AUSTRALIAN FIELD ORNITHOLOGY 2006, 23, 109–124

Breeding Habits and Conservation Status of the Musk Lorikeet *Glossopsitta concinna* and Little Lorikeet *G. pusilla* in Northern New South Wales

JOHN COURTNEY[1] and S.J.S. DEBUS[2]

[1]40 Sapphire Street, Inverell, New South Wales 2360
(Email: jycourtney@northnet.com.au)
[2]Division of Zoology, University of New England, Armidale, New South Wales 2351

Summary

Long-term observations, spanning 43 years, established that on the North-west Slopes of New South Wales (NSW) Musk Lorikeets *Glossopsitta concinna* and Little Lorikeets *G. pusilla* used traditional nest-sites in mature and old-growth stands of smooth-barked gums *Eucalyptus* spp., within 2 km of stands of their key food trees (flowering White Box *E. albens* and Yellow Box *E. melliodora*). Nest-sites were tight knotholes in live trees, at 3.0–15.2 m (Musk) or 2.4–15.2 m (Little) above the ground; entrance dimensions (vertical × horizontal) of ~ 37 × 43 mm and ~ 29 × 34 mm, respectively, were maintained by regular biting of the regrowing bark. Breeding adults were resident for most of the year, returning periodically in the non-breeding season to maintain and defend nest-hollows. Eggs were laid in winter, and second clutches were laid in spring if Yellow Box flowered profusely. Because of a loss of nest-trees and food resources, breeding Little Lorikeets have declined almost to local extinction in the region, and the species warrants recognition as at least vulnerable, if not endangered, in NSW.

Introduction

Breeding of the Musk Lorikeet *Glossopsitta concinna* in the wild is 'poorly known, with no detailed studies' and there are no records in the Birds Australia Nest Record Scheme (NRS). Similarly, the Little Lorikeet *G. pusilla* is 'not well known, with no detailed studies' and there are only 19 records in the NRS to December 1995 (Higgins 1999). It is apparent that few nests have been found or documented; Horton & Black (2006) listed 19 Little Lorikeet clutches taken in New South Wales (NSW), mostly from the 19th and early 20th centuries but with one taken in 1957, one in 1960 and two in 1995. Eleven Little Lorikeet clutches from South Australia (SA), seven from Victoria and ~ 14 from Queensland are all historical collections, with little biological information recorded (see Horton & Black 2006).

Little Lorikeets are sometimes said to nest at great heights, but this is apparently a myth among ornithologists who are unfamiliar with their nests (Courtney in Low 1998). Both species' nests are said to be 'like that of [the Rainbow Lorikeet] *Trichoglossus haematodus*', though the Little Lorikeet nests 'in much smaller hollows'; they are said to nest 'once each year' and (for Musk) 'rarely twice' (Beruldsen 2004). Both species are believed to be nomadic or seasonal in occurrence (reviewed by Higgins 1999), although breeding adults on the North-west Slopes of NSW periodically visit their traditional nests, to maintain them, in the non-breeding season (Courtney in Low 1998).

Courtney's 43-year experience of nesting Musk and Little Lorikeets was summarised by Low (1998). The purpose of this paper is to make the information more accessible to Australian ornithologists, to supplement it with recent observations, and to assess the conservation status of the breeding population of these lorikeet species west of the Great Dividing Range watershed, in northern NSW.

Study area and methods

The area within which Courtney resided and observed lorikeets, on his 400-ha property 'Ashgrove' at Swan Vale (29°45′S, 151°25′E) from 1962 to 2005, is 50 km long and 15 km wide, between Glen Innes and Inverell on the North-west Slopes of NSW, in the Macintyre River catchment. Remnant grassy woodland, within an agricultural landscape, was dominated by various eucalypts depending on soil type and topographic position: Manna Gum *Eucalyptus viminalis*, Blakely's Red Gum *E. blakelyi*, Yellow Box *E. melliodora* and White Box *E. albens*, with Rough-barked Apple *Angophora floribunda* at some sites and Tumbledown Gum *E. dealbata* on ridges. In the 27 years to 1989, Courtney observed about 50 Little Lorikeet nests and ~ 60 Musk Lorikeet nests. Further details are given by Courtney in Low (1998). Clearing of remnant woodland since 1989 has continued on private land and to some extent on roadside verges, though some woodland has persisted on public land in the study area.

Observations of nesting lorikeets by Courtney continued until 2005; in late July and mid September 2005 Courtney and Debus revisited the nesting sites around Swan Vale detailed by Low (1998). The sites visited in 2005 are here designated as below, with the lowest nests examined by stepladder and the entrances measured with Vernier calipers. In previous years, the internal dimensions of several nests were measured when storm damage exposed nest-cavities, or when trees (or parts thereof) containing nests fell down. Measurements of exposed cavities were made with a steel ruler or, for a few shallow or horizontal nest-tunnels, *in situ*, with a rigid steel tape-measure.

Site 1: town common of ~ 10 ha, classified as public land; a stand of mature and old-growth Blakely's Red Gums on a creek-flat on basalt soil (an unusual combination of tree community and physiography locally), surrounded by stands of Yellow Box.
Site 2: highway verge of ~ 1 ha at Swan Vale; stand of mature Blakely's Red Gum.
Site 3: highway verge of ~ 2 ha slightly farther east and higher elevation than site 2 at Swan Vale; stand of mature Manna Gum with some Rough-barked Apple.
Videotape and digital photographs of nests and activity of both species were obtained at these sites by Professor Dominique Homberger and Dr Ravi Rau in June 2004, and by Peter Odekerken in June 2005.

