

## Order CORACIIFORMES

A morphologically heterogeneous group of birds, with large heads, short necks, short legs and, mostly, large bills. They comprise the kookaburras and kingfishers, todies, motmots, bee-eaters and rollers. Widely distributed, occurring on all continents except Antarctica, but most species occur Asia and Africa. In total, about 143–154 species in about 29–40 genera. Nine families recognized here (after Sibley *et al.* 1988; Sibley & Ahlquist 1990; Fry *et al.* 1992):

(1) **ALCEDINIDAE**: River kingfishers; 22–24 species in 2–4 genera: *Alcedo* and *Ceyx* (sometimes *Ispidina* or *Myioceyx* also recognized); distributed in Africa, s. and e. Asia, Indonesia, Philippines, Melanesia, New Guinea and Aust. Two species of *Alcedo* in HANZAB region.

(2) **HALCYONIDAE** (Dacelonidae of Sibley & Monroe 1990, cf. Sibley & Monroe 1993): Tree (or wood) kingfishers; 56–61 species in 8–12 genera; distributed in Africa, s. and e. Asia, Indonesia, Papuasias, Micronesia, Polynesia and Aust. and NZ. Eight non-vagrant species in four genera in HANZAB region.

(3) **CERYLIDAE**: Water (or belted) kingfishers; nine species in three genera: *Chloroceryle*, *Megaceryle* and *Ceryle*; distributed in Africa, s. and e. Asia, and New World.

(4) **MEROPIDAE**: Bee-eaters; 24–26 species in three genera: *Nyctyornis*, *Meropogon*, *Merops*; distributed Africa, s. and e. Asia, Indonesia, Melanesia, New Guinea and Aust. One species, Rainbow Bee-eater *Merops ornatus*, in HANZAB region.

(5) **CORACIIDAE**: Rollers; 12 species in two genera: *Coracias* and *Eurystomus*; distributed Africa, s. and e. Asia, Indonesia, Philippines, New Guinea and Aust. One species, Dollarbird *Eurystomus orientalis*, breeds HANZAB region; another species vagrant.

(6) **BRACHYPTERACIIDAE**: Ground-rollers; five species in three genera: *Atelornis*, *Brachypteracias*, *Uratelornis*. Endemic to Madagascar.

(7) **LEPTOSOMIDAE**: Monotypic Cuckoo-roller *Leptosomus discolor*, endemic to Comoro Is.

(8) **TODIDAE**: Todies; five species in monotypic genera *Todus*; distributed Caribbean islands of Cuba, Hispaniola, Jamaica and Puerto Rico.

(9) **MOMOTIDAE**: Motmots; eight or nine species in six genera: *Aspatha*, *Baryphthengus*, *Electron*, *Eumomota*, *Hylomanes* and *Momotus*; distributed in Neotropics from Mexico to n. Argentina.

Taxonomy of this and related groups somewhat controversial. Monophyly of the Coraciiformes has been variously questioned and supported, and further study needed. Probably polyphyletic (BWP), and have been split into as many as six orders (Stresemann 1959). Current views tend to recognize one order, but treatment of subordinal taxa varies (see Forshaw & Cooper 1983; Sibley & Ahlquist 1990; Fry *et al.* 1992; BWP). Conventionally, all kingfishers have been treated as a single family, Alcedinidae, with three subfamilies (e.g. Fry 1980; Forshaw & Cooper 1983; Schodde & Mason 1997; Peters; BWP); here, these subfamilies elevated to familial level (after Sibley *et al.* 1988; Sibley & Ahlquist 1990; Fry *et al.* 1992; Christidis & Boles 1994). The division into three families supported by DNA–DNA hybridization (Sibley & Ahlquist 1990) and chromosome studies (see Christidis & Boles 1994), but this view has been challenged (Schodde & Mason 1997) since these three groups are also considered as monophyletic with respect to their nearest relatives within Coraciiformes (Sibley *et al.* 1988). The most closely related groups are Trogoniformes (trogons), Upupiformes (hoopoes) and Bucerotiformes (hornbills) (Fry *et al.* 1992). These, too, have also been classified as families within the Coraciiformes (e.g. Peters; BWP). Other distantly allied groups include Galbuliformes (jacamars and puffbirds) and Piciformes (toucans, barbets, honeyguides and woodpeckers) (Fry *et al.* 1992).

Coraciiforms are a diverse group, with few anatomical characters that apply to all families. Palate desmognathous. Feet vary; usually have three toes directed forward and a hallux, but inner front toe reduced or missing in some Alcedinidae, and outer toe reversible in Leptosomidae; forward toes often fused or partly fused. Basipterygoid process absent or rudimentary. Hypotarsus complex. Syrinx tracheo-bronchial. Plumage bright, mainly iridescent or pigmentary greens and blues. Seldom much variation in plumage between ages or sexes.

Not well represented in HANZAB region; four families recorded, with 12 non-vagrant species in seven genera. Extralimital families not considered further here.

Coraciiformes occur in most habitats, from arid and semi-arid zones to tropical rainforest and mangroves. Kingfishers, rollers and bee-eaters all require habitats with at least a few trees, from which to hunt. All breed within hollows in branches or trunks of trees, or in tunnels excavated into banks of earth or termitaria (both arboreal and terrestrial). In HANZAB region, some species (e.g. Laughing Kookaburra *Dacelo novaeguineae*) may benefit from partial clearance of wooded habitats, though most are adversely affected by removal of hollow-bearing trees; others (e.g. Azure Kingfisher *Alcedo azurea*) adversely affected by removal or degradation of vegetation surrounding wetlands.

Generalized predators of arthropods and small vertebrates. Most are sit-and-wait predators; most hunt by sallying. With few exceptions, kingfishers do not pursue prey, unlike bee-eaters, which do. Both kingfishers and bee-eaters regurgitate pellets of indigestible material, such as insect sclerites.

In kingfishers, bee-eaters and rollers, hatching of broods always staggered, with up to 1 week difference between oldest and youngest nestlings. Nestlings squabble for food brought by parents, and nestlings soon learn to move toward entrance of nest when they perceive parent entering with food. If two or more nestlings, eldest (unless replete) usually takes prominent position when food arrives. When food scarce, only older nestlings are fed and others starve and die. Just before fledging, to encourage young to leave nest adults may starve them for 1–2 days. Parents stay near fledgelings, calling and bringing food in response to begging of young (Fry 1980; Fry *et al.* 1992).

Worldwide, 11 species considered threatened. Overall, the major threatening process is the clearance of habitat, though several species are adversely affected by the introduction of predators, particularly the Common Myna *Acridotheres tristis* (Collar *et al.* 1994).

Given the great similarities between Halcyonidae and Alcedinidae in social organization and behaviour and most aspects of internal structure, they are summarized together below.

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## Alcedinidae and Halcyonidae

Diagnostic features common to Alcedinidae and Halcyonidae (based on Ridgeway 1914; Sibley & Ahlquist 1990; Schodde & Mason 1997; BWP): Pelvic muscle formula, AX. No vomer. No caeca. No aftershaft. Carotid arteries paired. No spinal aperature. Palate desmognathous. Tongue and hyoid much reduced. Nares holorrhinal and impervious. Basisphenoid notch (unique to kingfishers) present in many Alcedinidae and some Halcyonidae. Neck short; 14–15 cervical vertebrae. Wings short with rounded tips, flight rapid and direct with fast wing-beats; 11–14 secondaries; 12 rectrices except *Tanysiptera* with ten. Oil-gland usually bilobed and tufted; naked in *Tanysiptera*. Bills, long and pointed. Three toes forward and one hind; feet strongly syndactylous: basal half to two-thirds of outer and middle toes fused; basal third of inner and middle toes fused, though inner toe reduced or absent in Alcedinidae, and often wholly fused to middle toe (reduced inner toe can lack claw). Syndactyl forms rather flattened soles.

Mating system and social structure of most species not well known (Fry *et al.* 1992) but breeding biology appears to be similar throughout (Fry 1980). Nearly all kingfishers live in pairs or, after dependent fledgelings have dispersed, live solitarily. The few species that breed co-operatively are more gregarious (Thomson 1964; Campbell & Lack 1985; see also accounts for Laughing *Dacelo novaeguineae* and Blue-winged *D. leachii* Kookaburras). In Aust., several species of kingfishers can live alongside one another, e.g. five species were seen within c. 200 m: Azure *Alcedo azurea*, Sacred *Todiramphus sanctus*, Forest *T. macleayi* and Collared *T. chloris* Kingfishers and Laughing Kookaburra (Mayo 1931); and during one breeding season, in c. 16–20 ha, there were three pairs of Collared Kingfisher, two pairs of Forest Kingfisher, two pairs of Laughing Kookaburra and 19 pairs of Sacred Kingfisher, all breeding except, possibly, one pair of Kookaburras (Miller 1937). Kingfishers often nest in active termitaria; for a discussion of this relationship, see Miller (1937), Hindwood (1959), Forshaw & Cooper (1983), North, and Campbell.

Generally breed as simple monogamous pairs in territories, and young are expelled from territories annually. The known exceptions are the kookaburras *Dacelo* and Striped Kingfisher *Halycon chelicuti*, in each of which some of population breed co-operatively: young of the year stay in parents' territory for 1 or more years, and become 'helpers' at the nest; their social, and sometimes sexual, roles almost indistinguishable from those of their parents (Campbell & Lack 1985; Fry 1980; Fry *et al.* 1992). More recently, the Mangaia Kingfisher *Todiramphus ruficollis* also found to breed sometimes as trio of mated pair and extra adult (Rowe & Empson 1996). Suggested that smaller alcedinid kingfishers probably begin to breed earlier in life than do larger halcyonid kingfishers (Fry *et al.* 1992). In kingfishers, both members of pair incubate and care for young. After fledging, young fed by adults for up to 10 weeks or more (Thomson 1964; Fry 1980; Campbell & Lack 1985). Nest solitarily or in loose colonies (Fry 1980). Pairs defend

nesting territories quite aggressively, though they often nest near other species of breeding birds. Non-migratory adults probably spend their lifetime within a territory or surrounding home-range, often using same nesting hole for many successive years (Hindwood 1959; Fry *et al.* 1992).

Kingfishers seem very uniform in behaviour (Fry 1992), though for many species little is known. Many are rather quiet and inconspicuous, though many species of Halcyonidae have loud songs and conspicuous tree-top territorial displays; mates may display together; kookaburras socially defend their territories with their well-known laughing song. Songs and displays among Alcedinidae weak or non-existent, and Alcedinidae much less conspicuous than Halcyonidae when defending territories (Campbell & Lack 1985; Fry 1980; Fry *et al.* 1988). During daylight, often quietly perch without moving for long periods; this is the main way kingfishers hunt, but at least sometimes they may be resting, though it is mostly impossible to distinguish. Allopreening uncommon in many kingfishers.

