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BREEDING SUCCESS AND TIMING OF NESTING BY FOREST BIRDS ON THE NORTHERN TABLELANDS OF NEW SOUTH WALES, AUSTRALIA

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The pattern and timing of nesting by 57 bird species in open eucalypt *Eucalyptus* forest on the northern tablelands of New South Wales (30°30'S, 151°40'E; 990–1 390 m amsl) were studied in the breeding seasons of 1988–1992, 1994, and 1996. The first nests were initiated in mid-July with numbers increasing through August. Nest initiation peaked in early September and again in mid- to late October, but declined rapidly in November. Few birds initiated nests in December and no new nests were found after December. From 1988 to 1992, 29 per cent of open-nests fledged young; 70 per cent of nests that failed were predated, two (3%) were lost due to storms and the remainder were abandoned without laying. Weather conditions affected the number and species of birds nesting, the time nests were initiated, and success at fledging young. 1994 had a dry autumn-spring with catastrophic rain, hail and wind storms in late October and early November. 1996 had above average rainfall without climatic extremes during the nesting season. Of the 49 species for which data are available, 18 had failed to breed by the end of November 1994, whereas in 1996 all but three species had initiated nesting by this time. Environmental factors influenced each species uniquely. Of the 28 species that bred in both years, 15 showed similar timing, while 13 differed in timing by 2–8 weeks, 10 of which started later in 1994 and three earlier. Largely due to poor weather and the lack of rain, only 29 per cent of nests (both open- and hole-nests) in 1994 succeeded in fledging young compared with 41 per cent in 1996 when predation rates on nests appeared higher, but weather conditions were more favourable.

INTRODUCTION

Recher *et al.* (1983) and Recher and Holmes (1985) described the seasonal pattern of nesting of birds in eucalypt forest at Bondi (37°08 'S, 149°09'E; 790–870 m amsl) on the southern tablelands of New South Wales. They reported a strongly seasonal pattern with nesting initiated in late winter (July) followed by a rapid increase in the number of nesting birds and species during August and September. Nesting activity remained high during late spring and early summer (October-December) and then declined rapidly, finishing in late summer (February). Early nest initiation was by resident species (July-September) with migrants being a major component of the breeding community from October to December. Marchant (1981, 1992) reported a similar pattern for forest birds at Moruya (35°52'S, 150 °03'E; 80–110 m amsl), on the southern coast of New South Wales. At Moruya, the breeding of almost all species occurred between early August and late December. Only a few species began nesting before August, with a small number of nests initiated as late as February or March (Marchant 1981). At least one species nested every month at Moruya except May (Marchant 1992).

Marchant (1981, 1992) reported that the pattern of nesting between September and December was similar between years, but the time of initiating nesting by species at the start of the season could differ by as much as three weeks between years. Similarly, the number of birds nesting into late summer was variable between years. However, most species were consistent between years and the variability in the initiation of nesting in winter and its conclusion in summer was attributable to a small number of resident species (Marchant 1992). Variation between years in either nest initiation or the conclusion of nesting appeared to be determined by weather, with rainfall and temperature affecting patterns of nesting. Low rainfall in autumn and winter delayed the start of nesting, whereas late rain could prolong the season (Marchant 1981).

Community-wide studies of the nesting ecology of eucalypt forest and woodland birds, such as those of Recher *et al.* (1983) and Marchant (1981, 1992), are important for several reasons. Apart from increasing our knowledge of the natural history of Australian birds, data on the time and pattern of nesting have important management applications. For example, when the nesting season is well known, habitat manipulations, such as hazard reduction burns, can be timed to mitigate adverse impacts on either the entire community or on species of special concern. Seasonal data on nesting provide benchmarks against which the developing effects of global warming can be monitored. They are also useful in evaluating the impact on birds of nest predation and changes in community composition, both of which are affected by human-induced habitat changes. Unfortunately, such data are rare.

Here, we describe the pattern and timing of nesting by 57 species of birds in eucalypt *Eucalyptus* forest on the northern tablelands of New South Wales. We focus on the initiation of nest building and incubation, and on the influence of environmental factors on nesting effort and success. Our aim is to provide an overview of the breeding success and timing of nesting of an entire avian community.

METHODS

Study site

Data were collected on the Newholme Field Station (30°30'S, 151°40'E; 990–1 390 m amsl) of the University of New England ten kilometres north of the town of Armidale. Newholme has a temperate climate with about 50 frosts per year, occasional snow in winter, and moderate summer temperatures. Summers tend to be wet and winters dry, although rain falls throughout the year (Fig. 1).

Newholme centres on Mt Duval (1 393 m), a dome about 300 metres higher than the surrounding countryside. Mt Duval is capped by moist, tall-open eucalypt forest of *Eucalyptus obliqua* and *E. nobilis*. With decreasing altitude the moist forest grades into an open, dry forest dominated by stringybarks *E. caliginosa* and *E. laevopinea* and woodland dominated by boxes *E. melliodora* and *E. bridgesiana*. *E. dalrympleana* and *Angophora floribunda* are abundant on fluvial flats. Shrubs are sparse with patches of *Acacia*, *Bursaria*, *Rubus* and *Leptospermum* on lower slopes and along creeks. Native grasses dominate the ground vegetation.

Mt Duval is surrounded by open farmland with woodland patches. Domestic stock were excluded from the higher elevations of Mt Duval from the mid-1980s, but lower slopes and creek lines are heavily grazed by sheep and cattle and this affects both ground cover and the density and floristic composition of the shrub layer. Fires are rare at Newholme and none of any extent has occurred since the 1950s.