The basis for the accounts in Low (1998) and this paper is the diary notes and photographic records kept by Courtney, on eucalypt flowering, weather, lorikeets (occurrence, breeding activity) and their nest-sites since 1962. Data on nest-sites were analysed for patterns in their physical characteristics (tree species, site, height).

Flowering of eucalypts, in particular White Box and Yellow Box, was monitored by regular and frequent commuting from Courtney's farm residence (near site 2) 5 km to his other landholding at site 3. Site 1, 17 km south-west of site 2, was visited opportunistically in most years. Most stands of these trees in the study area were in narrow roadside strips, so daily travel provided a visual index of obvious (moderate or heavy) flowering. A local beekeeper (B. Weiss) kept hives on Courtney's land and moved them out of the study area when local flowering was poor, which provided an additional qualitative flowering index. During local travel, Courtney also stopped opportunistically to search for sparse blossom or signs of flowering (e.g. flowers dropped by parrots) if blossom was not obvious from the vehicle.

Courtney searched for lorikeet nests every year, particularly for new ones in the last 20 years, whenever he was at the study sites during routine agricultural activities, by scrutinising every likely tree for the characteristic raised knotholes. Known or potential nests were visited early in the breeding season (April–May) at sunset, when the pair typically performed a circuitous flight around the nest-stand (the grove of trees that contained the nest) then entered the hollow to roost. Occupation of nests was also checked in the daytime throughout the breeding season by approaching the tree, and scratching or tapping on the trunk if necessary, to induce a lorikeet to emerge or peer out of the hollow.

In this paper, standard notation for clutch and brood sizes (× number) is given (cf. Higgins 1999), for example C/3 × 1 = one clutch of three eggs, B/2× 3 = three broods of two chicks, where accessible nests were inspected to determine the contents.

Results

Eucalypt flowering phenology

The key to understanding the lorikeets' biology is the role played by the flowering of the various woodland tree species. White Box (rich in pollen) and Yellow Box (rich in nectar) provide the main sources of food, and smooth-barked gums provide nest-sites. The nest-trees and other eucalypts in the area flower unpredictably and for a short time only: Blakely's Red Gum and Tumbledown Gum may flower only for a fortnight sometime between November and January (with individual trees for only 10 days), other species for 10 days to a month with no continuity or overlap, and some are erratic and unpredictable. White Box and Yellow Box flower for many months and individual trees may flower for several months, thus providing a reliable, continuous food supply. White Box usually flowers from March or April (rarely February) through to September, with occasional light flowering persisting as late as November or December in some years, and Yellow Box generally from about August to November or December (rarely January), with some flowering as early as April or May in some years.

Within the study region, Little Lorikeets have been observed feeding in flowering mistletoe *Amyema* sp. in February, stringbybark *Eucalyptus* spp. in March–April, and Caley's Ironbark *E. caleyi* in June; Musk Lorikeets have also been seen feeding in mistletoe in February. In the study area, the lorikeets have usually left their breeding sites before Blakely's Red Gum or Narrow-leaved Ironbark *E. crebra* flower in summer; the latter flowers for only about a month in December–January. Courtney has no observations of lorikeets feeding on lerps.

Populations

In 1944, in Courtney's childhood, it was common to see 30, sometimes 50 or 60, Little Lorikeets in one heavily flowering tree, with similar numbers in adjacent trees, in autumn to spring. These birds were still abundant through the 1960s, but numbers declined through the 1970s and 1980s and dropped steeply in the 1990s. For instance, of 93 woodland sites surveyed bimonthly by Oliver *et al.* (1999) within 50–100 km of Courtney's study area in 1994–97, an average of 2.4 to 10.7 Little Lorikeets (maxima 4–92 birds) occurred per site, at 3–35 sites per survey (D. Oliver unpubl. data). Although Musk Lorikeets were twice as abundant, some sites supported many Little Lorikeets in flowering Mugga Ironbark *E. sideroxylon* (D. Oliver pers. comm.).

The Little Lorikeet is now facing local extinction as a breeding species in Courtney's study area. Before 1989, about 50 Little Lorikeet nest-sites were known within an area of 50 × 15 km. In 1974 there were many flowering Yellow Box trees in part of the study area, in which large numbers of Little Lorikeets were feeding. At the adjacent town common (site 1), in a stand of mature Red Gums, four nests were found in a brief inspection over several minutes. By 1989, only four or five of the known Little Lorikeet nests in the entire study area had survived (most nest-holes or nest-trees having been lost to the threats discussed herein), and in September 1996 only three nests were occupied; flocks of Little Lorikeets were no longer seen. By 1989, a single land-clearing event at Swan Vale, adjacent to site 2, had destroyed over 15 Musk and Little Lorikeet nests; this figure amounted to > 60% of the Little Lorikeet nests on a site that supported 75% of the breeding population of that species in the study area (see Threats, p. 118). After the loss of these 15+ nests, in Tumbledown Gums on private land, about six Musk and perhaps two Little Lorikeet nests remained in that area (these nests were additional to the study sample of ~ 50 nests of each species).

The Musk Lorikeet has also declined locally, but less so than the Little Lorikeet. In the early 1990s there was a slight improvement in the situation for Musk Lorikeets, with some recruitment of nest-sites around Swan Vale. For example, two new Musk Lorikeet nests were derived from former nests of the Crimson Rosella *Platycercus elegans*. In these cases a long crack in the tree-trunk gradually closed over with living bark, thus excluding the Rosellas; the Lorikeets took over and kept the hole open by biting the bark to the required entrance size, a process that took about 12 months until they could enter the nest-hollow.