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## Family HALCYONIDAE tree kingfishers

The familial name Dacelonidae has been used in the past, but Halcyonidae has priority (Christidis & Boles 1994). Roughly 56–61 species in 8–12 genera (Sibley & Ahlquist 1990; Fry *et al.* 1992); widespread through Asia and A'asia, also occurring in Africa and islands in the Pacific and Indian Oceans; centre of distribution is region from Indochina to Bismarck Arch. Eight non-vagrant species in four genera occur in HANZAB region.

Medium to large kingfishers, with graduated tails that are longer than bills. Vary in size from New Britain Kingfisher *Halcyon albonotata* (c. 16 cm total length, weighing c. 32 g) to Laughing Kookaburra *Dacelo novaeguineae* of Aust. (c. 40 cm total length, weighing c. 400 g). The following characters distinguish from Alcedinidae (based on Schodde & Mason 1997; BWP; characters shared with Alcedinidae listed elsewhere): *Musculus expansor secundariorum* present. Skull relatively broad. Bill less laterally compressed than in Alcedinidae. Wings usually eutaxic, but diastataxic in some species of *Halcyon*. Usually 11 primaries, though p11 much reduced. Tail rather long, always greater than half length of wing. Tibiotarsus feathered to distal end. Tarsus rather long. Inner toe not reduced (cf. Alcedinidae). Sexes often differ slightly in plumage of upperparts and tail.

Adults often brightly coloured, with blue, green and yellow-brown plumage common. Bare parts dull in most temperate Aust. species, but often bright in tropical species. Bill, large and prominent. Post-breeding moult complete. Primaries moult outward from p1 (Forshaw & Cooper 1983; this study). Secondaries moult from outermost and innermost toward central feathers (Forshaw & Cooper 1983). Rectrices moult outward from t1 to t6 (Forshaw & Cooper 1983; this study). Nestlings altricial; naked at hatching; do not develop natal down, developing directly into juvenile plumage. Nestlings have characteristic spiny appearance, with feathers remaining ensheathed for some time. Adult plumage usually attained in first or second year. Most probably capable of breeding when c. 12 months old.

Worldwide, and in HANZAB region, variously sedentary or resident, migratory or partly migratory. Buff-breasted Paradise-Kingfisher *Tanysiptera sylvia* is only species to completely leave HANZAB region in winter, though large proportion of populations of Sacred *Todiramphus sanctus* and Forest *T. macleayii* Kingfisher also leave. Sacred Kingfishers exhibit altitudinal movement in NZ. Red-backed Kingfishers *T. pyrrhopygia* may be resident in N and partly migratory elsewhere, but overall movements poorly understood.

Feed on a wide variety of insects and small vertebrates, usually taken from ground, tree trunks, foliage and, less often, from water; none really specialized as a fisher. Sit-and-wait predators; spend much time perched searching for prey. Many species catch large proportion of diet by sallying, particularly species of *Halcyon* in w. Pacific Ocean and *Todiramphus* in Aust. Prey grasped in bill and bashed, then swallowed.

Normal breeding unit a monogamous pair, which nest solitarily or in loose colonies; cooperative breeding known to occur in some species, including kookaburras. Most Aust. species breed Sept.–Feb. Nest in natural tree-hollows (sometimes partly excavated by birds), or holes excavated by both sexes in earth banks or termitaria (both arboreal and terrestrial); some exclusively in termitaria. Nest usually an extended chamber, and in all species no nest material added. Eggs roughly spherical, glossy, white. Clutch-size varies from one to six. Usually lay at intervals of 1–2 days. Incubation by both sexes, normally starts after laying of first egg or just before laying of last egg in clutch. Incubation period 18–23 days in *Todiramphus*, <24–29 days in kookaburras. Hatching asynchronous. Young hatch naked, blind. Pin-feathers appear after c. 1 week and young fully feathered by 4–5 weeks old. Both parents care for and feed young; in co-operatively breeding kookaburras, all members of group share responsibilities at nest. Fledging period 24–29 days in *Todiramphus*, 33–38 days in kookaburras. Young independent 6–10 weeks after fledging.

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*Dacelo novaeguineae* **Laughing Kookaburra**

COLOUR PLATE FACING 1121

*Alcedo novae Guineae* Hermann, 1783, *Tabl. Affin. Anim.*: 192, note — New Guinea, ex Daubenton, *Planches Enlum.*: pl. 663; in error = north of Appin, County of Cumberland, New South Wales (*apud* Schodde & Mason, 1997, *Zool. Cat. Aust. Aves*).

Although frowned upon by nomenclatural purists, it was formerly considered acceptable to reflect the close relationship between birds by coining anagrams of existing generic terms. Here we have an anagram of the kingfisher genus *Alcedo*. The specific toponym, after New Guinea, is erroneous.

**OTHER ENGLISH NAMES** Kookaburra or Kooka; Jackass, Jack, Jacko, Jacky, John, or Johnny; Laughing Jack, Jackass, John, Johnny, Johnass or Johnniebottom; Brown, Great Brown, Giant or Laughing Kingfisher; Bushman's, Settler's or Shepherd's Clock; Ha Ha or Woop Woop Pigeon; Ha Ha Duck; Alarm Bird or Breakfast Bird.

**POLYTPIC** Nominate *novaeguineae*, e. and se. Aust.; introduced to Tas., sw. Aust. and NZ; subspecies *minor*, Robinson, 1900, C. York Pen. S to about Cooktown in E.

**FIELD IDENTIFICATION** Length 40–48 cm; wingspan 66–80 cm; weight 310–380 g. Largest kingfisher in HANZAB area; slightly bigger than Blue-winged Kookaburra *Dacelo leachii*, with shorter, more conical bill. Very large robust kingfisher; head, neck and underparts mostly white, marked with prominent dark eye-stripe; upperparts mostly dark brown, with light-blue mottling on upwing-coverts and rump; and tail barred rufous and black; iris dark. Loud raucous laughing call distinctive. While no separate breeding (alternate) plumage, primary adults have slightly brighter plumage than auxiliary (and non-breeding) birds (see Plumages). Sexes differ only slightly in plumage; females average slightly bigger but not reliable distinction. No seasonal variation. Much individual variation (see Plumages). **Adult male PRIMARY MALE:** Head and neck mostly white, with varying dark-brown streaking and barring on forehead and centre of crown, dark-brown patch on nape, and dark-brown eye-stripe from in front of eye and broadening into square-ended dark patch on ear-coverts. Saddle, rump and tertials, dark brown with fine off-white scaling to most of saddle, and pale-blue patch of varying size in centre of rump. Uppertail-coverts and uppertail, rufous, finely barred dark brown and tipped white. Upperwing: mostly black-brown, with mottled light-blue shoulder-patch, and white patch in outerwing, prominent in flight and sometimes visible on folded wing. Underbody, white, sometimes showing fine brownish-grey vermiculations, particularly along flanks. Undertail, rufous with narrow dark barring and broad white tip. Underwing mostly white, with fine dusky barring on secondary coverts; dark patch on primary coverts; dark-grey wing-tip and trailing edge; and translucent white patch on bases of outer primaries (as upperwing). Bill: upper mandible, black; lower mandible, buff-yellow, pink-buff, or cream, with small black patch at base. Iris, dark brown or red-brown. Orbital ring, brownish grey. Legs and feet, cream or light brown. **AUXILIARY MALE:** Very similar to primary adult female and not reliably distinguished in field (see Plumages for subtle distinctions). **Adult female PRIMARY FEMALE:** Very similar to primary males, though never have obvious bright blue patch on rump. **AUXILIARY FEMALE:** Like auxiliary male and primary adult female (see Plumages). **Juvenile** At fledging, appear very similar to primary adult female in fresh plumage but darker overall, especially on head, neck and underbody; best distinguished by much shorter and still growing tail, and much shorter and all-black bill; tail fully grown and bill is adult size and colour when c. 3 months old, after which not reliably separated from adult female and auxiliary males (though pointed tips to rectrices may sometimes be visible in field).

**Similar species** In e. and ne. Aust. could be confused with **Blue-winged Kookaburra** (q.v.); otherwise generally unmistakable.

Often gregarious; usually in pairs or family parties of mated pair and up to seven (and sometimes more) auxiliaries; roost communally. Inhabit wide variety of open eucalypt forests and woodlands. As with other kingfishers, forage by perching quietly for long periods then pouncing on prey on ground; prey

then immobilised by a vigorous beating. Normal flight rather heavy and direct, with rowing wing-beats; raise tail on alighting. Commonest call unmistakable; Laugh usually heard in morning or evening; chuckle or repeated *kook-kook-koo* developing into rising staccato shouted *kook-kook-kook-ka-ka-ka*, then fading; usually taken up in chorus by other members of group. Also utter various short harsh gurglings.

**HABITAT** From contribution by S. Legge. In E. AUST., mostly in open sclerophyll forest or woodland, with open or sparse understorey or grass ground-cover and tree-hollows for nesting (Kikkawa *et al.* 1965; Parry 1973a; Leach 1988; Slater 1995). Possibly prefer more open areas on ridges rather than denser vegetation in gullies near Bega, NSW (Smith 1984). Sometimes occur in or at edges of logged forest (Marshall 1935a; Robertson & McGill 1948; Loyn 1980, 1985); in plantations of pines *Pinus* (Stevens 1975; Friend 1982; Traill 1985); in partly cleared areas with remnant vegetation, especially farmland with vegetation remaining along roadsides or fencelines (McEvey 1965; Bravery 1970; Emison & Porter 1978; Sedgwick 1984). Often occur in parks and gardens in suburban areas (e.g. Hindwood 1947; Hopkins 1948; McEvey 1965; Price 1977; McCulloch 1981; Wood 1995); or near wetlands (Storr 1953a; McEvey 1965; Vic. Atlas). Sometimes in regrowth forest (Laurance *et al.* 1996). In Boola Boola SF, Vic., recorded at densities of 0.03 territories/ha in young regrowth, 0.22–0.23 territories/ha in old regrowth, 0.10 territories/ha in advanced regrowth, 0.17–0.22 territories/ha in mature forest and, in gullies, 0.17 territories/ha in recently logged areas and 0.23 territories/ha in mature forest (Loyn 1980). Rarely in rainforest (Marshall 1935b; Bravery 1970; Roberts & Ingram 1976; Laurance *et al.* 1996) or burnt or unburnt heathland (Preston 1983; McFarland 1988); and usually avoid habitats with dense undergrowth (Hyett & Gottsch 1963; Parry 1973a; Loyn 1980). In semi-arid areas, mostly confined to stands of River Red Gum *Eucalyptus camaldulensis* or Black Box *E. largiflorens* bordering watercourses, lakes or other wetlands, or within gorges (Jones 1952; Hobbs 1961, 1966; Gell 1977; Henle 1989; Roberts 1993; North); rare or absent in mallee shrubland (Rix 1943; Hobbs 1961). In TAS., mostly inhabit open woodland or open sclerophyll forest, and cleared areas, including farmland and settled areas with parks and gardens; sometimes in dense temperate rainforest or mixed rainforest–*Eucalyptus* forest, away from clearings; also in plantations of pines (Thomas 1979; Green 1989, 1995; Tas. Bird Reps) and in orchards (Fielding 1979). In WA, inhabit native forests and woodlands, including open mixed Jarrah *Eucalyptus marginata* and Karri *E. diversicolor* forest, Marri *E. calophylla* forest, and Western Australian Flooded Gum *E. rudis* woodland, as well as parkland and pasture with some remnant native vegetation (Sedgwick 1964; Ford 1965; Sedgwick 1973, 1984; Nichols & Nichols 1984; How & Dell 1990; Saunders & Ingram 1995). Habitat in NZ not well described; recorded in farmland and settled areas and riparian habitats (Falla *et al.* 1981; CSN).