Data collection and analysis

Recher and McLean and his colleagues (henceforth McLean) collected their data independently and followed different procedures. Their data are therefore presented and analysed separately. The names of birds and the abbreviations of bird names used in tables are presented in Appendix 1.

Recher's procedures and study site

From September 1988 through December/January 1990/91, Recher attempted to locate all nests in forest and woodland along the western drainage of Dumaresq Creek (1 070–1 100 m amsl). During the 1991/92 and 1992/93 breeding seasons, the same area was searched for nests, but less frequently than previously. Outside the nesting season, Recher regularly visited the area to conduct other studies on birds and forest arthropods.

The area searched by Recher was mainly box woodland with *E. dalrympleana/A. floribunda* forest on the fluvial flats. Shrubs were sparse in the box woodland, but an extensive shrub layer dominated by *Bursaria*, *Rubus*, *Leptospermum* and *Acacia* occurred along the creek and on the flats. The area was heavily grazed by sheep. During summer, this resulted in extensive patches of bare soil.

Recher recorded all nests located regardless of whether the nest was completed or eggs laid. Fledglings being fed by adults, which could not be assigned to a known nest, were taken as evidence of nesting and recorded as a successful nest. Mostly he did not approach nests to record the number of eggs or nestlings, and apart from warbler (gerygone) and thornbill nests, nests were only re-visited opportunistically. Consequently, Recher can provide a time for the initiation of incubation for only a small number of nests and his data are analyzed on the basis of when nest building commenced regardless of whether or not eggs were laid. For nests located after incubation commenced or when nestlings were present, he used the same criteria as McLean (see below) to estimate the date at which nest building commenced. Thus, only a few nests of hole-nesting species recorded by Recher can be assessed for nest initiation. As his effort was spread equally between months regardless of year and total effort, Recher's data from different years are combined for analysis.

For open-nests, Recher made a decision about whether or not the nest had succeeded in fledging young. These decisions were based on whether or not fledglings were observed with the breeding unit or whether the empty nest appeared intact and not predated. Decisions about success were facilitated by the large number of banded and colour-banded birds from Recher's other studies on the study area, and the obvious damage done to nests by nest predators. In deciding whether or not a nest had been predated, Recher was conscious of the fact that birds building nests will take material from old nests, including those of other species. Ninety-five per cent confidence limits for the proportion of nests estimated to succeed or fail, and the reasons for failure, were calculated following Zar (1984; Pp. 378–379, Confidence Limits for Proportions).

McLean's procedures and study sites

McLean worked at Newholme from 13 October to 27 November 1994, and 9 October to 15 December 1996. Two observers searched for nests for 5–10 hours daily and recorded other breeding data (e.g. courtship, fledglings). Forty-nine species were monitored sufficiently closely to be confident that any breeding or nesting would have been detected. Effort was equally distributed among six study sites (1 080–1 390 m amsl), each about 5 hectares in size. These encompassed the full range of habitats available on Newholme. Five sites were the same in both years, but each year a site was searched that was not used in the other year. One site was part of the area in which Recher had worked. Opportunistic observations of nesting were made throughout Newholme as observers moved between study sites and are included as part of McLean's data set.

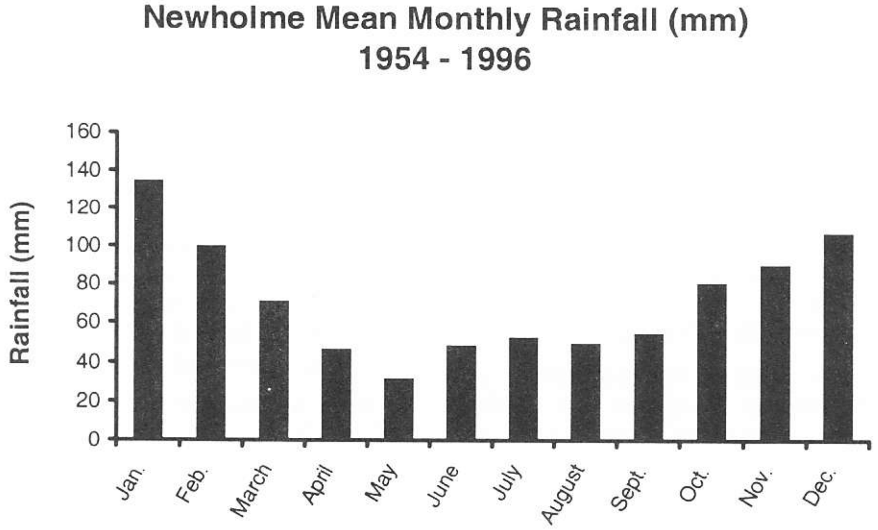

Figure 1. *Mean monthly rainfall (1954–1996) at the Newholme Field Station of the University of New England near Armidale, New South Wales.*

Nests found by McLean were at any stage of the breeding cycle, and it was necessary to estimate dates of nest initiation, egg laying and incubation, hatching and fledging. To estimate the date of initiating incubation, McLean calculated back as follows: from date of fledging, back five weeks for open-nesting birds and back six weeks for hole-nesters and cracticids; from date of hatching back 2.5 weeks (after Woinarski 1985). If the date of initiating incubation was not known or could not be estimated to within one week, the record was excluded from analyses. As the time taken to complete a nest changes seasonally (McLean and Recher, pers. obs.), two weeks were allowed for nest building and egg laying during July and August, and one week for September through February.