In July 2005, site 1 supported 11 Musk Lorikeet nests and five Little Lorikeet nests. In July 2005, site 2 supported five Musk Lorikeet nests and the adjoining area supported two Little Lorikeet nests. In July 2005, site 3 supported four Musk Lorikeet nests, having by then lost one Musk and one Little Lorikeet nest-site that had been active at this location. Site 3 was, in past decades, a much more extensive (~ 20 ha) strip of woodland, but the lorikeet nesting area has contracted greatly in extent and breeding population since the loss of most of the nest-hollows or nest-trees (see Threats). By 2005 the formerly used area of site 3 had lost at least 14 Musk and 14 Little Lorikeet nests, with one nest of each remaining but of unknown status, and one other Musk Lorikeet nest possibly still occupied.

Symptomatic of the decline in habitat and numbers of the smaller lorikeets is the local situation for the Rainbow Lorikeet. The latter species visits Swan Vale in late autumn to spring when White Box and Yellow Box trees are flowering, and formerly nested there. It ceased nesting in about 1927 when most big gums along Swanbrook Creek were ringbarked. At Bonshaw (80 km north of Inverell), Rainbow Lorikeets and Scaly-breasted Lorikeets *Trichoglossus chlorolepidotus* nested in a stand of River Red Gums *Eucalyptus camaldulensis* on the Dumaresq River in the 1980s (first noted by Mervyn Goddard, pers. comm. to Courtney). They were still present in June 2005, when a pair of Scaly-breasted Lorikeets had an active nest in a Red Gum (P. Odekerken pers. comm.). During a brief inspection by Courtney in August 2005, late in the day when it was not possible to confirm breeding, about 20 pairs each of Rainbow and Scaly-breasted Lorikeets were present (behaving as individual pairs, rather than as flocks). This site, south-east of Bonshaw, still supports an old-growth stand of River Red Gum and box trees in a Crown reserve for travelling livestock, with a similar reserve on the western side of the town, in a landscape otherwise completely cleared for irrigated agriculture.

The nectarivorous parrot assemblage in the study area formerly included the Swift Parrot *Lathamus discolor*: in early October 1968 hundreds of these birds passed over Swan Vale; they flew high, from west to east, in tens of groups each numbering about a dozen (Courtney's only record of the species). Courtney's sighting is the largest number recorded for the NSW North-west Slopes (D. Saunders pers. comm.), and the species is now endangered nationally [federal *Environment Protection and Biodiversity Conservation Act (EPBC Act)*]. In October 1971 and before then, but not since that time, a pair of Regent Honeyeaters *Xanthomyza phrygia* nested at Swan Vale, and small numbers of this species (< 10) formerly visited flowering White Box in the now-defunct part of site 3 (where they also nested). The Honeyeater is also now endangered nationally.

Movements

In the case of the Musk Lorikeet, although mobile flocks may follow blossom, it is apparent that in the study area only a few adult pairs are resident for most of the year, and it is these birds that produce most of the young locally. From mid December (the onset of moult) most nesting pairs of both species leave the area, returning for a day or so every few weeks in the non-breeding season (January–March) to maintain their nest-holes. They bite the bark around the entrance-hole to prevent it from growing over, and they attend the nest-hole and sometimes roost in it to prevent it from being occupied by other birds. Biting of bark is frequently observed in March, and some birds are roosting in their nests regularly in April or May.

Musk Lorikeets usually start to congregate in the study area in April or May, and stay to breed through winter and spring. Small, mobile flocks of non-breeding birds can arrive at any time, if a few eucalypts are flowering.

Little Lorikeets settle in the study area around April and stay permanently until early December, when the blossoms are no longer available. During their normal time of absence (January–March) they occupy the nest area for short periods if one or more White Box trees are in flower. For example, in February 1993 when a White Box was in heavy flower, two Little Lorikeet pairs were in residence at known nests.

Breeding season

In the study area, both species breed only when White Box is flowering in the vicinity (~ 2 km radius) of their traditional nest-sites. Most small nestlings are present in late July, August and early September. Even in drought years, when human observers are unable to locate blossom (though birds apparently can locate sparse blossom), some of the pairs occupying permanent, prime nest-sites (as described herein) always manage to breed successfully.

Musk Lorikeets lay and hatch their first clutch of eggs in winter, with young in the nest in August. If the Yellow Box then flowers heavily, a second brood is started, with fledging in late November or early December and occasionally January. Eggs were observed in August; nestlings from July to October and in December (B/2 × 3); and fledglings in September, November, December (B/2 × 1) and January (B/1 × 1).

Little Lorikeets show the same pattern as for Musk Lorikeets. Eggs were observed in July (C/3 × 1); nestlings in August, September, November and December (B/3 × 1, B/4 × 1); and a fledgling in December.

In the rare years when White Box fails to flower, the lorikeets rear a single brood (sometimes late in the season) on Yellow Box blossom. In poor blossom years a single brood is raised during the usual winter season, then the lorikeets leave in spring if there is no blossom upon which to feed (Appendix 1).

Nest-sites

Preferred nest-trees of both lorikeet species were smooth-barked gums. For the Musk Lorikeet, of 61 nest-holes 25 (41%) were in Manna Gum, 23 (38%) in Blakely's Red Gum, five (8%) in Rough-barked Apple, two each in Yellow Box (3%) and Tumbledown Gum (3%), one each in White Box (2%) and Orange

Nesting Musk Lorikeets. Above: Musk Lorikeet squeezing out of nest-hollow.
Below: Pair of Musk Lorikeets at nest-hollow.

Plate 17 Photos: John Courtney

Nesting Little Lorikeets. Above: Little Lorikeet above its nest-hollow (note concentric ridges of hard wood inside nest-entrance, from annual biting of living bark; see text. Below: Little Lorikeet levering itself out of tight nest-hollow.

