for the Swift Parrot 2006-2010.' (Commonwealth Department of Environment, Water, Heritage and the Arts: Canberra).
- Saunders, D. L. (Ed.) (2007b). 'Draft National Recovery Plan for the Swift Parrot 2006-2010. Background document.' (Commonwealth Department of Environment, Water, Heritage and the Arts: Canberra).
- Schodde, R. and Mason, I. J. (1997). Psittacidae: Platycercinae, *Lathamus discolor* (Shaw, 1790). In 'Zoological Catalogue of Australia. Aves (Columbidae to Caraciidae).' (Eds W. W. K. Houston and A. Wells) pp. 148-151. (CSIRO Publishing: Melbourne)
- Seton, R. (c. 1800). Red-shouldered Parrakeet. In (Ed. R. Seton), 'Drawings / Album of watercolour drawings of Australian natural history'.
- Shukuroglou, P. and McCarthy, M. A. (2006). Modelling the occurrence of rainbow lorikeets (*Trichoglossus haematodus*) in Melbourne. *Austral Ecology* **31**, 240-253.
- Smith, G. A. (1975). Systematics of parrots. *Ibis* **117**, 18-68.
- Stone, S. (1790). Red-shoulderd [sic] paroquet. In (Ed. J. White), 'Journal of a Voyage to New South Wales'. (J. Debrett: London).
- Sunshine Coast Regional Council (2008). 'Voluntary Conservation Agreements (VCAs).' (Sunshine Coast Regional Council: Caloundra) Available at <http://www.caloundra.qld.gov.au/website/cityenvironment/environment/VCA.asp>, accessed 17 July 2008.
- Swift Parrot Recovery Team (2001). 'National Swift Parrot Recovery Plan 2001-2005.' (Department of Primary Industries, Water and Environment: Hobart).
- Swift Parrot Recovery Team (2008). 'Swift Parrot *Lathamus discolor*.' Educational DVD (Ed. G. Evans) (Department of Environment and Climate Change: Queanbeyan).
- Symes, C. T. and Perrin, M. R. (2003). Seasonal occurrence and local movements of the grey-headed (brown-necked) parrot *Poicephalus fuscicollis suahelicus* in southern Africa. *African Journal of Ecology* **41**, 299-305.
- Terrill, S. B. (1990a). Ecophysiological aspects of movements by migrants in the wintering quarters. In 'Bird Migration. Physiology and ecophysiology.' (Ed. E. E. Gwinner) pp. 130-143. (Springer-Verlag: Berlin)
- Terrill, S. B. (1990b). Food availability, migratory behaviour, and population dynamics of terrestrial birds during the non-reproductive season. *Studies in Avian Biology* **13**, 438-443.
- Terrill, S. B. and Ohmart, R. D. (1984). Facultative Extension of Fall Migration by Yellow-Rumped Warblers (*Dendroica-Coronata*). *Auk* **101**, 427-438.

- Thomson, R. L., Forsman, J. T. and Monkkonen, M. (2003). Positive interactions between migrant and resident birds: testing the heterospecific attraction hypothesis. *Oecologia* **134**, 431-438.
- Timewell, C. A. R. and Mac Nally, R. (2004). Diurnal foraging-mode shifts and food availability in nectarivore assemblages during winter. *Austral Ecology* **29**, 264-277.
- Troy, J. (1994). 'The Sydney Language.' (Pacific Linguistics?: Canberra).
- Tzaros, C. (2002a). Living in suburbia - opportunities and dangers for Swift Parrots on mainland Australia in 2002. *Eclectus* **13**, 13-14.
- Tzaros, C. (2002b). Swift parrots: Swift flight to recovery. In 'Wingspan'. Vol. 12, pp. 8-11.
- Underhill, L. G., Oatley, T. B. and Harrison, J. A. (1991). The Role of Large-Scale Data-Collection Projects in the Study of Southern African Birds. *Ostrich* **62**, 124-148.
- Underhill, L. G., Prys-Jones, R. P., Harrison, J. A. and Martinez, P. (1992). Seasonal patterns of occurrence of Palaearctic migrants in southern Africa using atlas data. *Ibis* **134**, 99-108.
- van Dongen, W. F. D. and Yocom, L. L. (2005). Breeding biology of a migratory Australian passerine, the golden whistler (*Pachycephala pectoralis*). *Australian Journal of Zoology* **53**, 213-220.
- Victoria Parliament (1865). Report on the advisableness of establishing state forests. Parliamentary paper 77. In 'The votes and proceedings of the legislative assembly 1864-5.' Vol. 4, pp. 1203-1209. (Government Printer: Melbourne).
- Victoria Parliament (1874). Papers relating to forest conservancy. Parliamentary paper 86. In 'Legislative assembly papers presented to parliament'. Vol. 3, pp. 923-932. (Government Printer: Melbourne).
- Villard, M., Merriam, G. and Maurer, B. A. (1995). Dynamics in subdivided populations of Neotropical migratory birds in a fragmented temperate forest. *Ecology* **76**, 27-40.
- Voogdt, J. (2006). 'Characteristics of swift parrot (*Lathamus discolor*) nesting habitat.' Honours thesis. Department of Biology, Gerof-August-University of Gottingen, Germany.
- Wadham, S. (1967). 'Australian Farming 1788-1965.' (F.W. Cheshire: Melbourne).
- Walther, G. R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J. C., Fromentin, J. M., Hoegh-Guldberg, O. and Bairlein, F. (2002). Ecological responses to recent climate change. *Nature* **416**, 389-395.
- Warkentin, I. G. and Hernandez, D. (1996). The conservation implications of site fidelity: A Case study involving nearctic-neotropical migrant songbirds wintering in a Costa Rican mangrove. *Biological Conservation* **77**, 143-150.
- Watson, I. (1955). Migratory flight of honeyeaters. *The Emu* **55**, 312-313.