Assessment of the time of nest initiation for a species by McLean could be based on a single nest. However, for most species the assessment was based on more than two indicators of breeding (e.g. building and fledging). McLean made 4–20 independent observations of nests or other indications of breeding for most species. Fewer observations were available in 1994, when few birds nested (see results), than in 1996. Failure rates of nests found by McLean were calculated using Mayfield estimates (Mayfield 1975).

RESULTS

Rainfall

From 1987 through 1992, the mean annual rainfall (839 mm; range 771–880 mm) was slightly below the long-term average of 886 millimetres (range 526–1 283 mm) (unpubl. Newholme weather records — Fig. 2). For 1993 through 1996, rainfall was average (891 mm; range 735–1 147 mm). Autumn through early spring (April-August) in 1994 was dry with 106 millimetres of rain compared with the long-term average for the period of 255 millimetres. September through November was also dry with only 115 millimetres of rain (long-term average 224 mm). 1996 had a higher than average annual rainfall (1 147 mm). For the April-August period in 1996, rainfall totaled 302 millimetres; for September-November, rainfall totaled 234 millimetres.

Recher's observations

Between 1988/89 and 1992/93, Recher found 333 nests or dependent fledglings of 46 species. A date for nest initiation was assigned to 285 of the 333 breeding events (Table 1; Fig. 3). The others were either hole-nests where the status of the nest was uncertain or where nests were found after they had been abandoned or predated. Species for which breeding was recorded by Recher, but no dates for nest initiation were assigned were Eastern Rosella (n = 6), Crimson Rosella (8), Galah (2), and Common Starling (2).

Forty-nine species nested on Recher's study site between 1988/89 and 1992/93. This includes cuckoos and species known to breed at Newholme, but for which nests or fledglings were not found (e.g. Tawny Frogmouth *Podargus strigoides*). In 1988/89, 165 nests of 34 species were found; in 1989/90, 57 of 23; in 1990/91, 62 of 18; and, in 1991/92–1992/93, 49 of 22. As Recher spent different amounts of time searching for nests each year, it is not possible to attribute differences in the number of nests found between years to breeding effort and hence to differences in rainfall or other environmental factors.

SEASONAL PATTERNS OF NEST INITIATION

Based on Recher's observations, nest building began each year in the last fortnight of July (Fig. 3). Striated, Brown and Yellow-rumped Thornbills were the first to commence nesting (Table 1). Australian Magpie and Pied Currawong began building in early August, although they did not lay until later (see below). White-naped Honeyeaters were the earliest honeyeaters to begin nesting. By late August, thornbills, two honeyeaters, both treecreepers, Laughing Kookaburra, Orange-winged (Varied) Sittella and Spotted Pardalote were nesting. Residents dominated nesting until October when an increasing proportion of nesting birds were migrants and nomads (e.g. Rufous Whistler, White-throated Warbler (Gerygone), Black-faced Cuckoo-shrike) (Table 1; Fig. 4).

The number of nests initiated increased from July to late September with a second peak in late October (Fig. 3). Nest initiation decreased sharply in November (Fig. 3), by which time most birds were already nesting or had fledglings. Only a few birds initiated nests in December and no new nests were initiated after December (Table 1).

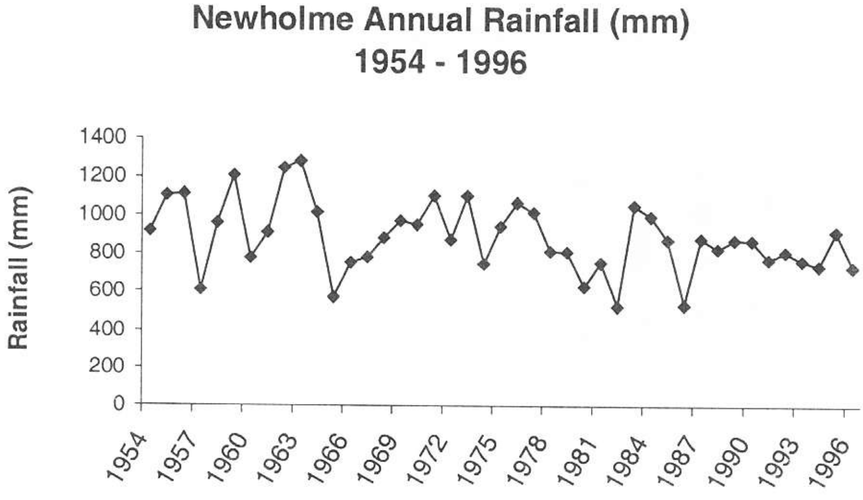

Figure 2. *Annual rainfall (1954–1996) at the Newholme Field Station of the University of New England near Armidale, New South Wales. Mean annual rainfall was 886 millimetres over this period.*

TABLE 1

Timing of nest initiation for forest and woodland birds on the Newholme Field Station Armidale, New South Wales from 15 July to 31 December during 1988/89–92/93 breeding seasons inclusive. More than one nest may have been initiated in each week by a species; number of breeding events assigned a date for nest initiation in parentheses. Dates based on data of H. Recher. Species names as in Appendix 1.