Plate 18

Photos: John Courtney

Gum *Eucalyptus prava* (2%), and two (3%) in dead trees (both Manna Gums). The nest in the White Box was in a smooth-barked section of the tree. For the Little Lorikeet, of 48 nest-holes 19 (40%) were in Manna Gum, 12 (25%) in Blakely's Red Gum, five (10%) in Tumbledown Gum, two each in Rough-barked Apple (4%), White Box (4%) and Red Stringybark *E. macrorhyncha* (4%), one (2%) in Yellow Box, and five (10%) in dead trees (three Yellow Box, two Blakely's Red Gum). Nests in White Box and Stringybark were in smooth-barked sections of the trees.

Nest-holes of the Musk Lorikeet (Plate 17) were 3.0–15.2 m above the ground (mean 7.1 m, standard deviation 3.0, n = 56). Twenty-two of 53 nests (42%) were located in the trunk (three in dead trunks), 23 (43%) in live limbs, four (8%) in dead limbs, and four (8%) in dead spouts on live limbs. Five nest-holes in trunks were located in bulges or protrusions (presumably branch-scars), and six in live limbs were in 'elbow' situations. Nest-holes of the Little Lorikeet [Plates 16 (front cover) and 18] were 2.4–15.2 m above the ground (mean 6.8 m, standard deviation 3.5, n = 41). Thirty-one of 46 nests (67%) were located in the trunk (three in dead trunks), nine (20%) in live limbs, two (4%) in dead limbs, and four (9%) in dead spouts on live limbs. Eight nest-holes in trunks were located in bulges or protrusions, and one in a live limb was in an 'elbow'.

An exceptional case was a Little Lorikeet nest in a traditional nest-tree that had been bulldozed. When the tree fell, the nest-entrance was only 90 cm above the ground, yet the pair nested in the hole for a further 3 years while the tree's roots (still in the ground) kept it alive, until the landowner burned the tree.

The birds used small knotholes, just large enough to wriggle and squeeze through, and maintained precise entrance-hole size by regularly biting the living bark around the rim. In one case, the entrance was so tight that the Little Lorikeets levered themselves out by pulling on the outer rim with their bills (Plate 18). Most entrance-holes were in the sides of trunks or limbs, rare exceptions being in the top of a limb where the surface sloped away from the knothole such that rainwater did not gather and run into the nest. The annual cycle of bark growth and biting was visible as concentric ridges just inside the entrance (Plate 18). Nests contained fine, almost dry wood-dust, and were always clean and free of excreta. Almost every nest examined was inhabited by a small skink, probably the Wall Skink *Cryptoblepharus virgatus* and possibly commensal in nature.

Five Musk Lorikeet nest-entrances were (vertical × horizontal) 37 × 40 mm, 38 × 42 mm, 32 × 65 mm, 44 × 44 mm, and 34 × 25 mm. The first went 10 cm into the trunk, thence 30 cm down the shaft to a chamber ~ 23 cm in diameter; another hollow was also 30 cm deep. Three Little Lorikeet nest-entrances were 27 × 31 mm, 29 × 32 mm and 32 × 39 mm. In the first case, a 55-cm shaft led to a chamber ~ 10 × 15 cm in diameter. Two other nest-chambers were 36 and 55 cm in diameter, and one was ~ 30 cm down the shaft. The entrance-holes of Little Lorikeet nests appeared to be consistently ~ 9 mm smaller than those of Musk Lorikeet nests, and apparently excluded the latter species. A greater number of nest-entrance measurements would reveal whether this difference is significant.

Nest-sites were used traditionally. One Musk Lorikeet nest was known to have been active for at least 26 years, and two were still active after 21 and 15 years. Two Little Lorikeet nests were known to have been active for at least 26 and 29 years, and two were still active after 24 years. It is not known whether these nests were repeatedly occupied by the same individuals.

There were occasional cases of Sugar Gliders *Petaurus breviceps* and small bats (Microchiroptera) temporarily occupying Musk Lorikeet nests in the lorikeet non-breeding season. Sacred Kingfishers *Todiramphus sanctus* had nestlings in a Musk Lorikeet nest-hole in December 1978, after the Lorikeets had raised a brood in mid August (near-fledged) and again in mid October; the hole had nearly closed over by March 1979 until the Lorikeets reopened it in May and reoccupied it in June. The Kingfishers were again brooding in this nest-hole in December 1980, after the Lorikeets had brooded in August. The Lorikeets then cleaned out and reused the hollow in August–November 1981. Striated Pardalotes *Pardalotus striatus* occasionally inspected a Little Lorikeet nest (in November 1983 and August 1985) when Lorikeet nesting activity had lapsed.

Musk and Little Lorikeets nested in intra- and interspecific semi-colonial situations. Four Little Lorikeet pairs nested in a stand of mature gums: three nests were in one tree ~ 1.5 m and 0.3 m from their nearest neighbour, and one was 5 m away in a nearby tree. Two trees each contained two Musk Lorikeet nests. In other cases, one tree contained two Musk and one Little Lorikeet nests; one tree contained two Musk and two Little Lorikeet nests; and five trees each contained one Musk and one Little Lorikeet nest (four of these interspecific cases involved nests that were < 1, 1.5, 1.6 and 3 m apart, and in another the nests were at the same height in the tree). This clustering of nests was formerly common, when Little Lorikeets were common, but became less so as the number of Little Lorikeet pairs declined.

Nests of Rainbow and Scaly-breasted Lorikeets, inland at Bonshaw during June–July, had entrances that were round holes in the trunks of live River Red Gums, into which the birds could barely squeeze, or short dead spouts leading into a living limb or trunk (much as described herein for Musk and Little Lorikeets, though of appropriate size for the respective species: Courtney pers. obs.; P. Odekerken pers. comm.). It appears, therefore, that the larger lorikeets also maintain precise entrance dimensions by biting the living bark around knotholes and that, in and near the study area, they also start breeding in winter.