Usually breed among trees, in or near edge of forest or woodland, including remnant vegetation in partly cleared areas (Smith 1992; NRS); also among riparian trees in semi-arid areas (Rix 1976). Mostly in hollows, in living or dead trees; occasionally excavate holes in arboreal termitaria, banks or low cliffs; rarely, in other structures such as haystacks or holes in walls (see Breeding).

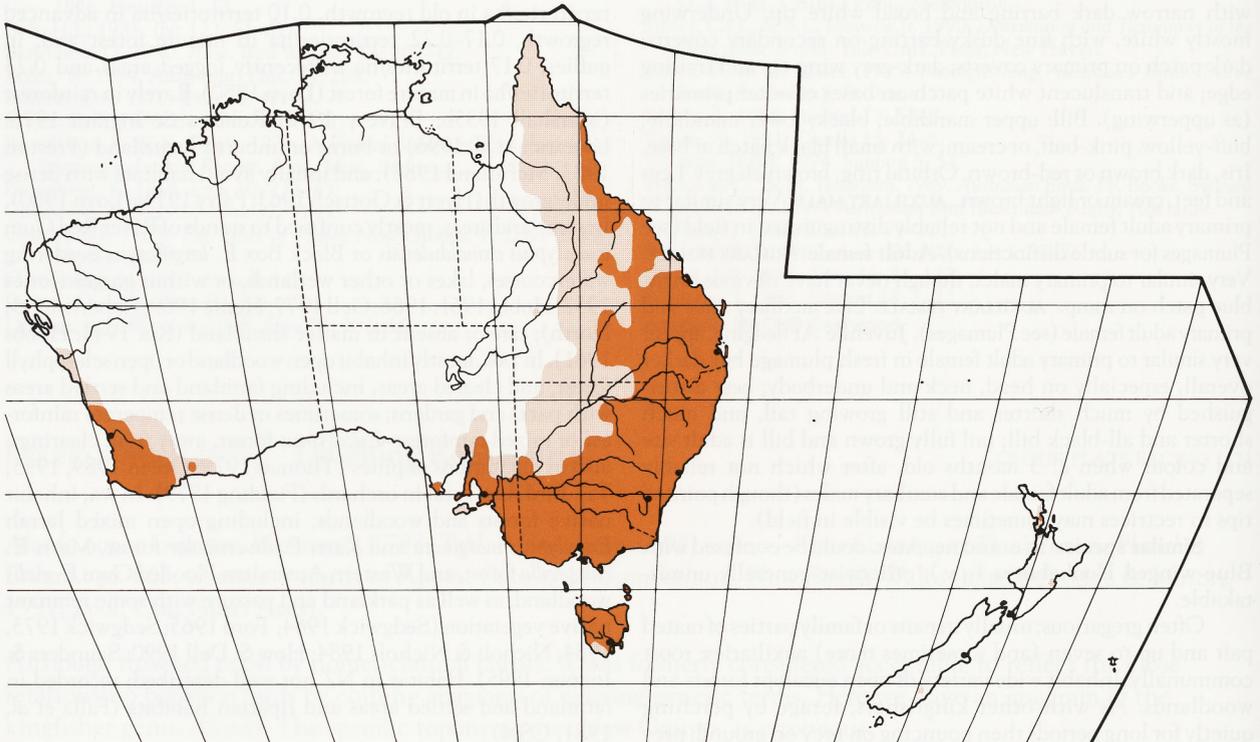
Food mostly taken from ground in open or grassy areas; often beneath trees (Chisholm 1934; Hindwood 1947; O'Grady 1961; Hermes & Williams 1979; Smith 1992). Sometimes from streams, dams or ornamental ponds (Hindwood 1947; Brown 1949; Parry 1973a; Green 1995; Tas. Bird Rep. 24; CSN 3). Often fed by people in suburban gardens (Roberts 1961; Foster 1962; Parry 1968a; Morris 1975; Buchanan 1983), and may scavenge round other sites of human use, such as picnic areas or rubbish bins (Hindwood 1947; Morris 1986). Rarely, enter buildings to steal food (Hindwood 1947). Sometimes raid nests of other species of birds in shrubs or trees (Cooper 1948), or take insects from foliage or air (Hindwood 1947). Rarely, dig insect larvae from beneath ground (Chisholm 1934).

Roost on roughly horizontal branches in crowns of trees, often, but not always, among dense foliage (Hays 1920; Hindwood 1947; Eastman 1970; Wood 1995; S. Legge). Sometimes roost on lower branches on windy nights (Wood 1995), though in some areas of s. Vic., regularly roost on branches well below canopy, regardless of weather (J.M. Peter). Once recorded roosting in open on overhead wires (J.M. Peter). During day, often perch on dead limbs of trees or on artificial structures, especially overhead wires, poles and fences (Dove 1939; O'Grady 1961; Roberts 1961; Vallenga 1965).

Can benefit from partial clearance of wooded habitats, but adversely affected by removal of trees with hollows (Smith 1992). Though may inhabit suburban habitats, numbers decline in areas where farmland is subdivided into residential blocks (Templeton 1992).

**DISTRIBUTION AND POPULATION** Endemic to e. mainland Aust.; introduced to NZ.

**Aust.** Widespread from w. C. York Pen., Qld, to s. Eyre Pen., SA. Introduced to Tas. and s. WA. **Qld** Widespread in e. and central regions. Absent from islands in Torres Str. (Draffan *et al.* 1983). Widespread on C. York Pen. from Jardine R. S to Edward R. in W and to C. Melville in E; also widespread farther S, in North-Eastern and North-Central Regions, W to line from middle reaches of Mitchell R., S through Croydon and Gregory Ra. to Richmond. Widespread in Central and South-Central Regions, from coastal areas W to 144°E. Also occur on many nearshore islands (Storr 19; Aust. Atlas). Rarely in South-Western Region, with recent records at Windorah and Thargomindah (Roberts 1993; Qld Bird Rep. 1989). **NSW** Widespread in all e. regions, W to w. slopes of Great Divide. Farther W, widespread but scattered from North-West Plain S to Riverina, and in e. parts of Upper and Lower Western Regions, W to round Barnato L., Yallock and Clare Calpa Stn, and middle and lower reaches of Lachlan R.; generally absent between Lachlan and Darling Rs. Farther W, mainly restricted to courses of Warrego, Paroo and Darling Rs (Schmidt 1978; Morris *et al.* 1981; Cooper & McAllan 1995; Aust. Atlas; NSW Bird Reps). **Vic.** Widespread, though sparse in parts of Western District and, in Mallee, mostly restricted to Murray R. Valley and lake system from L. Agnes S to L. Albacutya (Vic. Atlas). **Tas.** Introduced (see below). Currently, widespread in N, E and SE, mostly E of line from Huonville, through L. Rowallan and Waratah, to Marrawah (Thomas 1979; Jones 1985; Aust. Atlas; Tas. Bird Reps). Rarely farther S: at Castle Forbes Bay and Southport (Thomas 1979; Aust. Atlas). Widespread on Flinders I. (Green 1969; Aust. Atlas). **SA** Widespread in S, W to Yorke Pen. and N to s. Flinders Ras, round Alligator Gorge, Mt Brown, Pichie Richie Pass and Warren Gorge (Storr 1953b; Cooper 1955; Aust. Atlas; SA Bird Reps). Occasional records farther N, in central Flinders Ras, at Wilpena Stn, Bunyeroo



Gorge and Parachilna Gorge may represent either small disjunct population or vagrants (Jeffrey 1958; Paton 1989; Reid *et al.* 1997; Aust. Atlas). Also recorded farther W, on s. Eyre Pen. (Jenkin & Waterman 1965; Eckert 1972; Aust. Atlas). Introduced to Kangaroo I. (Aust. Atlas). **WA** Introduced (see below). Currently widespread S of line from Hopetoun to Geraldton. Rarely recorded elsewhere, e.g. Esperance and near Southern Cross and Kalbarri (Long 1988; Saunders & Ingram 1995; Serventy & Whittell; Aust. Atlas). Also found on some nearshore islands, such as Bald I. (Sedgwick 1977), Eclipse I. (Warham 1955; Fullagar & van Tets 1976) and Garden I. (Abbott 1980). **NT** No confirmed records. Said to have been heard on Roper and McArthur Rs, also Groote Eylandt (Tindale 1925), but this doubtful (Condon 1948).

**NZ** Introduced, though two historical records and one recent record on w. coast, at C. Maria van Deimen, Raglan and Barrytown, after w. or nw. storms were possibly blown from Aust. (Oliver; CSN 28). Mostly confined, in small numbers, to n. NI. **NI**: Since 1980, many records round Whangarei. Rarely recorded on Little Barrier I., but widespread through much of w. Hauraki Gulf, from Leigh, near C. Rodney, S to Kumeu, and W to e. and s. Kaipara Harbour, and, rarely, S. Kaipara Head (CSN). In Hauraki Gulf, single record on Motuoropapa I., Noises Grp, 26 Oct. 1979 (Cunningham & Moors 1985). Rarely farther S: Hamilton, 1993–94 (CSN 42); Raglan, on shore after westerly storm, 5 Jan. 1980 (CSN 28); Hastings, 13 Jan. 1980 (CSN 28). **SI**: During early 1970s, recorded Andersons Bay and Sawyers Bay in Otago (CSN 19).