	NESTS INITIATED																					
MONTH	July		August				September				October				November				December			
WEEK	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
StTh (52)	■	■		■	■	■	■	■	■	■	■	■	■									
YRTh (20)	■		■	■	■	■	■	■		■	■	■	■			■						
BrwnTh (11)		■	■	■	■			■														
AuMa (9)			■		■	■	■	■	■													
WNHo (12)			■			■	■	■	■		■	■	■	■		■						
PiCu (7)				■			■	■	■													
BRTh (26)					■	■	■	■	■	■	■	■	■	■		■						
ReWb (6)					■			■		■												
SpPa (4)					■		■		■													
LaKo (4)						■	■					■										
OrWSit (13)						■	■	■	■	■							■					
RBTc (4)						■			■								■	■				
WTTc (5)						■		■	■		■	■										
BrwnGos (1)							■															
CrstPig (1)								■														
FuHo (5)								■				■	■	■								■
GrFa* (26)								■	■	■	■	■	■	■		■	■					
KingParr (1)								■														
NoMi (1)								■														
ScRo* (1)								■														
WEHo (2)								■	■													
WiWa (9)								■	■		■	■	■			■	■					
EaSb* (5)									■	■	■	■										■
MaLa (1)									■													
RuWh* (5)									■		■	■										
StPa (8)									■	■		■	■	■								
BFCS* (4)										■				■								
GrST (2)										■	■											
SuBW (8)										■	■		■									
WBSW (1)										■												
WTWa* (7)										■		■		■			■					
MistB* (2)											■				■							
YFHo (6)											■	■		■		■						■
DuWs* (2)												■		■								
NoFr* (3)												■		■		■						
ObOr* (2)												■										
Goldf(1)													■									
LeFc* (3)													■	■		■						
SaFc* (2)														■		■						
RbFi (1)																	■					
SaKf* (1)																	■					
CrStit (1)																			■			

*migrant or nomad absent in winter.

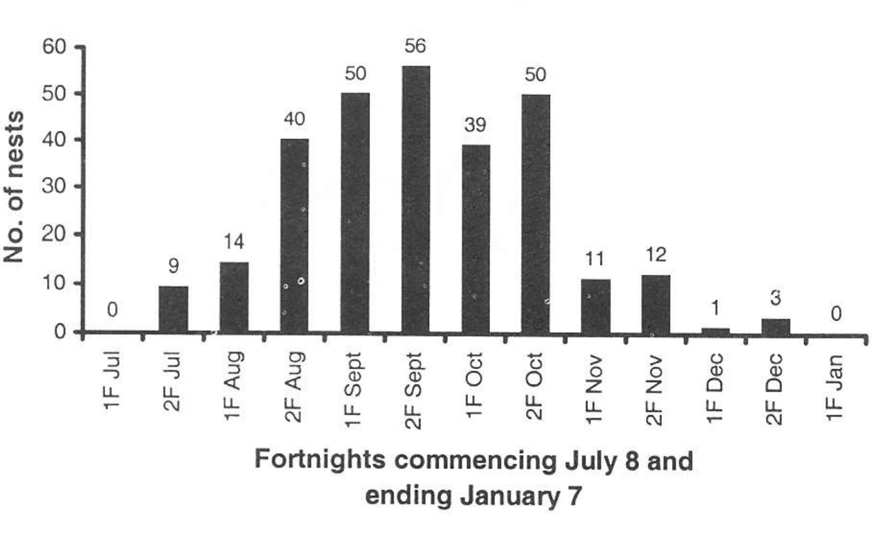

Figure 3. *The number of nests initiated each fortnight by forest and woodland birds in the western catchment of Dumaresq Dam on the Newholme Field Station of the University of New England near Armidale, New South Wales from September 1988 through the 1992/93 breeding season. No new nests were found from January through June with the first nests being initiated in mid- to late July.*

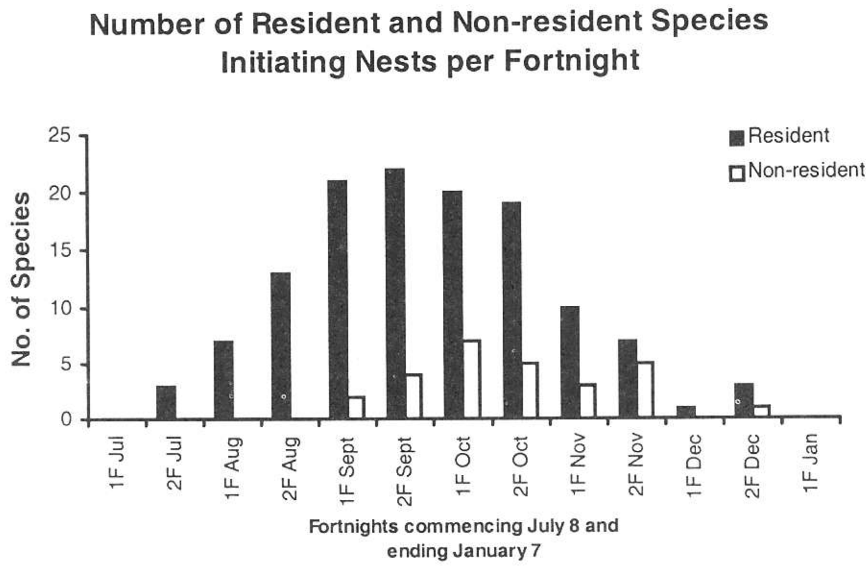

Figure 4. *Number of species of resident forest and woodland birds initiating nesting each fortnight from July to December (1988/89–1992/93 breeding seasons inclusive) compared with number of migratory and nomadic species (non-residents) initiating nesting. Data are from the western catchment of Dumaresq Dam on the Newholme Field Station of the University of New England near Armidale, New South Wales.*

Of the 42 species for which dates of nest initiation could be assigned, 34 initiated nesting over a period of one to three months and eight for four months or longer. The increase in nest initiations in late October was due to the commencement of nesting by migrants and second or third nesting attempts by resident species.