Fledging

One observation of fledging behaviour was made. On 22 September 1992 the first flight of a young Musk Lorikeet was witnessed: at 0955 h a juvenile was looking out of the nest; at 1000 h a parent landed at the nest but did not feed the young, then flew up into a nearby tree. The juvenile then started to push its way out of the hole, squirming from side to side, until at 1005 h it suddenly emerged and flew immediately, instantly accompanied by both parents, which flew on either side of the juvenile (within 0.3 m). The trio flew in a large semicircle, at a height of 3 m with the young bird flying weakly, and returned to land 125 m from the nest-tree in the dense tops of Yellow Box trees. That evening, at dusk, at least one of the parents flew in to roost in the nest, apparently unaccompanied by the juvenile. Next evening, at dusk, the pair repeatedly flew to the nest and retreated to a small tree 2 m away, then suddenly flew to the dense canopy of a Yellow Box 80 m away and remained there. Thus, in this single example the juvenile apparently did not return to the nest to roost; further observations are required to confirm whether this behaviour is repeated at other nests.

Threats

Nest-sites were lost to natural and human-related causes. Of 61 Musk Lorikeet nests, 11 (18%) were lost when the tree or limb fell, four (7%) were deserted when the tree died, two (3%) were abandoned during drought, one nest-tree (2%) was burnt, two (3%) were bulldozed, and six nest-holes (10%) were usurped by feral Honeybees *Apis mellifera*. That is, 26 nests (43%) were lost over the 43-year study, with nine losses (15% of nest-trees, or one-third of losses) caused directly or indirectly by human agency, if one includes bees. Of 50 Little Lorikeet nests, six (12%) were lost when the tree or limb fell, one (2%) was deserted when the tree died, two (4%) were abandoned during drought, one (2%) was usurped by Musk Lorikeets, three nest-trees (6%) were burnt, five (10%) were bulldozed, and two nest-holes (4%) were usurped by feral bees. That is, 20 nests (40%) were lost over the 43-year study, with 10 losses (20% of nest-trees, or half the losses) caused directly or indirectly by human agency.

When storms damaged trees and exposed (and hence destroyed) the nest-cavity, the lorikeets abandoned the nest. For example, one Little Lorikeet nest closed over within 14 months of desertion, after a storm damaged the tree above the nest-hole. In 1991 a deliberate grassfire (the common practice of 'burning off' long grass) threatened a stand of nest-trees. Although the trees were saved, the fire killed small nestlings in one Musk Lorikeet nest, probably by the thick smoke around the tree. Some bulldozing of nest-trees was conducted, unnecessarily, by council road-maintenance workers. By 1993, many Little Lorikeet nests had gone: trees blown over, limbs snapped off, with no new nest-sites being created (no new nests were found, despite intensive annual searching). After the death of a nest-tree, the nest was usually deserted after about 2 years even if the tree was still standing. One Musk Lorikeet nest-hole had closed over with regrown bark since it was usurped by bees.

In March and May 1992, June 1995 and April 1996 a Common Starling *Sturnus vulgaris* roosted in a Musk Lorikeet nest-hole (monitored since 1978), apparently not yet occupied by the Lorikeets in those years. However, the Lorikeets were known to use this nest until 1999, so evidently they can defend their nests against Starlings when the Lorikeet pair occupies the nest through the winter, well before the Starlings' breeding season. Musk Lorikeets are successful aggressors against similar-sized birds; one pair ejected a brood of downy young Red-rumped Parrots *Psephotus haematonotus* and claimed occupancy of the hollow that became a long-term Lorikeet nest.

The greatest threat is ongoing land-clearing, including roadside verges that are lost through road upgrades. An important stand of nest-trees on private property was bulldozed; it supported 75% of the study area's Little Lorikeet population, and at least 60% of the nests on the site were destroyed. As in that case, clearing has pushed into marginal, rocky or stony ground of doubtful agricultural value. In the present political climate, public land such as travelling stock reserves and town commons (e.g. site 1) is likely to be sold or leased to private interests, with consequent habitat degradation and clearing. These woodlands are the last remnants of rich habitat on productive soil. Widespread ringbarking of trees around 1880–1920, coupled with ongoing clearing, has meant a net loss of nest-sites and a lack of recruits to maintain the supply of trees reaching hollow-bearing age.

Many Little Lorikeet nests in the study area now survive only on roadside verges, as the key nest-trees (Manna Gum and Blakely's Red Gum) have largely been removed from farmland. The few remaining trees, for example on stream banks where they have legal protection, are approaching the end of their lives and are not being replaced because livestock destroy the seedlings. Old hollow-bearing trees on private land have been selectively removed, leaving only young trees (typically boxes) suitable for future fence-posts and firewood, and Rough-barked Apple for drought fodder.

Discussion

It is apparent that these two small lorikeet species have highly specialised nesting requirements, with traditional nest-sites being a limiting and declining key resource for breeding birds. The annual biting of living bark encroaching on the entrance-hole results in a tunnel of hard, dead wood just inside the entrance that would be difficult for competing parrot (and other) species to enlarge. The size of the nest-hole appears to exclude predators and, for the Little Lorikeet, also most competitors. If, for example, bees usurp the hole or it is deserted for any reason, the bark closes over the hole and the nest-site is lost to the lorikeet population. This situation stands in stark contrast with the popular but erroneous belief that lorikeets are nomadic, opportunistic nesters that simply follow the blossom (e.g. Sparks & Soper 1990).