- Webb, M. (2008). 'Swift Parrot Breeding Season Survey Report – 2007/08'. (Department of Primary Industries and Water: Hobart).
- Webb, M. and Voogdt, J. (in prep). The swift parrot: nest site selection, breeding aggregations and management implications.
- Webster, M. S. and Marra, P. P. (2004). The importance of understanding migratory connectivity and seasonal interactions. In 'Birds of two worlds. The ecology and evolution of migration.' (Eds R. Greenberg and P. P. Marra) pp. 199-209. (Smithsonian Institution: Washington, D.C.)
- Webster, M. S., Marra, P. P., Haig, S. M., Bensch, S. and Holmes, R. T. (2002). Links between worlds: unraveling migratory connectivity. *Trends in Ecology & Evolution* **17**, 76-83.
- Weston, M., Fendley, M., Jewell, R., Satchell, M. and Tzaros, C. (2003). Volunteers in bird conservation: insights from the Australian Threatened Bird Network. *Ecological Management and Restoration* **4**, 205-211.
- White, J. (1790). 'Journal of a Voyage to New South Wales.' (J. Debrett: London) Available at <http://gutenberg.net.au/ebooks03/0301531h.html>, accessed
- Wilkelski, M., Kays, R., Kasdin, N. J., Thorup, K., Smith, J. A. and Swenson, G. W. (2006). Going wild: what a global small-animal tracking system could do for experimental biologists. *The Journal of Experimental Biology* **210**, 181-186.
- Williams, J., Read, C., Norton, A., Dovers, S., Burgman, M., Proctor, W. and Anderson, H. (2001). 'Biodiversity: Australian State of the Environment Report 2001, Theme Report.' (CSIRO Publishing: Melbourne).
- Wilson, J. and Bennett, A. F. (1999). Patchiness of a floral resource: flowering of Red Ironbark *Eucalyptus tricarpa* in a Box and Ironbark Forest. *Vict. Nat.* **116**, 48-53.
- Woinarski, J. C. Z. (1984). Small birds, lerp-feeding and the problem of honeyeaters. *Emu* **84**, 137-141.
- Woinarski, J. C. Z., Cullen, J. M., Hull, C. and Nayudu, R. (1989). Lerp-feeding in birds: a smorgasbord experiment. *Australian Journal of Ecology* **14**, 227-234.
- WWF (2002). 'National Threatened Species Day Poster.' (World Wide Fund for Nature - Australia: Sydney).
- Youl, R., Marriott, S. and Yabben, T. (2006). 'Landcare in Australia, founded on local action.' (SILC and Rob Youl Consulting: Melbourne).
- Ziembicki, M. and Woinarski, J. C. (2007). Monitoring continental movement patterns of the Australian Bustard *Ardeotis australis* through community-based surveys and remote sensing. *Pacific Conservation Biology* **13**, 128-142.

Appendix 1

Table 10 – A collection of swift parrot specimen records from institutions around the world.

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
1	AMNH	619002	10/1/1891	1891	Unknown	(N. Queensland)	no details	skin	no details	Rothschild Collection
2	AMNH	619003	10/6/1891	1891	Queensland	Unknown	no details	skin	no details	Rothschild Collection
3	AMNH	619004	no details	no details	Unknown	(Bowen Queensland)	no details	skin	no details	Rothschild Collection
4	AMNH	619005	no details	no details	Unknown	(Bowen Queensland)	no details	skin	no details	Rothschild Collection
5	AMNH	619006	August	1908	NSW	Singleton	no details	skin	Mathews, G. and Schrader	Rothschild Collection
6	AMNH	619007	August	1908	NSW	Singleton	no details	skin	Mathews, G. and Schrader	Rothschild Collection
7	AMNH	619008	August	1908	NSW	Singleton	no details	skin	Mathews, G. and Schrader	Rothschild Collection
8	AMNH	619009	August	1908	NSW	Singleton	no details	skin	Mathews, G. and Schrader	Rothschild Collection
9	AMNH	619010	May	1885	NSW	Mudgee	no details	skin	Mathews, G. and others	Rothschild Collection
10	AMNH	619011	May	1885	NSW	Mudgee	no details	skin	Mathews, G. and others	Rothschild Collection
11	AMNH	619012	May	1885	NSW	Mudgee	no details	skin	Mathews, G. and others	Rothschild Collection
12	AMNH	619013	May	1885	NSW	Mudgee	no details	skin	Mathews, G. and others	Rothschild Collection
13	AMNH	619014	May	1885	NSW	Mudgee	no details	skin	Mathews, G. and others	Rothschild Collection
14	AMNH	619015	July?Apr.14	1909	Victoria	Mornington	no details	skin	Mathews, G. and others	Rothschild Collection
15	AMNH	619016	14-April-1909	1909	Victoria	Mornington	no details	skin	Mathews, G. and others	Rothschild Collection
16	AMNH	619017	no details	no details	Victoria	Mulgrave	no details	skin	Mathews, G. and others	Rothschild Collection
17	AMNH	619018	no details	no details	Victoria	Mulgrave	no details	skin	no details	Rothschild Collection
18	AMNH	619019	14-August	1910	Victoria	Parwan	no details	skin	Mathews, G. and others	Rothschild Collection
19	AMNH	619020	13-August	1910	Victoria	Parwan	no details	skin	Mathews, G. and Tregellas	Rothschild Collection