NEST SUCCESS

Excluding hole-nesters, raptors, magpies and currawongs, of 256 nests of 32 species of open-nesting birds Recher made a decision on the fate of 122 nests of 23 species. Thirty-five nests (29%) (95% confidence intervals: 21–38%) fledged young, while 87 (71%) (64–79%) failed. Of the 87 nests which failed, a cause was assigned for 63; 44 (70%) (60–79%) were predated, 17 were abandoned, usually without laying (27%) (17–39%), and two were destroyed by rain and strong wind (3%) (0–11%).

LENGTH OF BREEDING SEASON

Nests were initiated over a 22-week period from July to December (Fig. 3). More than 80 per cent of nests were initiated during the 10 weeks from mid-August to late-October. Three species commenced nesting in July, 10 in August, 18 in September, and eight in October, two in November and one in December (Table 1). Approximately equal numbers of species initiated nests through September and October (Fig. 4). Because searching for nests was less intensive early and late in the season, it is possible that nesting occurred over a longer period. However, there was no evidence of breeding during late summer (January-February) and autumn when Recher conducted other fieldwork on birds on the same study site.

McLean's observations

McLean located and monitored 90 nests of 31 species in 1994, and 200 nests of 46 species in 1996. These counts do not include all the nests of highly synchronised colonial or semi-colonial species such as Common Starling, Tree and Fairy Martins. Additionally, nest records of some abundant hole-nesting species (i.e. pardalotes and parrots) were not maintained once their breeding pattern had been established. Excluding nest counts of colonial and semi-colonial species, the week for initiation of incubation was estimated for 38 nests of 31 species in 1994 and 113 nests of 46 species in 1996 (Table 2).

In 1994, there was less rainfall than in 1996 and from April through October only a small number of birds attempted to nest. Birds with nests were subsequently affected by heavy rain and hail in late October and early November, and by severe windstorms on 5–7 November. Nests were saturated by the heavy rain and most open nests above 3 metres were destroyed by the November winds.

Effects of storms in 1994 differed between species: some open-nesters appeared little affected (e.g. Noisy Miner), some lost almost all nests (e.g. canopy-nesting honeyeaters), and some did not lay even if a nest had been built (e.g. Satin Flycatcher, Crested Shrike-tit). From the second week of November 1994, rain fell every few days and storms were less intense. During 1994, some species, which normally initiated nesting earlier in the season, only commenced nesting in mid- to late November following the rain. However, 18 species had failed to breed by the end of November, whereas in 1996 almost all species had initiated nesting by this time. No nests of Red-browed Treecreeper, or Scarlet and Flame Robins were found in 1996, but this could have been a sampling error as all three are uncommon or rare at Newholme.

Two common resident species, Silvereye *Zosterops lateralis* and Golden Whistler *Pachycephala pectoralis*, did not nest in either 1994 or 1996. Red-browed Finches did not nest in 1994, but were frequently seen at nests in 1996.

TABLE 2

Earliest estimated date that incubation was initiated for bird species at Newholme Field Station, Armidale, New South Wales in spring 1994 and 1996 (□). Dates based on observations of I. McLean. Species names as in Appendix 1.

INCUBATION INITIATED																								
MONTH	SEPTEMBER								OCTOBER								NOVEMBER							
WEEK	1		2		3		4		1		2		3		4		1		2		3		4	
YEAR	94	96	94	96	94	96	94	96	94	96	94	96	94	96	94	96	94	96	94	96	94	96	94	96
StTh		□																						
BrwnTh		□	□																					
AuMa	□			□																				
WNHo	□													□										
BRTh	□			□																				
WBSW		□			□																			
WeSw	□											□												
YRTh				□									□											
WTTc				□					□															
NoMi			□	□																				
WEHo			□													□								
AuRa			□	□																				
WWCh				□															□					
SuBW						□							□											
BHHo						□																		
EaSb*						□									□									
SpPa							□	□																
StPa							□	□																
RBTc									□															
SaKf*										□														
FuHo											□			□										
DuWs*											□			□										
MaLa											□			□										
ComSt											□	□												
Gala												□												
FaMa*												□												
TrMa*												□			□									
FlRo*													□											
OrWSit													□			□								
LaKo														□										
WiWa														□			□							
ReWb														□										
YFHo*														□							□			
GrBu														□										
GrFa*															□	□								
PiCu															□	□								
EaR																□								
CrR																□								
RRPa																□								
GrSt																□								
RuWh*																□								
NoFr*																□								
ScRo*																	□							
BFCS*																		□			□			
LeFc*																		□						
SaFc*																		□						
WTWa*																		□						
DoBd*																					□	□		
WWTr*																								□

*migrant or nomad absent in winter.

However, incubation was not confirmed due to the difficulty of checking domed nests without damaging them and the persistent nest attendance by these birds whether or not they were breeding. Thus, they are not included in analyses.

Seasonal patterns of nest initiation

Based on the estimated time of initiating incubation, McLean's data suggest that only a few species lay eggs before September or commence first clutches after October (Table 2). In 1994, White-naped Honeyeaters had fledglings when McLean arrived in mid-October and, in 1996, thornbills had fledglings by early October. Species initiating incubation after mid-October were mainly migrants (e.g. Dollarbird, White-winged Triller), but some nomads (e.g. Black-faced Cuckoo-shrike) and residents (e.g. Scarlet Robin, Willie Wagtail) also appeared to be late nesters (Table 2), although residents might have been re-nesting.