**Breeding** Throughout most of range (Aust. Atlas; NRS). In NZ, recorded breeding at Puhoi R. (CSN 6).

**Introductions Aust.** Introduced to many places, often because of reputation as snake-killers (Jenkins 1977; Long 1988; Lever 1992; North). **TAS.**: Probably first released from Vic., unsuccessfully, in 1902 (Jenkins 1977); subsequently, successfully released on Waterhouse I. and other sites on mainland, including Epping Forest in 1906, and Scottsdale 'much later' (Fletcher 1907, 1909; Sharland 1968; Jenkins 1977). There was probably an undocumented release near Hobart in c. 1906, as the species was seen at Mt Wellington in Dec. 1906 (North). After releases in N in early 1900s, numerous around Launceston and Epping Forest and seen at Tooms L. in 1940s (Sharland 1958); range expanded slowly, S to Ouse and Antill Ponds by mid-1950s (Sharland 1958; Jones 1985); by early 1970s, found in most areas E of line from Penguin to Huonville (Tas. Bird Rep. 3); by mid-1970s, range was expanding in S and in NW. Recorded in NW at Sisters Beach in 1974, Waratah in 1975 and Mawbanna in 1976 (Tas. Bird Reps 4–6); reached nw. coast near Marrawah by early 1980s (Thomas 1979; Aust. Atlas), and several records between Stanley and Temma in July 1992 (Moverley 1992). In SE, established in foothills of Mt Wellington by mid-1970s (Tas. Bird Rep. 7) and by 1980, populations round Hobart were expanding (Tas. Bird Rep. 10); common on Tasman Pen. by 1985 (Tas. Bird Rep. 14). Successfully introduced to Flinders I. in c. 1940, where populations have expanded since introduction, but had not reached n. or s. coasts by late 1960s (Green 1969); by early 1980s recorded at Stanley Pt in N and Lady Barron and Trousers Pt in S (Aust. Atlas). **SA**: Two pairs successfully released at Flinders Chase, w. Kangaroo I., in Jan. 1926, though not found in 1948 (Anon. 1948). Recorded e. Kangaroo I. in 1934 (Lashmar 1935) but not found in 1946 (Lashmar 1946). Single bird recorded in 1959 at Cygnet R. (Wheeler 1960), and locally common there in 1975 (Reid 1976); small breeding populations now established, and possibly locally common in some parts especially in E (Baxter

1989; SA Bird Rep. 1975; S. Legge). **WA**: First release in or before 1896; seen at Mullewa in 1896 (Campbell); between 1897 and 1912, hundreds imported from Vic., most being released in South Perth, but also at Serpentine, Blackwood R., Guildford, Gingin, York, Canning and Pinjarra (Jenkins 1977; Long 1988). Bred within 1 year of first release round Perth. First recorded Stockyard Gully, 1908 (Chapman *et al.* 1977), and established in many areas by 1912 (Long 1981). By 1920s, numerous between Darling Ra. and coast (Kingsmill 1919); first recorded breeding along Avon R. in 1926, and population there stabilized by c. 1940 (Masters & Milhinch 1974). By 1940s, all suitable habitat in SW had been invaded, and by 1960s, established from Jurien Bay S to Albany (Glover 1951; Jenkins 1977; Serventy & Whittell). Sometimes temporarily visit areas farther E (D.L. Serventy 1948; V.N. Serventy 1948; Long 1981, 1988; Saunders & Ingram 1995). **NZ** Many introductions, most of which unsuccessful. Two pairs first imported in 1864, but no record of release (Long 1981). Successfully introduced on Kawau I., Hauraki Gulf, in early 1860s, and though at first thought unsuccessful (Hall 1920; Thomson 1922), populations on Kawau I. thought to have survived and colonized adjacent mainland (Falla *et al.* 1981; Oliver; CSN). All other introductions failed (Long 1981): in 1866, four birds released at Silver Stream near Dunedin, Otago, with two more released 3 years later, but all soon disappeared; birds imported to Nelson in 1867 and Auckland in 1868, but no record of release (Thomson 1922; Long 1981), though included in a later list of birds of Nelson (Moncreiff 1938); in Wellington, 14 released in 1876 and one released in 1879, but last recorded in 1885 (Thomson 1922; Long 1981). Population in Hauraki Gulf said to be stable (Falla *et al.* 1981). Many recent records around Whangarei (CSN), where formerly considered vagrants (Falla *et al.* 1981). Interestingly, released near Dunedin in 1860s but quickly disappeared, though recorded there twice in early 1970s (CSN 19). Unsuccessfully introduced to FIJI in either late 19th or early 20th century, but extinct by 1926 (Wood 1926; Blackburn 1971).

**Change in range** First recorded at Edward R., w. C. York Pen., in 1974; now common (Garnett & Bredl 1985). Said to have colonized Mootwingie NP, w. NSW, in 1991, after good season (NSW Bird Rep. 1991). Greatest expansions of range recorded in areas where introduced (see above). **Irruptions** Minor irruption recorded round Warren, NSW, in May 1970, during plague of mice (Hobbs 1971).

**Populations** Near Armidale, NSW, recorded at densities of 0.11 birds/ha (Reyer & Schmidl 1988), up to 0.8/ha (Ford *et al.* 1985) and up to 0.14/ha (Ford & Bell 1981); at Wollomombi, NSW, 0.05/ha (Aust. Atlas). Along Hawkesbury R., NSW, 0.2/ha (Keast 1985); near Canberra, 0.04/ha (S. Legge) and up to 0.23/ha (Bell 1980). At Jamieson, Vic., 0.5/ha (Aust. Atlas); Dandenong Ra., Vic., 0.77/ha (Parry 1973a); in Boola Boola SF, Vic., mean minimum number of territories/km<sup>2</sup> (study sites in which breeding territories recorded) 17.1 (7.24; 3–23; 8 study sites) (Loyn 1980). Along Margaret R., WA, 0.2/ha (Keast 1985).

Often killed by vehicles on country roads (e.g. Hollands 1971; Parry 1973a; Vestjens 1973; Disney & Fullagar 1978; Brown *et al.* 1986; Lepschi 1992). Sometimes killed by dogs or cats (Dowling *et al.* 1994). Sometimes shot because they kill young poultry (Templeton 1992). In Tas., not protected since 1942 (Dickison 1951; Robinson & Brouwer 1989). May have been affected by use of DDT before it was phased out, but little data available on real impact (Parry 1973b). Nesting hollows often taken over by feral Honey Bees *Apis mellifera* (Parry 1973a; Ashton 1985, 1987).

**MOVEMENTS** Account prepared by S. Legge. Sedentary (e.g. Forshaw & Cooper 1983; Fry *et al.* 1992; S. Legge). Occasionally make short temporary movements to feed on abundant prey (Anon. 1919, 1948; Lord 1956a). In ACT, birds with territories next to human settlement may seasonally adjust use of territory, typically moving in winter into suburbs where people offer food to birds (S. Legge). Reports of seasonal variation in numbers (e.g. Bedggood 1973) can be misleading, as birds less conspicuous at certain times of year (ACT Atlas). Dispersal peaks before breeding season (July–Sept.); dispersing birds usually non-breeding auxiliaries of either sex, and at least 1 year old, that disperse into vacant breeding positions. Auxiliaries make long-distance forays to explore surrounding territories, probably to gain information about vacancies and potential mates. Distance of dispersal varies from <1 km (into neighbouring territories), to up to 50 km, and very rarely over 100 km (see Banding). Possible that some isolated records on w. coast of SI of NZ are of birds blown from Aust. during storms (see Distribution).

**Banding** Of 3566 banded in Aust., 1953–96, 559 recoveries (15.7%): 506 (90.5%) <10 km from banding site; 51 (9.1%) 10–49 km; 1 (0.2%) 50–99 km; 1 (0.2%) ≥100 km. Long-distance recovery: Jamieson, Vic., to Wanganella, NSW (260 km, 332°, 67 months, July; 1+). Longest lived, 138 months.

**FOOD** Account prepared by S. Legge. Carnivorous; occasionally scavenge. Feed on wide range of invertebrates and vertebrates; mostly invertebrates (including insects, earthworms and snails) and lizards; also snakes, small birds and rodents, and, when near water, aquatic insects, crayfish, frogs and fish. **Behaviour** Diurnal and crepuscular. Locate prey visually, attracted mainly by movement. Hunt solitarily, but other members of group may be nearby (Parry 1968a; S. Legge). Sit-and-wait predator. Perch motionless for long periods, usually 1–10 m above ground, watching for prey; occasionally cock head to study ground below. Catch prey on ground, and sometimes trunks of trees, by sally-pouncing from perch (Forshaw & Cooper 1983), usually swooping down, with wings folded or partly folded then spread just before landing; prey grasped with bill; feet, weak and not used (S. Legge). Also sally-strike for flying insects (Hindwood 1947; S. Legge). Catch aquatic prey by surface-plunging (Brown 1949). After sally, usually glide or make a short flight to another perch (usually 10–30 m away), whether attempt was successful or not; may also move between perches without sallying (Parry 1968a; S. Legge). Occasionally dig into ground with bill to capture burrowing prey, but do not dig deeply. In Perth, seen to forage at garbage tips (Eastman 1970). Occasionally take young nestlings or fledgelings but rarely attack older birds (S. Legge; see Other records). In some areas, readily accept food offered by people (Pearse 1938; Hindwood 1947; Packe 1960; Parry 1968a). Small prey swallowed whole; large prey killed by beating it against ground until it is motionless, or by carrying it to perch and treating it similarly; may also be manipulated back and forth through bill, being systematically pulverized (Roberts 1961; Frauca 1969; Parry 1970; Green 1995; S. Legge). Renowned for taking snakes, usually catching them by holding them firmly behind head, thrashing them violently on ground or perch, and then swallowing them head-first; largest prey reported include snakes 0.6–1 m long (e.g. Ryan 1919; Dickison 1927; Mann 1933; Ralph & Ralph 1973); Frauca (1969) claimed they will attack snakes of over 1.2 m, but does not substantiate statement. Snakes probably small component of diet compared with invertebrates, but early and contemporary ornithologists often com-

ment on the Kookaburra's ability to kill snakes (e.g. Leckie 1908; Le Souëf 1915; Anon. 1916; Ryan 1919; Dickison 1927; Heumann 1927; Mann 1933; Parry 1970; Ralph & Ralph 1973; Poiani & Yorke 1989; Campbell). Opportunistic; although not presenting the supporting data, Parry (1968a) noted that proportions of crayfish, worms, soft-bodied insects, snakes and mammals increased during non-breeding season, but proportion of snails and frogs decrease, following seasonal abundance of these prey. Sometimes steal food from other animals: a pair stole a snake from a hawk (Batey 1910) and another stole a frog from mouth of a green tree-snake (O'Grady 1961). Rarely drink (S. Legge). Undigested food regurgitated as pellets, mostly during night but sometimes in daylight (Eastman 1970); large mounds of regurgitated pellets can form under regular roosting places (Hays 1920). Have a prominent bony ridge on back of the skull, with strong muscles attached to it, which keeps neck rigid and functions when killing and bashing prey (Parry 1970). Eyes also have some structural adaptations to enhance vision when perched and searching for prey (Moroney & Pettigrew 1987).

**Detailed studies** In TAS. (59 items in 15 stomachs, items <3% no. listed in Other records; Green *et al.* 1988): INSECTS: Coleoptera: Lucanidae: *Lamprima aurata* 8.5% no.; Scarabaeidae: *Adoryphorus couloni* 15.0; Tenebrionidae 3.0; Lepidoptera: Hepialidae: *Oncopera* 7.0; *Oxycanus* larv. 3.0; Noctuidae: *Persectania ewingii* 5.0; Orthoptera: Acrididae 3.0; Gryllidae: *Teleogryllus commodus* 34.0. REPTILES: Agamidae: *Amphibolurus diemersi* 3.0.