Lorikeets, which eat soft foods such as nectar, pollen and fruit, paradoxically have larger, sharper and more powerful bills than equivalent-sized, seed-eating platycercine parrots (our personal experience of handling many species; measurements in Higgins 1999). This difference may be explained by the lorikeets' nesting habits, notably their need to maintain nest-entrances by constantly biting the tough living bark of smooth hardwoods, compared with platycercines that find ready-made holes, often in dead wood (our pers. obs.; see also Higgins 1999).

In contrast with the dry and clean nests of wild lorikeets, aviculturists report that nests of captive lorikeets become fouled with wet, unsanitary excreta (e.g. Odekerken 2002). Perhaps the diet of wild lorikeets, presumably of mainly pollen, is drier than the food mix given to captive birds. Furthermore, in the wild nests may have an absorbent and antiseptic floor of eucalyptus wood-dust and powdered sap, and commensal insect larvae may clean the nest (hence the predatory skinks observed in lorikeet nest-hollows).

This study found that both small lorikeet species often nest lower than commonly believed, start breeding in winter, and have two broods if their key food-trees flower profusely through spring. Their nest-holes have much more precise characteristics than those, for example, of the abundant and adaptable rosellas *Platycercus*, which are flexible in choice and inter-year use of nest-sites (cf. Higgins 1999). Forest or woodland eucalypts may be at least 150–250, if not > 275, years old before they form cavities suitable as nest-sites for small parrots or other fauna (see discussion by Mawson & Long 1994, 1997; Calver 1997; Gibbons & Lindenmayer 2002, 2003; Adkins *et al.* 2005). Thus, nest-trees currently being lost will not be replaced by 'offset' plantings or regeneration until the latter develop suitable hollows in perhaps 200 years, with a shortfall of lorikeet nest-sites (and hence lorikeet recruitment to the area) in the interim. The two lorikeet species are also heavily dependent on White Box and Yellow Box for successful breeding, yet significant areas of key food resources have been lost as a result of agricultural clearing. Expanding rural-residential subdivisions around rural centres, and roadworks that remove trees from verges, also pose ongoing threats to these key feeding and nesting resources.

Protection of old trees on roadside verges and public land, especially stock reserves, from grass-fires that destroy hollow trees, will likely be critical to the survival of these lorikeets. Invasion of lorikeet nest-hollows by feral bees seems to be increasing, suggesting increasing competition for the remaining hollows, so that every current nest-site becomes increasingly valuable to the lorikeet population.

In the future, banding of the lorikeets in the study area is highly desirable, in order to confirm long-term occupancy of nest-sites by the same individuals. Ongoing monitoring of the known nests is necessary, to track any future changes in lorikeet populations and to monitor the longevity and fate of established nests. A major gap in knowledge is the whereabouts of the nest-owners during their absences in the non-breeding season, but the use of radio-transmitters on parrots, which can easily damage or remove transmitters, presents potential technical difficulties.

Nest-boxes or artificial hollows may be worth trialling, although the preference of wild lorikeets for knotholes in the living bark of trunks and limbs, with apparently precise microclimate and other characteristics of the nest-chamber, may mean that boxes are reluctantly accepted or are less successful (perhaps related to hygiene issues). Thus, it is vital to conserve the old hollow trees that still remain, as well as trees of appropriate ages to maintain the supply of hollows into the future. Although the Purple-crowned Lorikeet *Glossopsitta porphyrocephala* roosts and possibly nests in artificial cavities (Hicks 1997; Hutchinson 1998), this species is a mallee bird that may be flexible in nest-site choice (cf. Higgins 1999).

The North-west Slopes of NSW, and in particular the present study area, is a regionally significant centre for breeding populations of the two lorikeet species (cf. Blakers *et al.* 1984; Low 1998; Barrett *et al.* 2003). Although both lorikeet species were recorded more frequently during national bird atlases in 1999–2002 than in 1977–81 (Barrett *et al.* 2003), this difference may be an artifact of different recording methods, and itinerant non-breeding flocks may still be common. Nevertheless, for the Little Lorikeet, breeding populations on the NSW North-west Slopes are now reduced to remnants of their former numbers. Although mobile flocks occur and may create the impression of stable and relatively numerous populations, these birds are apparently non-breeders. Thus, if these birds reach the end of their lifespan without leaving offspring, the population could crash and become regionally extinct. It would be useful to resurvey the sites studied by Oliver *et al.* (1999) after a decade, and those sites and Courtney's at intervals into the future.

Conservation status

It is apparent that the breeding population of the Little Lorikeet on the NSW North-west Slopes, in the Nandewar and Brigalow Belt South Bioregions (see Thackway & Creswell 1995) around Courtney's study area, is endangered. If this situation extends throughout the inland slopes of NSW, as seems likely, then the Little Lorikeet may be vulnerable or endangered statewide. Flock sizes and occurrence of the Little Lorikeet have declined near Grenfell, on the South-west Slopes, since the 1980s, with only one nest record (R. Allen unpubl. data, per D. Saunders; see also Horton & Black 2006). A landholder near Temora, also on the South-west Slopes, has noted a dramatic decline in Little Lorikeet numbers during his lifetime (per D. Saunders). During searches on the NSW coast and western slopes, Saunders (pers. comm.) has recorded Swift Parrots more frequently than Little Lorikeets, and R. Allen has few observations, of small flocks, of the latter species on the South Coast where it is believed to have declined (per D. Saunders; see also Horton & Black 2006). The box–gum–ironbark woodlands on the inland slopes appear to be the Little Lorikeet's core foraging and breeding range; we note that most (63%) of the NSW clutches listed by Horton & Black (2006) came from the inland slopes.