Differences between 1994 and 1996

McLean recorded 31 species nesting in 1994 and 46 in 1996. Twenty-eight species nested in both years; three were only recorded nesting in 1994 and 18 only in 1996.

Although a few species may have initiated incubation before September, September and October were the main periods for incubation of first clutches in both 1994 and 1996. Nineteen species commenced first clutches in late October in 1996 compared with eight in 1994 (Table 2). Eight species began incubation in the same week in both years (Table 2). Seven species differed by one week (in 1994, 6 species nested earlier; in 1996, 1 species nested earlier); 4 species differed by 2 weeks (1994 earlier: 0; 1996 earlier: 4); 6 species differed by 3–5 weeks (1994 earlier: 1; 1996 earlier: 5); and 3 species differed by 6–8 weeks (1994 earlier: 2; 1996 earlier: 1). Thus, of the 28 species recorded breeding in both 1994 and 1996, 15 initiated incubation at about the same time in both years (i.e. within one week); 13 species initiated incubation at a different time, ranging from 2–8 weeks apart, with 10 of these being later and 3 earlier in 1994, relative to 1996.

Nest success/nest predation

Nest success of the larger predatory birds differed between years. In 1994, there were no successful nests of Sacred Kingfisher, Laughing Kookaburra, Grey Butcherbird and Pied Currawong, although all built nests. Only Pied Currawongs began incubation. Just one Australian Magpie and one White-winged Chough nest were located in 1994. The magpie nest fledged one chick and the choughs incubated late in the season with unknown success. By comparison, in 1996, success rates for these species were high: three of four kookaburra nests, all six magpie nests (known fledgling groups were 3, 3, 4), four of five currawong nests (fledglings: 1, 2, 3), both butcherbird nests (fledglings: 2, 3), and one of two chough nests (fledglings: 3; the single chick in the other nest was predated just before it was due to fledge) fledged young. No information on success was obtained for Sacred Kingfisher. Compared with the larger species in 1996, the smaller, open-nesting species had a high failure rate, mainly from predation. For example, all Rufous Whistler (n = 8) and Grey Shrike-thrush (n = 4) nests failed, while 12 pairs of Grey Fantails produced just two groups of fledglings from 20 known attempts.

Mayfield estimates of nest failure rates (all species) were 4.0 per cent/day in 1994 (n = 27 nests) and 2.96 per cent/day in 1996 (n = 74). For a 30-day incubation and nestling period, these values indicate survival rates to fledging of 29 per cent of nests in 1994 and 41 per cent of nests in 1996. It appeared that nest predation rates were lower in 1994 than in 1996, with the higher failure rate in 1994 due to nests being abandoned or destroyed by storms, rather than being predated.

The small number of nesting attempts in 1994 did not necessarily result in substantially lower productivity in 1994 relative to 1996 for some species. Some species failed to fledge young in either year, and some, such as Noisy Miner and Common Starling, did well in both years. Hole-nesters and seed-eaters (especially parrots) had much higher nest success in 1996 than in 1994. No parrots were known to breed successfully in 1994, although any birds fledging in late December would have been missed.

DISCUSSION

Initiation of breeding

When discussing the breeding season of birds at Newholme, we have kept in mind the small sample sizes for most species and therefore discuss our results in a community context. On a community-wide basis, the timing of nest initiation, incubation, fledging of young, and the cessation of breeding among forest and woodland birds on the northern tablelands parallels the timing of these activities for coastal and tableland forest bird communities in southern New South Wales (see Marchant 1981, 1992; Recher *et al.* 1983; Recher and Holmes 1985).

Small resident insectivores commenced nesting first, followed by other resident species. Migrants and nomads nested later. McLean's estimates of the time of initiation of incubation during 1994 and 1996 suggest that few individual birds laid before September regardless of when nests were started. However, Ford (*in litt.*) points out that early nests could have been mostly predated, a possibility that cannot be refuted as McLean did not begin fieldwork until October.

As migrants returned after residents had commenced breeding, the breeding season for most migrants was abbreviated (1–2 months) and most made only one attempt to nest, whereas many resident species had multiple broods or nested again if the first nest failed. Although some individuals of early nesting species attempted to nest in summer, only a few species initiated nests after November.

Recher *et al.* (1983) and Recher and Holmes (1985) show breeding on the southern tablelands as continuing actively through most of December, declining sharply only in the second half of the month. Marchant's (1981) graphs of nesting activity at Moruya also show nesting extending through December, whereas the data presented here for the northern tablelands show a sharp decline in November with few nests in December (Table 1; Fig. 3). The difference between our graphs of nesting activity and those from southern New South Wales are a result of using different measures of nesting activity. In this paper, we reported on the dates nests were initiated (Table 1; Figs 3, 4) and when incubation commenced (Table 2).

For the southern tablelands, the graphs of nesting activity are based on the number of active nests in a fortnight (Recher and Holmes 1985). This included nests being built, as well as those with eggs and nestlings and where fledglings were being fed by adults. Although not explained by Marchant (1981), this also appears to be the case with his graphs of nesting activity — that is, he plotted the number of active nests per fortnight, not just those being initiated. At Newholme, nests initiated in November remained active into December and a graph of 'active nests/fortnight' would be similar to those from southern New South Wales. Thus, there may be little difference in the timing of breeding activities between the three locations, despite the differences in latitude and altitude.