In E. NSW (139 items in 24 stomachs; items <2% no. or 5% freq. listed in Other records; Rose 1997, incorporating data from Rose 1973, collected 1966–86): MOLLUSCS: Gastropods 3% no., 8% freq. SPIDERS: Araneae 7, 26. INSECTS: Blattodea 3, 13; Coleoptera: Unident. 3, 18; Carabidae 2, 10; Scarabaeidae (mainly *Heteronychus arator*): 9, 23; Hymenoptera: Formicidae: unident. 2, 3; *Camponotus* 13, 3; Lepidoptera: larv. 5, 15; ad. moth 3, 23; Mantodea: Mantidae 3, 18; Orthoptera: unident. 2, 13; Acrididae 4, 28; Eumastacidae 2, 3; Gryllidae 5, 21; Gryllotalpidae 14, 18; Tettigoniidae 5, 13. REPTILES: Scincidae 2, 13.

**Other records** ANNELIDS: Oligochaetes: Lumbricidae<sup>11,43,63,64</sup>; Megascolecidae: *Megascolides australis*<sup>48</sup>. MOLLUSCS: Gastropods: Unident. snails<sup>19,41,44,63</sup>; Helicidae: *Helix*<sup>41,50</sup>; *H. aspersa*<sup>63</sup>. SPIDERS: Araneae<sup>11,21,43,61,63,64</sup>; Actinopodidae: *Missulena*<sup>41</sup>; Heteropodidae: *Neosparassus*<sup>43</sup>; Lycosidae<sup>43</sup>. CRUSTACEANS: Decapods: crabs<sup>21</sup>; Parastacidae: freshwater crayfish<sup>11,16,28,43,44,54,60</sup>. DIPLOPODS<sup>63</sup>. CHILOPODS<sup>43,63</sup>. INSECTS<sup>5,13,35,39</sup>: Blattodea: Blattellidae: *Blattella*<sup>43</sup>; Blattidae: *Platyzosteria*<sup>43</sup>; Coleoptera: Unident. beetles<sup>11,41,44,64</sup>; Carabidae<sup>60</sup>; Cerambycidae: *Phoracantha semipunctata*<sup>62</sup>; Chrysomelidae: *Paropsis*<sup>53,63</sup>; Cleridae<sup>21</sup>; Curculionidae<sup>21,43,53,60,63</sup>; *Chrysolopus spectabilis*<sup>43</sup>; *Gonipterus*<sup>62</sup>; *Leptopius*<sup>62</sup>; Elateridae: larv.<sup>43</sup>, ad.<sup>60</sup>; Geotrupidae<sup>62</sup>; Lathridiidae: *Corticaria*<sup>62</sup>; Lucanidae: *Lissotes rudis*<sup>53</sup>; Passalidae<sup>41</sup>; Scarabaeidae: ad.<sup>1,41,62,63,64,65</sup>, larv.<sup>25,41</sup>; *Anoplognathus* larv.<sup>21,61</sup>, ad.<sup>43</sup>; *Matanastes vulgivagus*<sup>62</sup>; *Onthophagus*<sup>61</sup>; *O. australis*<sup>53</sup>; *Scitula sericans*<sup>53</sup>; Tenebrionidae: *Cardiothorax*<sup>62</sup>; *Tenebrio* larv.<sup>43</sup>; Dermaptera: earwigs<sup>44</sup>; Diptera: Muscidae: *Musca domestica*<sup>62</sup>; Hemiptera: bugs<sup>43,44</sup>; Cicadidae<sup>21,38,64</sup>; *Psaltoda moerens*<sup>66</sup>; *P. plaga*<sup>66</sup>; Pentatomidae<sup>41</sup>; Hymenoptera: Formicidae: ants<sup>21,41</sup>; *Camponotus*<sup>62</sup>; *C. consobrinus*<sup>42</sup>; *Iridomyrmex*<sup>62</sup>; Lepidoptera: larv.<sup>26,35,41,62,63,64</sup>; Noctuidae: larv.<sup>43,62</sup>; Mantodea<sup>63</sup>; Mantidae: *Tenodera australasiae*<sup>43</sup>; Odonata: Zygoptera<sup>63,64</sup>; Orthoptera<sup>13,21,23,60,62,64</sup>; Acrididae<sup>41,44,63</sup>; *Chortoicetes terminifera*<sup>30</sup>; Gryllidae<sup>6,44,63</sup>; *Teleogryllus commodus*<sup>43</sup>; Gryllotalpidae: *Gryllotalpa*<sup>41,42,62,63</sup>; Tettigoniidae<sup>5,41,63</sup>. FISH<sup>22,32</sup>: Cyprinidae:

*Carassius auratus*<sup>57,60</sup>; Embassidae: *Velambassis jacksoniensis*<sup>41</sup>; Pomatomidae: *Pomatomus saltatrix*<sup>41</sup>; Salmonidae: trout<sup>65</sup>. AMPHIBIANS: Frogs<sup>36,43,44,62,64</sup>; Myobatrachidae: *Neobatrachus wilsmorei*<sup>54</sup>. REPTILES: Lizards<sup>8,11,16,39,60,62,64</sup>; Scincidae: *Lampropholis delicata*<sup>66</sup>; *L. guichenoti*<sup>66</sup>; *Leiopisma metallicum*<sup>53</sup>; *Tiliqua nigrolutea*<sup>53</sup>; *Trachydosaurus rugosus*<sup>28</sup>; Snakes, mostly 30–100 cm long<sup>7,8,10,12,15,20,34,39,40,41,43,57,60,64,65</sup>; Elapidae: Copperhead *Austrelaps superbus* 66 cm long<sup>18</sup>; Yellow-faced Whip Snake *Demansia psammophis* 60 cm long<sup>43</sup>; Black-bellied Swamp Snake *Hemiaspis signata* 30–40 cm long<sup>43</sup>; Eastern Tiger Snake *Notechis porphyriacus*<sup>60,63</sup>; Myall Snake *Suta suta*<sup>44</sup>. BIRDS: Ads<sup>5,11,16,29,57,60,64</sup>; eggs and young<sup>8,39</sup>; Brown Quail *Coturnix ypsilophora* ads<sup>41</sup>; Red-backed Button-quail *Turnix maculosa* ads<sup>58</sup>; Pacific Black Duck *Anas superciliosa* nestling<sup>51</sup>; Cape Barren Goose *Cereopsis novaehollandiae* eggs<sup>19</sup>; Bell Miner *Manorina melanophrys* nestlings<sup>55</sup>; New Holland Honeyeater *Phylidonyris novaehollandiae* nestling<sup>43</sup>, ads<sup>52</sup>; Scarlet Robin *Petroica multicolor* nestlings<sup>31</sup>; Golden Whistler *Pachycephala pectoralis* nestlings<sup>31</sup>; Rufous Whistler *P. rufiventris* nestling<sup>33</sup>; Magpie-lark *Grallina cyanoleuca* nestlings<sup>2,3,19</sup>; woodswallows *Artamus* nestlings<sup>39</sup>; European Goldfinch *Carduelis carduelis* juv.<sup>64</sup>; House Sparrow *Passer domesticus* fledgeling<sup>3,18,50</sup>; Common Starling *Sturnus vulgaris* nestlings<sup>9</sup>. MAMMALS: Small native mammals<sup>57</sup>; Burramyidae: Little Pygmy-Possum *Cercartetus lepidus*<sup>53</sup>; Dasyuridae: *Antechinus*<sup>45</sup>; Leporidae: Rabbits *Oryctolagus cuniculus*<sup>16</sup>; Muridae: House Mouse *Mus domesticus*<sup>5,11,14,34,39,43,44,53,59,60,64</sup>; rats *Rattus*<sup>5,11,34,37,39,41</sup>. OTHER ITEMS NEAR HUMAN HABITATION: Newly hatched poultry<sup>3,4,10,56,60</sup>; young, tame ducklings<sup>17</sup>; meat scraps<sup>25,27,46,49</sup>; pieces of cheese<sup>49</sup>; bread<sup>43</sup>. Unconfirmed report of eating bats<sup>47</sup>.

REFERENCES: Campbell<sup>1</sup> 1905, <sup>2</sup> 1907, <sup>3</sup> 1927; <sup>4</sup> D'Ombra 1905; <sup>5</sup> Tryon 1905; <sup>6</sup> Stephen 1907; <sup>7</sup> Leckie 1908; Le Souëf<sup>8</sup> 1909, <sup>9</sup> 1915; <sup>10</sup> Batey 1910; <sup>11</sup> Anon. 1914; <sup>12</sup> Crompton 1914; <sup>13</sup> MacGillivray 1914; <sup>14</sup> Morse 1918; <sup>15</sup> Ryan 1919; <sup>16</sup> Hays 1920; <sup>17</sup> Carter 1924; <sup>18</sup> Dickison 1927; <sup>19</sup> Heumann 1927; <sup>20</sup> Mellor 1927; <sup>21</sup> Jarvis 1929; <sup>22</sup> Sullivan 1931; <sup>23</sup> Miller 1932; <sup>24</sup> Chisholm 1934; <sup>25</sup> Crompton 1936; <sup>26</sup> Roberts 1936; <sup>27</sup> Pearse 1938; Sedgwick<sup>28</sup> 1940, <sup>29</sup> Phillips 1944; <sup>30</sup> Basse 1948; <sup>31</sup> Cooper 1948; <sup>32</sup> Brown 1949; <sup>33</sup> Jack 1949; Lord<sup>34</sup> 1956a, <sup>35</sup> 1956b; <sup>36</sup> O'Grady 1961; <sup>37</sup> Roberts 1961; <sup>38</sup> Parry 1968a; <sup>39</sup> Frauca 1969; <sup>40</sup> Ralph & Ralph 1973; Rose<sup>41</sup> 1973, <sup>42</sup> 1974, <sup>43</sup> 1997; <sup>44</sup> Vestjens 1977; <sup>45</sup> Hermes & Williams 1979; <sup>46</sup> Walters 1980; <sup>47</sup> Young 1980; <sup>48</sup> Smith & Peterson 1982; <sup>49</sup> Forshaw & Cooper 1983; <sup>50</sup> Caswell 1987; <sup>51</sup> Aston & Aston 1988; <sup>52</sup> Butterfield 1988; <sup>53</sup> Green *et al.* 1988; <sup>54</sup> McCarthy 1989; <sup>55</sup> Poiani 1991; <sup>56</sup> Templeton 1992; <sup>57</sup> Green 1995; <sup>58</sup> Frith & Frith 1997; <sup>59</sup> Lepschi 1997; <sup>60</sup> North; <sup>61</sup> Cleland; <sup>62</sup> Lea & Gray; <sup>63</sup> FAB; <sup>64</sup> NRS; <sup>65</sup> Tas. Bird Rep. 24; <sup>66</sup> T. Saunders.