The Little Lorikeet is recognised as one of the woodland birds in decline or at risk as a result of habitat clearance and fragmentation in the sheep–wheat belt (reviewed by Debus *et al.* 2006). It would qualify for nomination as vulnerable in NSW, under the *Threatened Species Conservation Act (TSC Act)*, on the following grounds: breeding populations severely reduced in number; key breeding sites and habitat severely reduced in number and extent; key feeding habitat (particularly for breeding) severely reduced in area; a key threatening process (i.e. land-clearing) severe and ongoing, with the prospect that remnant woodland on Crown land is not safe from degradation or clearing (e.g. by lease or sale of travelling stock reserves, or freeholding of leases with high conservation value). Key habitat (White Box/Yellow Box/Blakely's Red Gum grassy woodland) is declared an endangered ecological community in NSW (*TSC Act*) and federally (*EPBC Act*). Declaration of the inland breeding population of the Little Lorikeet in NSW (west of the Great Divide watershed) as endangered would seem warranted, and key breeding sites (such as site 1 of this study) and associated box stands on the inland slopes deserve consideration for listing as critical habitat. Site 1 is regarded by Professor Dominique Homberger and Dr Ravi Rau, international parrot authorities, as a 'unique and very special place' and well worth saving (pers. comm. to Courtney).

The Little Lorikeet is listed as vulnerable in SA (G. Carpenter pers. comm.), and as non-threatened in Victoria though recognised as a component of the threatened temperate-woodland bird community (J. Fitzsimons pers. comm.). It has declined drastically from a moderately common breeding species to virtual extinction over most of its former range in SA, where it may now be endangered rather than vulnerable (Horton & Black 2006). The situation in SA may also predict trends in the eastern states, as for some other woodland-dependent birds such as the Swift Parrot and Regent Honeyeater (Horton & Black 2006). Although over the last 5 years the Little Lorikeet has been numerous and breeding in the Capertee Valley and adjoining reserves in central-eastern NSW (G. Cam pers. comm.), this site may represent one of its last regional strongholds, as for the Regent Honeyeater (cf. Barrett *et al.* 2003).

Further field survey, particularly of breeding populations and nest-sites, may find that the Little Lorikeet warrants listing as an endangered species in NSW (and perhaps other states), given that the situation on the North-west Slopes is likely to prevail throughout the sheep–wheat belt. In NSW the Little Lorikeet is likely to be as imperilled as the Swift Parrot and Regent Honeyeater, with an additional requirement for specific types of hollow-bearing trees. We reiterate the recommendation of Horton & Black (2006) that an Australia-wide review of the Little Lorikeet's population trends should be conducted with some urgency.

Acknowledgements

We thank Peter Odekerken for information on the lorikeets at Bonshaw and for filming the study nests, and Professor Dominique Homberger & Dr Ravi Rau (Louisiana State University) for evaluating site 1. We also thank Julianne Farrell (Courtney's daughter) for help in searching the literature; Graham Carpenter and James Fitzsimons for information on the legal status of lorikeets in other states; Damon Oliver for his survey data; Hugh Ford and Debbie Saunders for comments on a draft; and Graham Cam and Andrew Ley for editing.

References

Adkins, M.F., Westbrooke, M.E., Florentine, S.K. & McDonald, S.P. (2005), 'Fire and hollow formation in box–ironbark forests of the Warby Range State Park', *Victorian Naturalist* 122, 47–56.

Barrett, G., Silcocks, A., Barry, S., Cunningham, R. & Poulter, R. (2003), *The New Atlas of Australian Birds*, RAOU, Melbourne.

Beruldsen, G. (2004), *Australian Birds: Their Nests and Eggs*, author, Kenmore Hills, Qld.

Blakers, M., Davies, S.J.J.F. & Reilly, P.N. (1984), *The Atlas of Australian Birds*, Melbourne University Press, Melbourne.

Calver, M.C. (1997), 'Hollow arguments?', *Emu* 97, 183–184.

Debus, S.J.S., Ford, H.A. & Page, D. (2006), 'Bird communities in remnant woodland on the New England Tablelands, New South Wales', *Pacific Conservation Biology* 12, 50–63.

Gibbons, P. & Lindenmayer, D. (2002), *Tree Hollows and Wildlife Conservation in Australia*, CSIRO, Melbourne.

Gibbons, P. & Lindenmayer, D. (2003), 'Respecting our forest veterans', *Nature Australia* 27(9), 27–33.

Hicks, R.K. (1997), 'Purple-crowned Lorikeets roosting and possibly nesting in metal pipes', *Australian Bird Watcher* 17, 216–217.

Higgins, P.J. (Ed.) (1999), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 4, Oxford University Press, Melbourne.

Horton, P. & Black, A.B. (2006), 'The Little Lorikeet in South Australia, with notes on the historical status of other lorikeet species', *South Australian Ornithologist* 34, 229–243.

Hutchinson, C. (1998), 'Nesting in power poles (Purple-crowned Lorikeets)', *Bird Observer* 783, 16.

Low, R. (1998), *Encyclopedia of the Lories*, Hancock House, Surrey, Canada.

Mawson, P.R. & Long, J.L. (1994), 'Size and age parameters of nest trees used by four species of parrot and one species of cockatoo in south-west Australia', *Emu* 94, 149–155.

Mawson, P.R. & Long, J.L. (1997), 'Size and age of nest trees: A reply to Stoneman, Rayner and Bradshaw', *Emu* 97, 181–182.

Odekerken, P. (2002), *A Guide to Lories and Lorikeets*, ABK Publications, South Tweed Heads, NSW.

Oliver, D.L., Ley, A.J., Ford, H.F. & Williams, B. (1999), 'Habitat of the Regent Honeyeater *Xanthomyza phrygia* and the value of the Bundarra–Barraba region for the conservation of avifauna', *Pacific Conservation Biology* 5, 224–239.