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
20	AMNH	619021	13-August-1910	1910	Victoria	Parwan	no details	skin	Mathews, G. and others	Rothschild Collection
21	AMNH	619022	14-August	1910	Victoria	Parwan	no details	skin	Mathews, G. and others	Rothschild Collection
22	AMNH	619023	6/9/1898	1898	Victoria	Castlemaine	no details	skin	Billinghurst, T.	Rothschild Collection
23	AMNH	619024	21-September	1901	Victoria	Auburn	no details	skin	Cole, C. and Mathews, G.	Rothschild Collection
24	AMNH	619025	November	1874	Victoria	Geelong	no details	skin	v. Hugel, A. and others	Rothschild Collection
25	AMNH	619026	no details	no details	Unknown	Australia	no details	skin	Smith, Cecil and others	Rothschild Collection
26	AMNH	619027	no details	1898	Unknown	Australia	no details	skin	From Sale Room [1898]	Rothschild Collection
27	AMNH	619028	no details	1898	Unknown	Australia	no details	skin	From Sale Room [1898]	Rothschild Collection
28	AMNH	619029	25-November	1912	Tasmania	Flinders Island	no details	skin	Cleland and Mathews, G.	Rothschild Collection
29	AMNH	619030	03-September	1914	Tasmania	Launceston	no details	skin	Thompson, H., Mathews, G.	Rothschild Collection
30	AMNH	619031	03-September	1914	Tasmania	Launceston	no details	skin	Thompson, H., Mathews, G.	Rothschild Collection
31	AMNH	619032	03-September	1914	Tasmania	Launceston	no details	skin	Thompson, H., Mathews, G.	Rothschild Collection
32	AMNH	619033	03-September	1914	Tasmania	Launceston	no details	skin	Thompson, H., Mathews, G.	Rothschild Collection
33	AMNH	619034	no details	no details	Tasmania	Unknown	no details	skin	Mathews, G. and others	Rothschild Collection
34	AMNH	619035	no details	no details	Tasmania	Unknown	no details	skin	Mathews, G. and others	Rothschild Collection
35	AMNH	619036	no details	no details	Tasmania	Unknown	no details	skin	no details	Rothschild Collection
36	ANS	22966	PRE 1846	1846	Unknown	Unknown	no details	no details	Wilson, Dr	Rivoli Coll.
37	ANS	22967	PRE 1848	1848	Tasmania	Unknown	no details	no details	Wilson, Dr	Gould Coll.
38	ANS	22968	PRE 1848	1848	NSW	Unknown	no details	no details	Wilson, Dr	Gould Coll.
39	ANS	22969	PRE 1848	1848	Tasmania	Unknown	no details	no details	Wilson, Dr	Gould Coll.
40	ANS	22970	PRE 1848	1848	Tasmania	Unknown	no details	no details	Wilson, Dr	Gould Coll.

Appendix 1

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
41	ANS	50700	no details	1906	NSW	Unknown	no details	no details	Tristram coll.	no details
42	ANS	133108	no details	1939	Unknown	Unknown	no details	no details	no details	no details
43	ANWC	248	22MAY1960	1960	ACT	Narrabundah	found dead	skin	no details	no details
44	ANWC	13482	08MAY1971	1971	NSW	Yambla Range, near Gerogery	SHOT	skin	Mark Clayton	no details
45	ANWC	15788	08MAY1971	1971	NSW	Yambla Range, near Gerogery	SHOT	skin, skeleton	Mark Clayton	no details
46	ANWC	28860	30AUG1999	1999	NSW	Reefton SF, 21km N of Temora	SHOT	skin	no details	no details
47	ANWC	30624	07DEC1958	1958	Tasmania	1 mile S of Antill Ponds	SHOT	skin	no details	no details
48	ANWC	30625	07DEC1958	1958	Tasmania	1 mile S of Antill Ponds	SHOT	skin	no details	no details
49	ANWC	30626	07DEC1958	1958	Tasmania	1 mile S of Antill Ponds	SHOT	skin	no details	no details
50	ANWC	30627	PRE 1970	1970	Tasmania	Wesley Vale, Devonport	Found injured	skin	no details	no details
51	ANWC	30733	DEC1989	1989	Tasmania	Launceston	no details	skeleton	no details	no details
52	ANWC	40599	1986	1986	Tasmania	Hobart	no details	skin	no details	no details
53	ANWC	40600	1986	1986	Tasmania	Hobart	no details	skin	no details	no details
54	ANWC	42298	26JUL1988	1988	Victoria	Marong SF, Bendigo	SHOT	skin	no details	no details
55	ANWC	42299	26JUL1988	1988	Victoria	Marong SF, Bendigo	SHOT	skin	no details	no details
56	ANWC	42300	26JUL1988	1988	Victoria	Marong SF, Bendigo	SHOT	skin	no details	no details
57	ANWC	47017	PRE 1994	1994	Tasmania	Hobart area	no details	skin	no details	no details
58	ANWC	47205	1992	1992	Tasmania	Hobart area	no details	skeleton	no details	no details
59	ANWC	47207	04SEP1992	1992	Tasmania	Bellvue, Hobart	no details	skin	no details	no details
60	ANWC	47209	PRE 1995	1995	Tasmania	Hobart area	no details	skin	no details	no details