Length of breeding season

Marchant (1992) described the breeding season for temperate eucalypt forest bird communities as 'sharp and short' and calculated that the average breeding season for species was 3–4 months. Based on a decade (1975–84) of nest data from Moruya, one to two months was typical for five species, 2–3 months for 10, 3–4 months for seven, and 5–6 months for one (Marchant 1992). Based on Recher's data from Newholme (Table 1), 34 species initiated nests over a period of one to three months, while eight species nested over a period of four to six months. Allowing for differences in data collection, the length of the breeding season for species on the northern tablelands appears to be about the same as for Moruya and is similar to the southern tablelands (Marchant 1981,1992; Recher *et al.* 1983; Recher and Holmes 1985; Recher, unpubl. data from the southern tablelands).

Comparison of Recher and McLean

At Newholme, McLean detected early nesting (i.e. July or early August) only if the nests were successful through sightings of fledglings. Thus, some early nesting attempts may have failed before the arrival of the researchers in 1994 and 1996 and not been detected. Recher monitored nests of thornbills in which incubation began in August, which is earlier than the estimates from McLean's data. It is therefore likely that McLean's estimates for starting dates of the earliest breeding species are later than normally occurs. However, most of the early breeding species in Recher's study did not lay eggs and begin incubation until later, despite early nest building. Early season nests, particularly of thornbills, appear bulkier and take longer to construct than nests built in warmer weather (Recher, pers. obs.). Therefore, despite differences in methodology and the time observations were made, there is a high level of consistency between the data of Recher and McLean.

Effects of weather

Seasonal conditions affect the timing of the breeding season. Nix (1976) predicted that breeding is timed to coincide with peak plant growth and the sequential availability of insects, nectar, fruit and seeds, and will differ in different parts of the continent. Within a season, breeding is affected by local conditions. Marchant (1981) reported that nesting was most successful in years with 'substantial' rain in autumn and early winter. In 1994, a drought year, relatively few birds nested on Newholme. Marchant (1981) and Recher *et al.* (1983) also found that breeding was depressed in dry years in southern New South Wales. However, rain, even late in the breeding season, may stimulate nesting for some species. While this is most apparent in semi-arid and arid environments (Serventy and Marshall 1957; Maclean 1976), Marchant (1981) found that late rain might also stimulate nesting in more mesic regions.

The effects of storms and rainfall were apparent at Newholme. At Newholme, 1994 was a 'dry' year with catastrophic environmental events during the breeding period. Fewer birds and species nested and those that did tended to initiate nesting later than in 1996 when conditions were more favourable. Following dry conditions from autumn through spring in 1994 there was an increase in breeding activity following rain in early November. For the bird, which did attempt to nest early in 1994, many nests were lost due to heavy rain and wind.

Weather can also affect the number of nesting birds by reducing population sizes. For example, during the winter of 1989, there was heavy snow, which persisted on the ground for several days. The snow prevented small ground-foragers, such as Buff-rumped and Yellow-rumped Thornbills, from feeding and more than 90 per cent of colour-banded individuals of these species disappeared during and immediately following the snow event (Recher, unpubl. data). As both species were previously abundant, the total number nests found the following spring and summer was reduced. The reduction in the number of nesting birds of the species affected persisted through 1993 (Recher, unpubl. data). Analogously, Marchant (1992) reported a decrease in breeding populations at Moruya following drought. Thus, climatic extremes and severe weather have considerable within season and between-year effects, either by preventing breeding, destroying nests or killing birds.

Nest success/nest predation

McLean's observations suggest that low productivity in 1994 and 1996 for some species at Newholme may be attributable to a link between predation rates, predator breeding success and environmental variability. Species whose nests are routinely preyed upon may only have high overall success in years in which conditions are suitable for them, but poor for the predators. Such a coincidence is likely to be rare.

The percentage of nests fledging young is highly variable. Ford *et al.* (2001), for example, reported success rates ranging from 10 per cent to 71 per cent for open-nesting passerines in Australia. Similar variability occurs in North America with Nolan (1963) reporting an average success rate of 21 per cent for 11 species. Nice (1957) reported an average success rate of 49 per cent for 'many species' (cited in Ford 1989, P. 108). At Newholme, Recher recorded a success rate of 29 per cent for open-nests from 1988/89 to 1992/93, the same as McLean in 1994 for both open- and hole-nests. Under the more favourable conditions of 1996, McLean recorded a success rate to fledging of 41 per cent, but many open-nesting species failed due to high nest predation rates. Predation appears to account for 50–60 per cent of nest failures among open-nesting passerines in Australia (Ford *et al.* 2001), which is similar to Recher's attribution of 60–79 per cent of nest failures at Newholme to predation. If anything, Recher's data overestimate nest success as some nest attempts were recorded after fledging, while nests that failed early (e.g. during egg laying and incubation) were more likely to be missed than those that hatched and/or fledged young.

The low success rate of nests on Recher's site compared with McLean's multiple sites requires explanation. Where Recher worked, there were several nesting pairs of currawongs and currawongs were regularly observed searching for nests. In addition, Recher's data are for open-nesters and small passerines, whereas McLean's include many hole-nesters and larger species, which suffered less nest predation so the difference may not be as great as it appears. At least some nests may have been abandoned before completion or laying due to the presence of currawongs; small passerines stopped nest building and feeding nestlings whenever currawongs were near the nests (Recher, unpubl. observ.).