Sparks, J. & Soper, T. (1990), *Parrots, A Natural History*, Lothian, Melbourne.

Thackway, R. & Cresswell, I.D. (Eds) (1995), *An Interim Biogeographic Regionalisation for Australia*, version 4.0, Australian Nature Conservation Agency, Canberra.

Appendix 1

Flowering patterns and intensity (rated as nil, light or heavy) of the main lorikeet food-trees in the study area (North-west Slopes of NSW) in sample years: WB = White Box, YB = Yellow Box. Nesting activity refers to Musk and Little Lorikeets. Data lacking for some years.

Year	*Weather*	*Flowering*	*Comments*
1964	Rain Sept.–Oct.	WB heavy Sept.; YB heavy Sept.–Dec.	Profuse honey flow for beekeepers; great influx of lorikeets though not exceptional numbers nesting.
1965	Dry year	YB light May	Few lorikeets nesting.
1968	Good year?	No data	Lorikeets nesting July–Oct., apparently 2 broods; large passage of Swift Parrots Oct.
1970	Rain Jan.; dry until rain Aug.–Sept.	WB, YB Aug.	Nesting Aug.

Appendix 1 Contd

Year	*Weather*	*Flowering*	*Comments*
1973	Mild winter, some rain	YB heavy July	Many lorikeets present.
1978	Very wet year	WB, YB starting June, then heavy	Nesting July–Oct.; influx of Rainbow and Scaly-breasted Lorikeets.
1979		WB nil to May, light by Nov.; YB heavy Nov.–Dec.	No lorikeets Mar.–Apr. when no blossom; nesting June–Dec. (2 broods), then lorikeets left when YB finished.
1980	Dry year	WB light July–Aug.; YB light Apr.–May, Aug.–Sept.	Blossom scarce; nesting June–Sept.
1981	Initially dry (some rain Feb.); rain May–July	Manna Gum Mar.; other blossom scarce May; WB starting June	Nesting May–Nov.
1982	Dry year	WB nil Apr., light Jul.–Aug.;YB heavy Apr.–June, light Oct.	Nesting May–Aug., none Oct.–Nov.; blossom scarce from Aug., few lorikeets by Nov.
1983	Jan.–Mar. dry; rain May	No WB/YB blossom Sept.;YB light Nov.	Nesting July–Sept.; none Nov.
1984	Rain May, July–Aug.	WB and YB light July	Nesting July–Nov.
1985	Rain Apr., June–Aug.	No blossom Mar.; poor flowering year	Few lorikeets nesting July–Aug.; lorikeets left late Aug.
1986	Dry Apr.–Dec.	WB light; YB light May; scant blossom July–Sept.	Nesting July–Sept.
1987	Rain Jan.–Mar., Aug.	WB initially light, then heavy July; YB light May–July	Nesting July–Sept./Oct.
1988	Some good rain to Aug., then dry	WB heavy July	Influx of Rainbow Lorikeets
1989	Rain Mar.–July and Oct. after dry spells	WB heavy May–Oct.; YB heavy Oct. to light Dec.	Nesting May–Oct.
1990	Dry Mar., then wet year; dry Dec.	WB nil; YB light Apr., heavy May to light Dec.	No blossom Jan.–Feb.; nesting June–Oct., on YB only.
1991	Rain Jan.–Mar.; dry Aug.–Sept.	WB light Aug., nil Sept.;YB light Apr.	Few lorikeets nesting, June–Sept.
1992	Wet year, notably in first half	WB light Apr.–July, heavy Sept.–Nov., light Dec.; YB light June–Aug., heavy Sept.–Dec.	No blossom Jan.–Mar; nesting June–Dec. (2 broods); influx of Musk and Rainbow Lorikeets.
1993	Rain Jan.; dry autumn; some rain winter	WB heavy Feb., light Apr., heavy May–Sept.; YB heavy Oct., light Nov.–Dec.	Nesting June–Dec.; influx of Rainbow Lorikeets

Appendix 1 Contd

Year	*Weather*	*Flowering*	*Comments*
1994	Dry year	WB nil May, light Sept.;YB heavy June but soon withered, light Sept.–Nov.	Few lorikeets nesting, June–Sept.
1995	Dry year June–Oct., then rain	WB nil Mar.–June, light Aug.–Oct.; YB nil Mar.–Sept., heavy Oct.–Nov., failing by Dec.	No blossom until Aug.; no nesting June then few lorikeets nesting Aug.–Nov. No early broods, nesting activity delayed, on YB only; nests still active mid Jan. 1996.
1996	Rain Jan.	WB light May, heavy June; YB heavy June, Nov.	Nesting May–Nov.
1997	Dry year	WB heavy Apr.–Sept., light Oct.	Profuse blossom; nesting June–Oct.; influx of Rainbow Lorikeets.
1998	Dry year	YB light Apr.	Nesting July–Sept.
2000	Dry spring	WB, YB heavy Aug.	
2001	Rain Jan.–Feb.	WB heavy, YB light May	Some Rainbow Lorikeets present.
2002	Dry year	WB nil; YB light July; few ironbarks W of study area Aug.	Blossom scarce; nesting June–Aug.
2003		WB heavy May, light Sept., heavy Oct.; YB nil	Nesting June–Oct.; influx of Rainbow Lorikeets.
2004	Dry year	WB ? (no data); YB light Mar. and July, heavy May–June and Oct.; Red Gums heavy Nov.	Nesting May–Oct.; 2 broods.
2005	Dry to May, then good rain June onwards	WB light Apr.–Sept.; YB nil to Sept. (no further data)	Nesting May–Sept. (no further data); blossom poor for bee-keepers (hives removed June).

Received 10 February 2006

■