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
61	ANWC	47210	18MAY1992	1992	Tasmania	Hobart area	no details	skin	no details	no details
62	ANWC	47211	18MAY1992	1992	Tasmania	Hobart area	no details	skin	no details	no details
63	ANWC	47217	OCT1993	1993	Tasmania	Hobart area	no details	skin	no details	no details
64	ANWC	47218	OCT1993	1993	Tasmania	Hobart area	no details	skin	no details	no details
65	ANWC	47219	OCT1993	1993	Tasmania	Hobart area	no details	skin	no details	no details
66	ANWC	47220	OCT1993	1993	Tasmania	Hobart area	no details	skin	no details	no details
67	ANWC	47221	OCT1993	1993	Tasmania	Hobart area	no details	skin	no details	no details
68	ANWC	47262	no details	no details	Tasmania	Hobart area	no details	skeleton	no details	no details
69	ANWC	47263	no details	no details	Tasmania	Hobart area	no details	skeleton	no details	no details
70	ANWC	49091	MAY1997	1997	ACT	Botanic Gardens West	no details	skin	no details	no details
71	ANWC	49838	29JAN1995	1995	Tasmania	Launceston	no details	spirit	no details	no details
72	ANWC	49839	1997	1997	Tasmania	Hobart	no details	skin	no details	no details
73	AustM	A.10	no details	no details	NSW	Dee Why, Sydney	no details	skin	no details	no details
74	AustM	A.11	no details	no details	NSW	Dee Why, Sydney	no details	skin	no details	no details
75	AustM	O.16477	no details	no details	NSW	Campbelltown	no details	skin	no details	no details
76	AustM	O.16479	no details	no details	NSW	Campbelltown	no details	skin	no details	no details
77	AustM	O.16481	no details	no details	NSW	Campbelltown	no details	skin	no details	no details
78	AustM	O.16748	no details	no details	NSW	Smithfield	no details	skin	no details	no details
79	AustM	O.17947	no details	no details	NSW	Ashfield, Sydney	no details	skin	no details	no details
80	AustM	O.17948	no details	no details	Unknown	Dawson River?, Queensland	no details	skin	no details	no details
81	AustM	O.17949	no details	no details	Tasmania	Unknown	no details	skin	no details	no details

Appendix 1

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
82	AustM	O.18794	no details	no details	Tasmania	Hobart	no details	eggs	no details	no details
83	AustM	O.18795	no details	no details	Tasmania	Hobart	no details	eggs	no details	no details
84	AustM	A.1969	no details	no details	Tasmania	Unknown	no details	skin	no details	no details
85	AustM	O.20397	no details	no details	NSW	Unknown	no details	skin	no details	no details
86	AustM	O.20398	no details	no details	NSW	Unknown	no details	skin	no details	no details
87	AustM	O.20399	no details	no details	NSW	Unknown	no details	skin	no details	no details
88	AustM	O.20400	no details	no details	Tasmania	Unknown	no details	skin	no details	no details
89	AustM	O.20401	no details	no details	Tasmania	Unknown	no details	skin	no details	no details
90	AustM	O.21657	no details	no details	Unknown	[irn: 3008084]	no details	skin	no details	no details
91	AustM	O.22770	no details	no details	Unknown	[irn: 3008084]	no details	skin	no details	no details
92	AustM	O.2311	no details	no details	Unknown	[irn: 3008084]	no details	skin	no details	no details
93	AustM	O.2312	no details	no details	Unknown	[irn: 3008084]	no details	skin	no details	no details
94	AustM	O.23546	no details	no details	Tasmania	Hamilton	no details	skin	no details	no details
95	AustM	O.23547	no details	no details	Tasmania	Unknown	no details	skin	no details	no details
96	AustM	O.27348	no details	no details	NSW	Boggabri	no details	skin	no details	no details
97	AustM	O.27665	no details	no details	Unknown	Cape York Peninsula?	no details	skin	no details	no details
98	AustM	O.28243	no details	no details	NSW	Delegate	no details	skin	no details	no details
99	AustM	O.28450	28/05/1915	1915	Tasmania	Railton	no details	skin	no details	no details

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
100	AustM	O.28451	1910	1910	Tasmania	Devonport	no details	skin	no details	no details
101	AustM	O.28452	1910	1910	Tasmania	La Trobe	no details	skin	no details	no details
102	AustM	O.28453	/10/1912	1912	NSW	Tarana	no details	skin	no details	no details
103	AustM	O.28454	/01/1909	1909	NSW	Tarana	no details	skin	no details	no details
104	AustM	O.28455	/10/1912	1912	NSW	Tarana	no details	skin	no details	no details
105	AustM	O.28456	/10/1912	1912	NSW	Tarana	no details	skin	no details	no details
106	AustM	O.28457	/01/1909	1909	NSW	Tarana	no details	skin	no details	no details
107	AustM	O.28458	/10/1903	1903	NSW	Richmond River	no details	skin	no details	no details
108	AustM	O.39756	10/07/1958	1958	NSW	Killara, Sydney	no details	skin	no details	no details
109	AustM	O.45427	12/09/1975	1975	Captive bird	EX-CAGE	no details	skin	no details	no details
110	AustM	O.48043	07/12/1915	1915	Tasmania	Knock Lofty	no details	eggs	no details	no details
111	AustM	O.50940	no details	no details	Tasmania	Unknown	no details	eggs	no details	no details
112	AustM	A.5372	no details	no details	Tasmania	Unknown	no details	skin	no details	no details
113	AustM	A.5373	no details	no details	Tasmania	Unknown	no details	skin	no details	no details
114	AustM	O.63948	30/11/1926	1926	Tasmania	Cleveland	no details	eggs	no details	no details
115	AustM	O.64467	/03/1991	1991	Tasmania	Devonport	no details	skin	no details	no details
116	AustM	O.64646	12/04/1992	1992	NSW	Baulkham Hills	no details	spirit	no details	no details
117	AustM	O.67955	27/10/1992	1992	Tasmania	Launceston	no details	bones	no details	no details
118	AustM	O.67956	30/11/1988	1988	Tasmania	Geilston Bay	no details	bones	no details	no details
119	AustM	O.68239	09/11/1996	1996	NSW	Tacoma	no details	skin	no details	no details
120	AustM	O.68481	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details
121	AustM	O.68481	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details
122	AustM	O.68482	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details