**Young** Food delivered to chicks whole (S. Legge), though often already bashed repeatedly against ground or branch by adult (Weber 1971). Young fed by both parents and varying number of helpers on a wide variety of food similar to that of adults. Rate of feeding at nest varies depending on number and age of nestlings, though rate per individual nestling remains fairly constant. Size of food brought to nest increases with increasing age of young: in Dandenong Ras, Vic. (number of nests not specified), in first week after hatching, items <2 cm long (27 of 37 items); from second week, modal class size, 2–5 cm long (91 of 157 items); largest item recorded, a snake 45 cm long (Parry 1968a). In Canberra (n=18 nests) mean length of prey 2.8 cm (n=75 items) when oldest young in brood 4 days old; 2.9 (125) at 11 days old; 3.0 (152) at 18 days old; 4.3 (126) at 25 days (S. Legge).

In CANBERRA, ACT (671 items in 1995, 275 in 1996; S. Legge): ANNELIDS: 1.5% no. in 1995, 6.5% no. in 1996. ARTHROPODS: 62.8, 56.4: CRUSTACEANS: Decapods: Parastacidae 0.1, 1.1. AMPHIBIANS: Frogs 1.2, 0.7. REPTILES: Lizards: Scincidae 17.3, 22.2; Snakes: 0.0, 0.4. BIRDS: 0.3, 0.4. UNIDENT. ITEMS: 16.8, 12.3.

At BELGRAVE, VIC. (items brought to nest by parents and auxiliaries; sample size not known; Parry 1968a): ANNELIDS: Lumbricidae 14.5% no. CRUSTACEANS: Parastacidae 8.1. INSECTS 31.7. REPTILES: Lizards: 29.6; snakes 5.4. MAMMALS: Rodents 0.5. OTHER MATTER: Pieces of meat 10.2.

Near SYDNEY, NSW (remains of food collected from one nest-hole; Hindwood 1947): SPIDERS: Araneae: Heteropodidae: *Isopeda*. INSECTS: Coleoptera: Buprestidae: *Melobasis*; *Stigmodera*; Cerambycidae: *Penthea*; Curculionidae: *Chrysolophus spectabilis*; Lucanidae: *Lamprima*; Scarabaeidae: *Anoplognathus*. REPTILES: Lizards. MAMMALS: Muridae: *Rattus*.

In MELBOURNE, VIC. (Food brought to semi-captive nestlings by primary male, primary female and two helpers; Packe 1960): ANNELIDS. SPIDERS: Araneae: Heteropodidae. CHILOPODS. CRUSTACEANS: Parastacidae. INSECTS: larv.; Cicadidae: nymphs, ads. AMPHIBIANS: Frogs. REPTILES: Lizards. MAMMALS: Muridae: House Mouse.

**Other records** INSECTS: Unident.<sup>3</sup>, larv.<sup>2</sup>; Coleoptera: Unident. beetles<sup>6</sup>; Scarabaeidae: *Anoplognathus*<sup>10</sup>; Hemiptera: Cicadidae<sup>3</sup>; Nepidae: *Laccotrephes tristis*<sup>10</sup>. REPTILES: Lizards<sup>2,6,8</sup>; Snakes (mostly 20–30 cm long)<sup>1,2,7</sup>; Elapidae: Copperhead *Austrelaps superbus*<sup>5</sup>. BIRDS: Superb Fairy-wren *Malurus cyaneus* fledgeling<sup>4</sup>; honeyeater ads<sup>6</sup>; White-plumed Honeyeater *Lichenostomus penicillatus*<sup>9</sup>; Common Starling nestling<sup>11</sup>. MAMMALS: Muridae: House Mouse<sup>2,7</sup>. (REFERENCES: <sup>1</sup> Anon. 1916; <sup>2</sup> Ryan 1919; <sup>3</sup> Dickison 1927; <sup>4</sup> Bridgewater 1932; <sup>5</sup> Mann 1933; Hood<sup>6</sup> 1935a, <sup>7</sup> 1935b; <sup>8</sup> Hyem 1936; <sup>9</sup> Ashton 1987; <sup>10</sup> Rose 1997; <sup>11</sup> S. Legge.)

**Intake** Only information is daily intake of captive chicks; see Packe (1960) and Timmis (1968), but see Breeding.

**SOCIAL ORGANIZATION** Account prepared by S. Legge. Well known. Detailed studies in Dandenong Ras, Vic., of general biology, including co-operative breeding (Parry 1967, 1968a,b, 1970, 1973a,b); and round Canberra, ACT, on breeding and social behaviour (S. Legge); information below from both these sources unless one author cited; additional references cited where appropriate. Usually live in groups, of 2–9 birds, in a territory; some groups larger (e.g. possibly up to 16 birds; Emmerson 1982); size of group may vary geographically: in Dandenong Ras, mean of 2.8 birds in 13 groups (Parry 1968a); in Canberra, mean of 3.6 birds in 27 groups (S. Legge). Members of group roost together at night (Hindwood 1947; Wood 1995) but do not necessarily move round territory together. Hunt solitarily, but other members of group may be nearby. Groups more cohesive during breeding season.

**Bonds** Long-term monogamy. Breed as single pair, or in co-operative group consisting of one breeding pair (primary male and female) and auxiliaries (helpers). Pairs begin mate-guarding behaviour up to 6 weeks before laying. Faithfulness of bond currently being studied with DNA fingerprinting (S. Legge). Death or disappearance of one member of breeding pair may cause remaining partner or other members of group, or both, to disperse. Both males and females sexually mature at 1 year old, but most delay breeding for 1 to several years (Parry 1968a; Smith 1976; Pyppe 1996; S. Legge); possibly some birds live many years without breeding. Near Canberra, sex-ratio even at fledging; adult sex-ratio biased toward males, and two-thirds of auxiliaries are male; females tend to disperse when

younger, which possibly results in higher mortality (S. Legge); sex-ratio even in Dandenong Ras (Parry 1968a), where pairs more common than groups, and auxiliaries scarce. **Co-operative breeding, Parental care** Auxiliaries usually related to breeding pair and other members of group, and are often offspring of previous breeding efforts. May be as young as 3 months old if helping at a nest in season they hatched (e.g. Parry 1968a); may stay with breeding pair for several years. Pair selects or excavates hollow; usually all members of group are involved in incubation, brooding and feeding of nestlings, and defence of nest and feeding of fledgelings. Contribution of individuals depends on breeding status and sex of bird, size of group and size of brood (S. Legge; see Breeding); auxiliaries of both sexes help equally, but male of breeding pair feeds young more than female does, and may incubate more than female (S. Legge). Young wholly dependent for food for 4–8 weeks after fledging, and feed independently 6–10 weeks after fledging (see Breeding). Juveniles (birds <1 year old) may continue to beg, unsuccessfully, for up to 10 months after fledging. Juveniles may wander together, often into neighbouring territories (S. Legge). Older auxiliaries make long-distance forays up to 14 km away from their territories (S. Legge), and then return to their territories; thought that they are assessing if there are any territories where they can breed. Female auxiliaries tend to leave group at an earlier age (1–2 years) than male auxiliaries (2–4 years) (S. Legge), mainly dispersing just before breeding season, and mainly to vacant breeding positions. Do not form flocks of non-breeding birds. Social bonds probably retained even after dispersal: birds that have successfully dispersed to breed can return to natal groups as auxiliaries; auxiliaries can help at nests of relatives (e.g. siblings) as well as at those of their parents; and auxiliaries sometimes 'go visiting' and spend time in a group that contains a relative (S. Legge).

**Breeding dispersion** Breeding pair or group breeds away from other individuals and groups, in large territories. In Canberra, ACT, territories usually contiguous if habitat suitable, and nests from 0.1 to 1.5 km apart (S. Legge). At Boola Boola SF, Vic., recorded at densities of 3–23 territories/km<sup>2</sup> (Loyn 1980; see Distribution). Nests can be reused between years, but not strictly traditional (see Breeding). **Territories** All-purpose, permanent and traditional, though boundaries may be altered by changes in size of groups of territory-owners or neighbours, or establishment of new groups. Occasionally birds may temporarily leave territory (see above, Movements). Use of some parts of territories may vary seasonally. Nest anywhere within territory, at any distance from boundary (S. Legge) but may sometimes prefer to be near boundary (Parry 1968a). Juveniles often trespass on neighbouring territories, but are more tolerated than older members of their group (S. Legge). Generally, territory boundaries remain unchanged even if one of breeders is replaced or if most of previous group disperses. Size of territory varies much: in Dandenong Ras, varied with size of group, and averaged 0.77 ha/bird (Parry 1968a); near Canberra, tends to increase with size of group but less clearly so, and average size of territories much larger, 89 ha (27–160) with c. 25 ha/bird (S. Legge).

**Roosting** At night; communally, within territory; usually as one group but sometimes in smaller sub-units (Wood 1995; S. Legge); fledgelings may roost separately from adults (Parry 1968a). During breeding season one bird sits on nest overnight (Hindwood 1947; Parry 1968a). Roost in trees, which are traditional; group may have several favourite trees that are used more or less sequentially throughout year. After some crepuscular hunting, birds arrive at roosts just before or after dark, preen, huddle, jostle for central position, make quiet contact calls, and

often break into characteristic chorus of Laughter. Leave early in morning (Parry 1968a; Wood 1995; S. Legge). Loaf anywhere within territory during day, not necessarily as a group; sit down over feet, often with one eye still turned toward ground; periodically preen or sun themselves by stretching a wing out and down and holding it there for several minutes (S. Legge).

**SOCIAL BEHAVIOUR** Account prepared by S. Legge. Well known. Detailed studies in Dandenong Ras, Vic., of general biology (Parry 1967, 1968a,b, 1970 1973a,b); and round Canberra, ACT, on breeding and social behaviour (S. Legge); information below from these studies unless one author cited; additional references cited where appropriate. Other studies include detailed observations at one nest by Hindwood (1947). In continual presence of people, can become tame and easy to observe; otherwise extremely shy. Birds less conspicuous at certain times of year (ACT Atlas); near Canberra, in Dec., presence of fledgelings can make groups more conspicuous (S. Legge). All displays between groups and some within group are accompanied by very loud calls (see Voice). When calling, point bill skyward and wag tail up and down. Some behaviour similar to that of other kingfishers but not the conspicuous displays that are related to group behaviour; many similarities to behaviour of Blue-winged Kookaburra, which also breeds co-operatively. Contact calls often given between separated members of group. **Comfort behaviour** In cold weather, ruffle and raise feathers, and sit down over feet. In hot weather open bill slightly, and stretch wings out and down facing sun, allowing air under wings. When preening: often ruffle feathers; draw bill through plumage with rapid nibbling motion; wipe side of bill along branch several times; often finish with a violent head-shake which sounds like a rattle and which can be useful in locating birds. When oiling, collect oil on bill then draw feather through bill; preen head by rubbing oil on carpal joint then wiping head against this. Use toes to scratch side and back of head. Often preen after disturbance, such as a territorial conflict. Stretch by holding wings straight down, or bent and raised over back, stretching head forward and tail up. Often bathe (Vallenga 1965), and can sometimes drown in pools and ponds with steep sides (Robinson 1950, 1951; S. Legge). Sometimes take objects that resemble food, like string-beans or spaghetti (Frauca 1969), and beat them incessantly as they would real prey (see also Foster 1962; Boles 1993).