Management

Nesting by birds in temperate Australian woodlands and forests peaks in early spring (September-October). This has significant management implications, particularly in respect to hazard reduction burning. Because of the need to burn under cool, moist conditions when fires can be controlled, forest managers in Australia tend to use fire to reduce fuel loads in late winter and spring. Fires are therefore set when the majority of resident birds have commenced nesting and migrants are returning to their breeding sites. Although resident species will re-nest, if a nest is lost, later nests may be at increased risk of predation or of parasitism from cuckoos, which are migratory and arrive after nesting by resident small insectivores commences. The consequences of losing a set of nests, or even a season of breeding, may be easily compensated for in later years. However, there are no data to confirm or reject this. It is equally plausible to suggest that as habitats become increasingly fragmented, the loss of a breeding season to fire may have significant long-term effects. If the next burn occurs after a short time period, populations may be reduced to levels that are not sustainable, especially in habitats where nest predation rates are high. Given that eucalypt forest and woodland birds have highly seasonal breeding seasons and that reproductive success is affected by high predation rates and unpredictable storm events, there is an urgent need to measure the impact of hazard reduction burning programs on bird communities. Until that is done, there is an argument to avoid burns during the breeding season (late winter–spring) in habitats with threatened communities and/or species.

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APPENDIX 1

Common and scientific names for forest bird species found nesting at Newholme Field Station, Armidale, New South Wales from 1988/89 to 1992/93, 1994 and 1996. Species are in alphabetical order with abbreviations (code) used in Tables 1 and 2.

CODE	SPECIES	
KingParr	Australian King Parrot	*Alisterus scapularis*
AuMa	Australian Magpie	*Gymnorhina tibicen*
AuRa	Australian Raven	*Corvus coronoides*
BFCS	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
BrwnGos	Brown Goshawk	*Accipiter fasciatus*
BrwnTh	Brown Thornbill	*Acanthiza pusilla*
BHHo	Brown-headed Honeyeater	*Melithreptus brevirostris*
BRTh	Buff-rumped Thornbill	*Acanthiza reguloides*
ComSt	Common Starling	*Sturnus vulgaris*
CrstPig	Crested Pigeon	*Ocyphaps lophotes*
CrStit	Crested Shrike-tit	*Falcunculus frontatus*
CrR	Crimson Rosella	*Platycercus elegans*
DoBd	Dollarbird	*Eurystomas orientalis*
DuWs	Dusky Woodswallow	*Artamus cyanopterus*
EaR	Eastern Rosella	*Platycercus eximius*
EaSb	Eastern Spinebill	*Acanthorhynchus tenuirostris*
EurGoldf	European Goldfinch	*Carduelis carduelis*
FaMa	Fairy Martin	*Hirundo ariel*
FlRo	Flame Robin	*Petroica phoenicea*
FuHo	Fuscous Honeyeater	*Lichenostomus fuscus*
Gala	Galah	*Cacatua roseicapilla*
GrBu	Grey Butcherbird	*Cracticus torquatus*
GrFa	Grey Fantail	*Rhipidura fuliginosa*
GrST	Grey Shrike-thrush	*Colluricincia harmonica*
LaKo	Laughing Kookaburra	*Dacelo novaeguineae*
LeFc	Leaden Flycatcher	*Myiagra rubecula*
MaLa	Magpie-lark	*Grallina cyanoleuca*
MistB	Mistletoebird	*Dicaeum hirundinaceum*
NoFr	Noisy Friarbird	*Philemon corniculatus*
NoMi	Noisy Miner	*Manorina melanocephala*
ObOr	Olive-backed Oriole	*Oriolus sagittatus*
OrWSit	Orange-winged (Varied) Sittella	*Daphoenositta chrysoptera*
PiCu	Pied Currawong	*Strepera graculina*
RbFi	Red-browed Finch	*Neochmia temporalis*
RBTc	Red-browed Treecreeper	*Climacteris erythrops*
RRPa	Red-rumped Parrot	*Psephotus haematonotus*
ReWb	Red Wattlebird	*Anthochaera carunculata*
RuWh	Rufous Whistler	*Pachycephala rufiventris*
ScRo	Scarlet Robin	*Petroica multicolor*
SaFc	Satin Flycatcher	*Myiagra cyanoleuca*
SaKf	Sacred Kingfisher	*Todiramphus sanctus*
SpPa	Spotted Pardalote	*Pardalotus punctatus*
StPa	Striated Pardalote	*Pardalotus striatus*
StTh	Striated Thornbill	*Acanthiza lineata*
SuBW	Superb Fairy-wren	*Malurus cyaneus*
TrMa	Tree Martin	*Hirundo nigricans*
WeSw	Welcome Swallow	*Hirundo neoxena*
WBSW	White-browed Scrubwren	*Sericornis frontalis*
WEHo	White-eared Honeyeater	*Lichenostomus leucotis*
WNHo	White-naped Honeyeater	*Melithreptus lunatus*
WTTc	White-throated Treecreeper	*Cormobates leucophaeus*
WiWa	Willie Wagtail	*Rhipidura leucophrys*
WTWa	White-throated Warbler (Gerygone)	*Gerygone olivacea*
WWCh	White-winged Chough	*Corcorax melanorhamphos*
WWTr	White-winged Triller	*Lalage sueurii*
YFHo	Yellow-faced Honeyeater	*Lichenostomus chrysops*
YRTh	Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*