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	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
123	AustM	O.68482	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details
124	AustM	O.68484	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details
125	AustM	O.68484	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details
126	AustM	O.70093	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details
127	AustM	O.70093	no details	no details	Captive bird	Ex-captive	no details	bones	no details	no details
128	AustM	O.70336	10/03/1964	1964	Tasmania	East Devonport	no details	skin	no details	no details
129	AustM	O.70580	30/07/2000	2000	NSW	Woolgoolga	no details	skin	no details	no details
130	AustM	O.70658	/06/2000	2000	NSW	The Rock	no details	skin	no details	no details
131	AustM	O.70692	18/07/2002	2002	NSW	Bateau Bay	no details	skin	no details	no details
132	AustM	O.70849	14/07/2002	2002	NSW	Shaw's Creek, via Yarramundi	no details	spirit	no details	no details
133	AustM	O.70882	13/05/2002	2002	NSW	Budgewoi	no details	spirit	no details	no details
134	AustM	A.7160	/10/1879	1879	Tasmania	near Launceston	no details	skin	no details	no details
135	AustM	A.7161	/10/1879	1879	Tasmania	near Launceston	no details	skin	no details	no details
136	AustM	A.7162	/10/1879	1879	Tasmania	near Launceston	no details	skin	no details	no details
137	AustM	A.7163	/10/1879	1879	Tasmania	near Launceston	no details	skin	no details	no details
138	AustM	A.7164	/10/1879	1879	Tasmania	near Launceston	no details	skin	no details	no details
139	FM	4038	no details	no details	Unknown	Unknown	no details	skin	no details	no details
140	FM	105128	1 June 1936	1936	Captive bird	captive bird	captive	skeleton	no details	no details
141	FM	300028	1979	1979	Captive bird	captive bird	captive	skin	no details	no details
142	FM	301879	no details	no details	Unknown	Unknown	no details	skin	no details	no details
143	NHM		no details	no details	Unknown	Unknown	no details	skin	no details	no details

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
144	NHM	unreg.	1842	1842	Tasmania	Van Diemen's Land	no details	no details	"Antarctic expedition"	no details
145	NHM	unreg.	1842	1842	Tasmania	Van Diemen's Land	no details	no details	"Antarctic expedition"	no details
146	NHM	unreg.	[1891]	[1891]	Unknown	Unknown	no details	no details	no details	Gould
147	NHM		[1891]	[1891]	Unknown	Unknown	no details	spirit	no details	no details
148	NHM		[1891]	[1891]	Unknown	Unknown	no details	skeleton	no details	no details
149	NHM	S/1989.26.37	[1891]	[1891]	Captive bird	died in captivity	no details	no details	G. Smith	no details
150	NHM		[1891]	[1891]	Unknown	Unknown	no details	eggs	no details	no details
151	NHM	E/1962.1.644	[1891]	[1891]	Captive bird	laid in captivity	no details	no details	no details	Henry Munt
152	NHM	1844.7.15.42	Sept 1842	1842	Tasmania	Van Diemen's Land	no details	no details	J.B. Jukes	no details
153	NHM	1844.7.15.43	July 1842	1842	Tasmania	Van Diemen's Land	no details	no details	J.B. Jukes	no details
154	NHM	1845.3.15.33	[1891]	[1891]	Unknown	New Holland	no details	no details	no details	Warwick
155	NHM	1847.8.14.72	18 May 1846	1846	Unknown	New Holland	no details	no details	Sir T. Mitchell	no details
156	NHM	1856.3.14.41	[1891]	[1891]	Unknown	Australia	no details	no details	Sir D.E. Cooper	no details
157	NHM	1881.5.1.4745	[1891]	[1891]	Unknown	Australia	no details	no details	no details	Gould
158	NHM	1881.12.7.31	[1891]	[1891]	Unknown	Australia	no details	no details	J.T. Cockerell	Salvin/Godman
159	NHM	1881.12.7.32	[1891]	[1891]	Unknown	Australia	no details	no details	J.T. Cockerell	Salvin/Godman
160	NHM	1884.9.29.6	[1891]	[1891]	Unknown	Australia	no details	no details	J. Abrahams	no details
161	NHM	1889.1.20.35	[1891]	[1891]	Unknown	Unknown	no details	no details	no details	Tweeddale
162	NHM	1889.6.12.113	[1891]	[1891]	Tasmania	Tasmania	no details	no details	C.G.H. Lloyd	no details
163	NHM	1889.6.12.114	[1891]	[1891]	Tasmania	Tasmania	no details	no details	C.G.H. Lloyd	no details
164	NHM	1893.4.4.173	[1891]	[1891]	Tasmania	Tasmania	no details	no details	Lord Leigh	no details
165	NHM	1893.4.4.174	[1891]	[1891]	Unknown	Unknown	no details	no details	Lord Leigh	no details
166	NHM	1921.11.28.2	[1891]	[1891]	Unknown	Unknown	no details	no details	Le Soef	no details
167	NHM	1924.1.16.1	15-Jan-24	1924	Captive bird	died in captivity	no details	no details	Marquess of Tavistock	no details