**Agonistic behaviour** Between groups, most aggression is ritualized, but some physical interactions occur, usually between neighbours, with most occurring in 3 months before breeding; caused by presence of, or calling by, neighbours at boundary or presence of intruders in territory. Aggression within group also peaks just before breeding, and often involves physical tussles (see Relations within family group). **Territorial advertising, Threat** Ownership of territory signalled by group giving loud Choruses (see Voice), particularly at dawn and dusk from near roosting tree; possibly triggered by changes in light conditions, as birds will call on moonlit nights (Cheney 1915) and at start and end of solar eclipses (Veerman 1982). **Aerial displays** Given in ritualized territorial disputes with neighbouring groups at borders of territories. **TRAPEZE FLIGHT:** A member of one group swoops to a nearby tree (5–10 m away) in its territory; often lands on lip of a hole in tree, but if none present belly-flops against tree-trunk. Another bird from opposing group does same to a tree in its own territory. Rapid alternation of such flights by birds in same group resembles a trapeze act. Such flights may continue for many minutes, even

up to 30 min. Primary birds may perform flight more often than auxiliaries. **CIRCLE FLIGHT:** From a high perch, a bird from one group flies above trees, dashes across border and toward opposing group, which is usually not more than 100 m away, then circles widely around opposing group (radius of 30–50 m from opponents) and returns to original perch; a bird from opposing group may chase it back, thereby initiating its own Circle Flight. Several birds from both groups can be airborne at once. Both Trapeze and Circle Flights can take place during one encounter, and are usually accompanied by much loud calling (mainly Choruses, Laughs and Cackles). Non-performing birds likely to adopt **AGGRESSIVE POSTURE:** Wings held down exposing rump, head and upper body pushed forward, plumage sleeked, and tail moved up and down in **TAIL PUMP.** Flights gradually occur less often till birds appear to lose interest and drift away. When intruder or intruders detected within territory, discoverer usually gives loud alarm call (Kooaa, Cackle or Chuckle) while in Aggressive Posture, then chases intruder. Other group members likely to be attracted by calls and often full chorus develops. To forestall attack, intruders must flee. Attacking birds will dive-bomb intruder and make physical contact with their bills, bodies and wings. **Fighting SPARRING:** Birds clasp bills and try to twist each other off branch. Loser may hang suspended by bill for several seconds before falling. Physical injury can be severe, even fatal. Most often occurs between members of group, but also between birds from neighbouring territories and intruders. **Alarm** If frightened, lift body off perch, open bill, and raise feathers of crown or sleek plumage on back; may turn head from side to side. Sometimes give alarm call (usually Chuckle, or occasionally Chuck or Kooaa); other times remain silent before fleeing. Response to potential predators varies: to aerial predators usually assume **STICK POSE,** staying still, with head and bill pointing straight up to sky (Frauca 1969); to people, give alarm call (usually Chuckle, occasionally Chuck or Kooaa), may adopt Aggressive Posture, then flee. May mob other birds (e.g. Barn Owls *Tyto alba*) or terrestrial predators (e.g. goannas *Varanus*) (Mellor 1905; White 1916; Chisholm 1918; Chisholm 1924; Cooper 1937). Predators known to take adult or fledgeling Kookaburras include: owls and Whistling Kites *Haliastur sphenurus* (Anon. 1903; Hobbs 1966; Parry 1968a; Scarborough 1987; see Breeding: Success); report of attack by Nankeen Kestrel *Falco cenchroides* (Cooper 1937) possibly nest-defence rather than predation.

**Sexual behaviour** Calling increases 2–3 months before breeding season. Sometimes calling (particularly Duets) may be a mate-guarding mechanism, used to check on proximity and attentiveness of partner during breeding season, as well as advertising ownership of territory (see above). Members of a pair call together more often than other members of group (also see Reyer & Schmidl 1988); if one member of pair starts calling, mate may fly toward it and join in; if mate does not respond, caller's song does not develop into full chorus (Immelmann 1960; S. Legge). **Courtship** Courtship displays and more obvious forms of mate-guarding may begin up to 6 weeks before laying. Members of pair stay near each other, to within 30 m but usually much closer; if one bird flies away, mate almost always immediately follows; tend to sit closer together on perches than other members of group. Nest-site selected by breeding pair. **NEST-SHOWING:** Courtship display very similar to Trapeze Flight, where members of pair duet with Laugh while alternately making swooping flights from a perch to a potential nesting site 5–10 m away (also see Wilson 1903). For weeks before laying, birds fuss round nesting site and even spend time in it. **Courtship feeding** All members of group feed breeding female, but

breeding male does so most often. Occasionally auxiliary females also fed by males in group. May occur several weeks before laying, and usually stops after clutch complete. **Greeting** Birds arriving at nest give Squawk, which sometimes develops into a Chuck call. Soft Squawk used only between members of pair but differs from other Squawks only in volume; if both are perched, one may shuffle closer to its mate while Squawking. No allopreening. **Copulation** Few preliminaries, perhaps some Squawking or Chucking or both, then male hops onto female's back, female leans body forward and down, and points tail up; male points tail down, flaps wings for balance, and may nibble back of female's head with bill. Copulation lasts up to 25 s but usually shorter. Sometimes conspicuous (Schmidl 1968). Reverse copulations occur, with female on top (England 1944; S. Legge). Copulation once seen between breeding female and male auxiliary (her son), and once attempted copulation seen between two males (S. Legge).

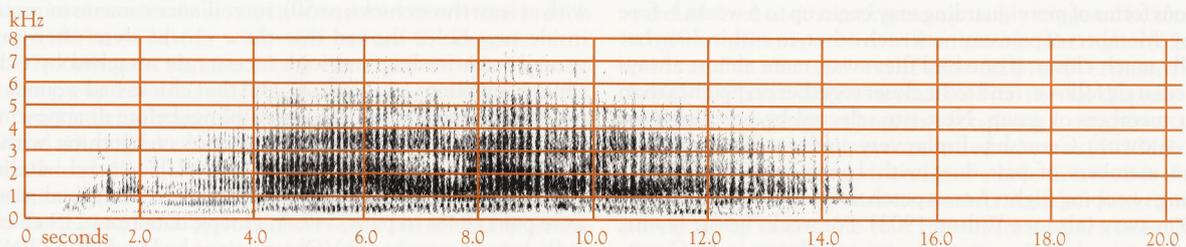
**Relations within family group** Aggression within group usually increases just before laying, with most interactions occurring between just two birds, usually a breeding bird and an auxiliary (Parry 1968a; Reyer & Schmidl 1988). Members of breeding pair may react aggressively if an auxiliary sings (Reyer & Schmidl 1988) or sits too close to mate: either sex swoops and knocks auxiliary off branch or fights by Sparring (see above); intention to Spar may be signalled by opening bill toward opponent. Birds can escape by flying away. Some conflict, at least, related to mating as, rarely, copulations occur between breeding birds and auxiliaries. Also, breeding females may behave aggressively toward other females in group (Parry 1968a). **Feeding of young** Birds arriving to feed young usually call from perch near nest before swooping to entrance (e.g. Immelmann 1960; Parry 1968a). In first week after hatching, chicks beg quietly; prompted by any noise near entrance to nest but usually by calls, usually Squawks, of adult arriving with food; also react to darkening of entrance to nest (which simulates adult entering nest), though they are blind for up to c. 2 weeks. By 2 weeks old, Food-begging Call is lower-pitched and whirring; very loud and easily heard outside nest; incessant and not confined to arrival of adults, though becomes a louder, squealy squawk when adults do arrive. Fledgelings beg with soft persistent sounds, similar to Squawk, which probably alerts adults to their location; call louder when adult with food gives Squawks; adult will continue to Squawk till it locates fledgeling. Food delivered to chicks whole (e.g. Weber 1971). Adults pass food (not regurgitated) directly to young or sometimes to brooding bird, who passes it on. **Brood-reduction** Based on study by S. Legge. **SIBLICIDE:** Asynchronous hatching (see Breeding) results in a hierarchy of size and competition maintained by active aggression from nest-mates which may result in siblicide, usually of youngest chick. Over 3 years near Canberra (1995–97), 30 last-hatched chicks in 70 broods (43% were killed by siblings; in 75% of these cases, within 10 days of hatching of last chick. Occasionally second-hatched chick also killed (10% of broods with at least three chicks; n=50); surveillance cameras mounted inside nest-holes showed that these chicks were often prevented from feeding and were incessantly attacked by elder sibling or siblings (A. Nathan), and that chicks had wounds to heads and backs caused by bills of siblings before disappearing. Sex of chicks correlated with sequence of hatching within brood: 62% of first-hatched chicks were male; second-hatched chick more likely to be female, especially when social group were pairs (84% in pairs, 54% in groups; data from 219 chicks in 91 broods over 3 years). Observations by Hindwood (1947) and Parry (1968a) also indicate that siblicide occurs. **INFANTI-**

**CIDE:** In captivity, sudden disappearance of eggs and hatchlings suggests infanticide (Seth-Smith 1941; England 1944; Gerrits 1958; Schmidt 1968). Similar disappearances observed in wild (S. Legge), but possibly result of predation. Adults very responsive to all young and fostering possible (see Breeding). **Anti-predator responses of young** Nestlings move to back of nest and squash against wall. When near fledging, may attack with bill. Fledgelings freeze on perch, pointing bill, head and body directly at threat, presenting smallest surface area. After 2–3 weeks, fly more competently and can fly away from threats. **Parental anti-predator responses** Usually one adult near nest even if chicks not being brooded. Before able to forage independently, fledgelings rarely left alone. Nest defended by aggressive diving and loud calling. In response to predator, adults sitting in nest tend to flush when disturbed, call loudly and then mob predator; calls attract other members of group, who join in. When people approach, often birds fly quickly from nest, drawing attention away from nest.

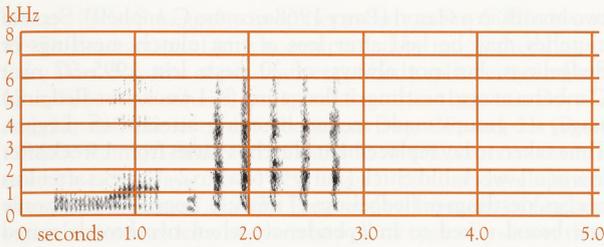
**VOICE** Well known from field study in Dandenong Ras, Vic. (Parry 1970); and detailed study in field at Armidale, NSW, and in captivity in Germany, by Reyer & Schmidl (1988), including sonagrams. Information from Parry (1970) unless stated. Noisy and conspicuous, call dominating dawn and dusk chorus and one of the most familiar calls of the Aust. bush (Parry 1970; Conole 1981). All calls that have been distinguished are related to either Laugh or Squawk. Respond to playback of taped calls (Reyer & Schmidl 1988). **NON-VOCAL SOUNDS:** Violent head-shake after preening sounds like a rattle (S. Legge) or castanets (D.A. Curl).