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	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
168	NHM	1924.1.16.2	18-Jan-24	1924	Captive bird	died in captivity	no details	no details	Marquess of Tavistock	no details
169	NHM	1925.11.1.415	Aug-24	1924	NSW	Dooralong, NSW	no details	no details	T.H. Wright	BM Exped.
170	NHM	1937.8.9.1	23-Aug-37	1937	Captive bird	bred and died in captivity	no details	no details	Marquess of Tavistock	no details
171	NHM	1937.8.9.1	23-Aug-37	1937	Captive bird	bred and died in captivity	no details	no details	Marquess of Tavistock	no details
172	NHM	1969.41.633	[1891]	[1891]	Tasmania	Tasmania	no details	no details	"WWS"	Hewitt
173	NHM	1991.7.36	[1891]	[1891]	Unknown	Unknown	no details	no details	no details	F. Marsh, G.L. Marsh
174	NHM	1991.7.37	[1891]	[1891]	Unknown	Unknown	no details	no details	no details	F. Marsh, G.L. Marsh
175	SAM	1,234	no details	1914	SA	Blackwood	no details	skin	Ashby E.	no details
176	SAM	1,235	no details	1914	SA	Blackwood	no details	skin	Ashby E.	no details
177	SAM	1,372	no details	1914	SA	Blackwood	no details	skin	Ashby E.	no details
178	SAM	1,373	no details	1914	SA	Blackwood	no details	skin	Ashby E.	no details
179	SAM	3,698	7-Nov-1885	1885	Tasmania	Austins Ferry	no details	eggs (2)	Moysey T.	no details
180	SAM	4,376	9-Jul-1914	1914	SA	Blackwood	no details	skin	Parsons F.E.	no details
181	SAM	8,340	x-Dec-1908	1908	NSW	Singleton	no details	skin	no details	no details
182	SAM	8,341	pre-1911	1911	SA	Adelaide, near Adelaide	no details	skin	no details	no details
183	SAM	8,342	x-Dec-1908	1908	NSW	Singleton	no details	skin	no details	no details
184	SAM	14,532	8-Nov-1925	1925	Tasmania	North Bruny Island	no details	egg clutch (4)	Deane N.	no details
185	SAM	19,501	18-Aug-1920	1920	SA	Blackwood	no details	skin	Ashby E.	no details
186	SAM	20,124	May-1892	1892	Victoria	Kaniva	no details	skin	no details	no details
187	SAM	20,125	May-1892	1892	Victoria	Kaniva	no details	skin	no details	no details
188	SAM	20,126	3-Jul-1878	1878	NSW (? Victoria locality)	Balranald	no details	skin	no details	no details

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
189	SAM	22,152	21-Nov-1926	1926	Tasmania	Cleveland	no details	egg clutch	no details	no details
190	SAM	22,939	18-Aug-1920	1920	SA	Blackwood	no details	skin	Parsons F.E.	no details
191	SAM	22,940	18-Aug-1920	1920	SA	Blackwood	no details	skin	Parsons F.E.	no details
192	SAM	47,142	28-May-1938	1938	SA	Hawthorndene	no details	skin	Rix C.E.	no details
193	SAM	47,143	28-May-1938	1938	SA	Hawthorndene	no details	skin	Rix C.E.	no details
194	Smith	9380	20 Jun 1865	1865	NSW	Dobroyde	no details	skeleton	Collector Unknown	no details
195	Smith	9381	no details	no details	NSW	Dobroyde	no details	skeleton	Collector Unknown	no details
196	Smith	70548	no details	no details	Unknown	Unknown	no details	skin: whole	Gaskell, J.	no details
197	Smith	88314	1800s	1800	Tasmania	Unknown	no details	skin: whole	Collector Unknown	no details
198	Smith	103709	no details	no details	Tasmania	Unknown	no details	skin: whole	Lloyd, C. G.	no details
199	Smith	103710	no details	no details	Tasmania (incorrect Northern Territory)	Unknown	no details	skin: whole	Lloyd, C. G.	no details
200	Smith	110548	1880	1880	Unknown	Unknown	no details	skin: whole	Bear, J.	no details
201	Smith	145782	no details	no details	Unknown	Unknown	no details	skin: whole	Cockerell, H.	no details
202	Smith	145783	no details	no details	Unknown	Unknown	no details	skin: whole	Cockerell, H.	no details
203	Smith	632243	Mar-2003	2003	Victoria	Healesville, Healesville Sanctuary	no details	Spirits	Collector Unknown	no details
204	Smith	632255	Mar-2003	2003	Victoria	Healesville, Healesville Sanctuary	no details	skeleton: skin	Collector Unknown	no details
205	Smith	632256	Mar-2003	2003	Victoria	Healesville, Healesville Sanctuary	no details	skeleton	Collector Unknown	no details
206	TMAG	ZV15261	no details	no details	Unknown	Unknown	no details	no details	no details	no details

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	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
207	TMAG	B5937	22/12/1998	1998	Tasmania	Mt Nelson	no details	specimen	Mr Bob Hayes	no details
208	TMAG	B1893	no details	no details	Unknown	Unknown	no details	specimen	no details	no details
209	TMAG	B1957	no details	no details	Unknown	Unknown	no details	specimen	no details	no details
210	TMAG	B2458	no details	no details	Unknown	Unknown	no details	specimen	no details	no details
211	TMAG	B4019	27/11/1979	1979	Tasmania	Rose Bay	no details	specimen	Alistair Hobday	no details
212	TMAG	B4273	17/08/1982	1982	Tasmania	Taroona	no details	specimen	Mrs. J Parrot	no details
213	TMAG	B4274	7/08/1982	1982	Tasmania	Taroona	no details	specimen	Mrs. J Parrot	no details
214	TMAG	B4375	30/10/1985	1985	Tasmania	Sandy Bay	no details	specimen	Mrs. B Tilley	no details
215	TMAG	B4387	26/10/1987	1987	Tasmania	Sandfly	no details	specimen	Mrs. Helen Mount	no details
216	TMAG	B4392	7/01/1986	1986	Tasmania	Neika	no details	specimen	Ms. Kiera Schaffer	no details
217	TMAG	B4404	11/12/1987	1987	Tasmania	New Town	no details	specimen	Ms. C Bourgeoise	no details
218	TMAG	B4459	5/09/1988	1988	Tasmania	Lindisfarne	no details	specimen	Timothy Kleywegt	no details
219	TMAG	B4577	25/01/1986	1986	Tasmania	Blackmans Bay	no details	specimen	Mrs. F Watson	no details
220	TMAG	B4594	29/07/1989	1989	Tasmania	Mt. Stuart	no details	specimen	Chris Walker	no details
221	TMAG	B4625	no details	no details	Tasmania	Hobart	no details	specimen	John Stevens	no details
222	TMAG	B4626	no details	no details	Tasmania	Hobart	no details	specimen	John Stevens	no details
223	TMAG	B4661	23/11/1992	1992	Tasmania	Lindisfarne	no details	specimen	Mrs. J Bindoff	no details
224	TMAG	B4663	9/01/1993	1993	Tasmania	Cambridge	no details	specimen	Mr. J Keil	no details
225	TMAG	W1994.224	no details	no details	Unknown	Unknown	no details	mount	no details	no details
226	TMAG	W1994.225	no details	no details	Unknown	Unknown	no details	mount	no details	no details
227	TMAG	W1994.68	no details	no details	Unknown	Unknown	no details	mount	no details	no details

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
228	VicM	R.10786	1926	1926	Victoria	Unknown Healesville	no details	skin	no details	no details
229	VicM	B.11142	1972	1972	Victoria	Sanctuary	no details	skeleton	no details	no details
230	VicM	HLW.113	01 09 1901	1901	NSW	Marrangaroo	no details	skin	no details	no details
231	VicM	HLW.114	01 09 1901	1901	NSW	Marrangaroo Clayton, Monash	no details	skin	no details	no details
232	VicM	B.12645	21 04 1978	1978	Victoria	University Clayton, Monash	no details	skin	no details	no details
233	VicM	B.12793	01 04 1978	1978	Victoria	University	no details	skeleton	no details	no details
234	VicM	HLW.137	05 1905	1905	Victoria	Somerville	no details	skin	no details	Ex A.G.Campbell Coll.
235	VicM	BE.1435	01 08 1895	1895	NSW	South Grafton, Clarence R	no details	eggs	no details	Jacksonian Coll. #176
236	VicM	B.14823	07 05 1898	1898	Victoria	Doctors Creek Bendigo, Marong State	no details	skin	no details	Ex Robert Hall Collection
237	VicM	B.15172	27 07 1988	1988	Victoria	Forest Bendigo, Marong State	no details	skin	no details	no details
240	VicM	B.15173	27 07 1988	1988	Victoria	Forest Bendigo, Marong State	no details	skin	no details	no details
241	VicM	B.15174	27 07 1988	1988	Victoria	Forest Bendigo, Marong State	no details	skin	no details	no details
242	VicM	B.15175	27 07 1988	1988	Victoria	Forest	no details	skin	no details	no details
243	VicM	B.1706	no details	no details	Victoria	Somerville area Bendigo, Marong State	no details	no details	no details	Deregistered
244	VicM	B.17863	26 07 1988	1988	Victoria	Forest Bendigo, Marong State	no details	skeleton, wing	no details	no details
245	VicM	B.17864	27 07 1988	1988	Victoria	Forest	no details	skeleton, wing	no details	no details

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	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
246	VicM	B.17865	27 07 1988	1988	Victoria	Bendigo, Marong State Forest	no details	skeleton, wing	no details	no details
278	VicM	B.1994	no details	no details	Victoria	Geelong district?	no details	no details	no details	Deregistered
279	VicM	B.20589	07 08 1992	1992	Victoria	Pakenham	no details	skeleton	no details	no details
247	VicM	B.20733	26 07 1988	1988	Victoria	Bendigo, Marong State Forest	no details	skeleton	no details	no details
248	VicM	B.20752	26 06 1990	1990	Victoria	Phillip Island	no details	skeleton	no details	no details
249	VicM	B.21140	no details	no details	Victoria	Unknown	no details	mount	no details	no details
250	VicM	B.2278	28 05 1948	1948	Victoria	Bendigo	no details	skin	no details	no details
251	VicM	B.2324	1948	1948	Captive bird	Captive bird	no details	skin	no details	no details
252	VicM	B.24065	09 05 2002	2002	Victoria	Donvale	no details	skin	no details	no details
253	VicM	B.25904	12 05 1898	1898	Victoria	Stawell	no details	skin	no details	Ex RAOU Collection
238	VicM	B.27741	no details	no details	Unknown	Australia	no details	no details	no details	no details
239	VicM	B.3095	18 08 1950	1950	Victoria	Big Hill, near Bendigo	no details	skin	no details	no details
254	VicM	B.3096	18 08 1950	1950	Victoria	Big Hill, near Bendigo	no details	skin	no details	no details
255	VicM	B.3097	23 08 1950	1950	Victoria	Eaglehawk, near Bendigo	no details	skin	no details	no details
256	VicM	B.30984	no details	no details	Victoria	Blackburn	no details	no details	no details	no details
257	VicM	B.30985	no details	no details	Victoria	Clayton, Monash University	no details	no details	no details	no details
258	VicM	B.30986	no details	no details	Victoria	Greensborough	no details	no details	no details	no details
259	VicM	B.30987	no details	no details	Victoria	Blackburn South	no details	no details	no details	no details

	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
260	VicM	B.31359	no details	no details	Unknown	Australia	no details	no details	no details	no details
261	VicM	R.4535	1910	1910	Victoria	Rosedale, Gippsland	no details	skin	no details	no details
262	VicM	BE.5129	21 10 1925	1925	Tasmania	North Bruny Is	no details	eggs	no details	no details
263	VicM	BE.5130	24 10 1928	1928	Tasmania	North Bruny Is	no details	eggs	no details	no details
264	VicM	B.5656	27 10 1951	1951	Victoria	Heidelberg	no details	skin	no details	no details
265	VicM	B.5657	27 10 1951	1951	Victoria	Heidelberg	no details	skin	no details	no details
266	VicM	B.598	03 04 1938	1938	Victoria	Healesville	no details	skin	no details	no details
267	VicM	B.6329	10 11 1951	1951	Victoria	Heidelberg	no details	skeleton	no details	no details
268	VicM	B.6898	10 10 1955	1955	Victoria	Ballan	no details	skin	no details	no details
269	VicM	BE.6898	no details	no details	Tasmania	Unknown	no details	eggs	no details	no details
280	VicM	B.7198	25 04 1956	1956	Victoria	Clunes	no details	skin	no details	no details
276	VicM	B.7580	27 07 1958	1958	Victoria	Mildura district	no details	skin	no details	no details
277	VicM	R.8776	1890	1890	Victoria	Boort	no details	skin	no details	no details
270	VicM	R.8777	1890	1890	Victoria	Boort	no details	skin	no details	no details
293	VicM	R.8778	1890	1890	Victoria	Boort	no details	skin	no details	no details
289	VicM	R.8779	1890	1890	Victoria	Boort	no details	skin	no details	no details
290	VicM	R.8780	1890	1890	Victoria	Boort	no details	skin	no details	no details
271	VicM	R.8781	1868	1868	Victoria	Unknown	no details	skin	no details	no details
284	VicM	R.8782	1868	1868	Victoria	Unknown	no details	skin	no details	no details
288	VicM	R.8783	1868	1868	Victoria	Unknown	no details	skin	no details	no details
283	VicM	R.8784	1871	1871	Victoria	Bungaree	no details	skin	no details	no details
287	VicM	R.8785	1905	1905	Victoria	Big Hill, near Bendigo	no details	skin	no details	no details
282	VicM	R.8786	no details	no details	Victoria	Melbourne area	no details	skin	no details	no details

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	Source*	RefNo.	Collection Date	Year	State	Locality	How collected	Specimen	Collector/Source	Collection Name
286	VicM	R.8787	no details	no details	Victoria	Melbourne area	no details	skin	no details	no details
281	VicM	34099	1869	1869	Victoria	Lake Bryngaree	no details	mount	no details	no details
285	VicM	34100	no details	no details	Victoria	Lake Bryngaree	no details	no details	no details	Deregistered
272	VicM	34101	1869	1869	Victoria	Lake Bryngaree	no details	mount	no details	no details
273	WAM	10656	04-January	1931	Tasmania	Bothwell	no details	eggs (3)	no details	no details
274	WAM	18928	no details	no details	Victoria	Box Hill	no details	no details	no details	no details
275	WAM	18929	no details	no details	Victoria	Box Hill	no details	no details	no details	no details
292	WAM	29179	00/12/1889	1889	NSW	Singleton	no details	skin	no details	no details
291	WAM	29180	no details	no details	NSW	Murray District	no details	skin	no details	no details

* Smith = Smithsonian Institution, Washington DC; AMNH = American Museum of Natural History, New York; FM = Field Museum, Chicago; ANS = Academy of Natural Science, Philadelphia; NHM = Natural History Museum, United Kingdom; ANWC = CSIRO Australian National Wildlife Collection, ACT; WAM = Western Australian Museum, Western Australia; SAM = South Australian Museum, South Australia; TMAG = Tasmanian Museum and Art Gallery, Tasmania; VicM = Victorian Museum, Victoria; AusM = Australian Museum, New South Wales; bold text = Gould collection

Appendix 2

Table 11 – Number of swift parrots held in captivity by private licensed aviculturalists in Australia
(as reported by state government licensing agencies in 2004).

State	Number of captive Swift Parrots	Number of licenses
NSW	118	12
Victoria	51	14
Queensland	0	0
ACT	0	0
South Australia	21	5
Tasmania	68	5
Total	258	36