**Adult CHORUS:** Chorus consists of two or more birds uttering Laugh (see below) independently, but is not known to be synchronized beyond that (see sonagram A). At each stage of Chorus, different participants may use different elements (e.g. male may give *CACKLE* while female may give *GURGLE*), and repetition rates of elements may differ (Cleland 1906; Reyer & Schmidl 1988); for further details, see Laugh (below). Choruses usually initiated by primary male while distant from primary female; she may then fly to male, starting her own call in flight; male may stop Laughing if she fails to arrive (Immelmann 1960; Reyer & Schmidl 1988); females also seen to initiate Chorus (S. Legge). Chorus given all year, at dusk or dawn, by all members of group, from or near roosting perch (Parry 1970; Reyer & Schmidl 1988); usually in response to, or results in, Choruses by neighbouring groups. A Chorus may be given several times by a particular group, interspersed with those of neighbouring groups, but Choruses of two groups seldom simultaneous. Appears to aid defence of territory, guarding of mate, and establishment and maintenance of dominance hierarchy between breeders and auxiliaries (Reyer & Schmidl 1988). Most often heard in the 3 months before breeding season, and least often Jan.–Feb. (when most intense moulting takes place). Evening

Chorus sometimes not heard during breeding season, especially where group consists of pair only. Daytime Choruses usually involve breeding pair only, and rarely occur with one or no members of breeding pair; are associated with: (1) territorial boundary disputes, and often given near boundary, including during Trapeze and Circle Flights, with neighbouring group replying; or (2) disputes within group (Parry 1970; Reyer & Schmidl 1988). Chorus of group lasts longer than Chorus of pair, and contains higher proportion of *HAHA* element (see below). At dawn, frequency with which Chorus given determined mainly by total number of neighbours and, at dusk, by size of group; the more birds in a group, the earlier the first Chorus and the later the last one (Reyer & Schmidl 1988). Chorus may be given at night, particularly if moonlit (Cheney 1915). **LAUGH (= SONG, LAUGH SONG or LAUGHING** of Reyer & Schmidl 1988): Full-throated boisterous laugh, starting with low chuckle of repeated *ooo* sounds lasting c. 2 s, rising in intensity to loud laugh of repeated *ha* sounds, 2–5 s in duration, then lowering to another chuckle of *ooo* sounds of c. 2 s. This series of *ooo* and *ha* notes may be repeated many times, finally stopping abruptly, or fading away as chuckle becomes less rapid. Studies in captivity provide finer detail; typical Laugh has five elements: (1) *KOOAA*, also uttered as separate call (see *Kooaa*); (2) *CACKLE*, also a separate call (see *Cackle*); (3) *ROLLING*, which is rapid repetition of identical syllables, lasting up to several seconds, also a separate call (see *Chuckle*); (4) *HAHA*, the actual laughing sound, which is also the loudest element; and (5) either male's *GOGO*, loud distinct syllables *GO-GO-GO...*; or female's *GURGLE*, which is similar to *ROLLING* element but lower-pitched and with longer pauses between syllables, which also a separate call (see *Chuckle*). However, much variation possible: elements other than *KOOAA* may initiate Laugh, particularly *CACKLE* and *ROLLING*; some elements may be omitted altogether, particularly *KOOAA*, *ROLLING* and *GOGO*; and partial sequences like *ROLLING-HAHA* and *HAHA-CACKLE* may be repeated several times within one Laugh (Reyer & Schmidl 1988). May fade away or stop abruptly. Laugh usually given in Chorus (see above); occasionally given solo, usually inducing Laughs from rest of group. Auxiliary giving Laugh, particularly during daytime, challenges status of breeding bird (Reyer & Schmidl 1988). Very common; heard all year. **KOOAA:** Short concise *kooaa* (sonagram B, left). When deep and guttural and *k* very pronounced, it warns of bird of prey. When soft, without *k*, it draws attention of other birds in group. Common; heard all year. **CACKLE:** Repeated *ha*, as in *HAHA* element of Laugh, but with short *a*. Used before attack, sometimes by more than one bird and sometimes in flight. Uncommon; heard all year. **CHUCKLE (= Rolling element of Laugh and Gurgle element of Laugh of female):** Repeated *ooo* sounds (sonagram B, right). A contact call; other birds usually reply with same call, whereupon first caller may fly to second. May be signal to relieve incubating bird or to announce to young that food available.



A T. Howard; Nimmitabel, NSW, Mar. 1995; priv. D8



B D. Stewart; Julatten, Qld, Dec. 1992; M22–18

Common; given all year; either solo or in chorus, and sometimes in flight. Bird intruding into territory of another group announces presence with low-pitched Chuckle; similar call given in reply. Parry (1970) did not distinguish between *ROLLING* and *GURGLE*, describing both as Chuckle (Reyer & Schmid 1988). *CHUCK*: Abbreviated Chuckle, repeated many times in a short staccato. Given by solitary birds or by several birds at once. Moderately common; heard only during breeding season, especially in connection with feeding young. *SQUAWK*: Hoarse, monosyllabic, low-pitched squawk, given singly or in short series in which first is slightly higher in pitch than successors. Moderately common; first heard intermittently in Aug., just before breeding season, increasing in use during incubation period, and most used when chicks present. Used by adults when begging for food, and as submissive call to reduce aggression between members of group during breeding season. *SOFT SQUAWK*: Similar to Squawk, but in lower, softer tone. May be given by solitary birds. Uttered during nest-showing ceremony, as courtship call. Uncommon; heard only in breeding season. *SCREECH*: Great noise, compared to 12 Sulphur-crested Cockatoos *Cacatua galerita* screeching at once, from two birds fighting, lying on ground with bills interlocked (Mathews).

**Young** *FOOD-BEGGING CALL*: In first week after hatching, call is a quiet, high-pitched squeaking, given in response to any noise near nest but usually by calls, usually Squawks, of adults; also given if entrance to nest-hole darkened. By 2 weeks old, call incessant, loud, lower-pitched and whirring, easily audible from outside nest, and breaking into louder, squealy squawk on arrival of adults (S. Legge). Squealy squawk given in alarm by nestlings. Fledgelings beg softly but persistently with call similar to Squawk of adult, with intensity rising to a shrieky squawk if adults approach with food (S. Legge). Captive young attempted to Laugh at 6 weeks after fledging; could do so competently before 3 months after fledging (Campbell).

**BREEDING** Account prepared by S. Legge. Well known; detailed studies in Dandenong Ras, Vic. (Parry 1968a, 1970, 1973a); near Canberra, ACT (S. Legge); and near Sydney, NSW (Hindwood 1947); 387 records in NRS till Jan. 1997, mainly from Vic. (75 records) and NSW (131 records). Breed co-operatively, though also breed successfully in solitary pairs; size of breeding groups varies (Parry 1968a; S. Legge; see Social Organization and Behaviour).

**Season** Throughout natural range, breed Aug. to Jan. or Feb.; inspection and building of nests may start in Aug.; laying mainly Sept. to Nov. or Dec.; dependent young found as late as Mar. (MacGillivray 1918; Lord 1956; Parry 1968a; Morris *et al.* 1981; Campbell; North; Storr 19; Vic. Atlas; ACT Atlas; NRS; S. Legge). In Tas. and WA, where introduced, breed Sept.–Dec., with laying mainly Sept.–Oct. (Masters & Milhinch 1974; NRS). No information for NZ. Eggs and young (from NRS unless stated): QLD: Eggs (10 nests): Sept.–Nov. (8), Jan.

(2); young (12 nests): Oct. (2), Nov.–Dec. (9), Feb. (1). NSW: Eggs (72 nests): Aug. (1), Sept. (17), Oct. (35), Nov. (14), Dec. (5); young (59 nests): Oct. (5), Nov. (30), Dec. (16), Jan. (8). Aseasonal breeding record near Sydney of four birds feeding nestlings in Apr.–May (Hindwood 1947). ACT: Eggs, Oct.–Dec., young, Oct.–Dec., dependent young, Nov.–Feb. (ACT Atlas). Near Canberra (93 nests, 1995–97): first egg, 15 Sept., last laid, 21 Dec. (S. Legge). VIC.: Eggs (52 nests): Sept. (14), Oct. (28), Nov. (10); young (24 nests): Sept. (1), Oct. (6), Nov. (14), Dec. (1), Jan. (1), Feb. (1). In Dandenong Ras (n=22 nests, 1965–66), laying 1 Sept.–26 Nov. (Parry 1968a). TAS.: Eggs, Sept. (1 nest); young, Nov. (1 nest) and Dec. (1 nest). SA: Eggs, Sept.–Nov., young, Oct.–Jan. WA: Eggs (9 nests): Sept. (6), Oct. (3); young (19 nests): Sept. (1), Oct. (11), Nov. (5), Dec. (2). Claim of nesting in n. Qld in July (Cochrane 1903) does not confirm that eggs present; may have been pre-nesting behaviour. Tend to be single-brooded, unless first brood lost; occasionally will raise two broods in a season; clutches started Dec. probably second attempt; differences in length of season may be result of variation in availability of food (Parry 1968a; S. Legge).

**Site** Nest in hollows; usually natural hollows in dead or living trees; also in hollows excavated in arboreal termitaria or in trees with soft or rotten centres; often in living eucalypts (e.g. MacGillivray 1914, 1918; Roberts 1945; Lord 1956a; Hindwood 1959; Weber 1971; Forshaw & Cooper 1983; North; NRS; S. Legge). Termitaria may be used more often in N of range (Frauca 1967; North; NRS); termitaria of *Nasutitermes walkeri* used often (NRS). Site selected by breeding pair; within territory; suggested that possibly prefer sites near boundaries (Parry 1968a), but this not so at Canberra (S. Legge). Occasionally use other sites, including holes excavated in banks or cliffs (Mattingley 1927; Hindwood 1943, 1947; Saunders 1984; Smith 1992); holes in walls or other man-made structures (Le Souéf 1925; Hindwood 1947; McCulloch 1981); in haystacks (Bourke 1941); stick-nests (Smith 1992); a staghorn fern (Campbell). Of 203 sites in NRS: 60% in hollows in living eucalypts, 16% in arboreal termitaria (*Eucalyptus* and other species), 8% in hollows in living non-eucalypt trees (e.g. *Acacia*, *Angophora*, *Banksia*, *Melia azedarach*, *Tristania*, fig trees, palms), 7% in dead trees and stumps (including *Eucalyptus*), and 9% in other sites (including 4% in nest-boxes, 4.5% in drums laid under roofs of sheds and in haystacks, and 0.5% in earth bank); c. 30 species of eucalypts recorded as being used (NRS). Apparently prefer sites that have convenient perches near hollows (Parry 1968a). Nest-holes often re-used in following year, or in later years: near Canberra, of 93 nests, about half re-used between 1995 and 1997 (S. Legge); in Dandenong Ras, four of nine were re-used between 1965 and 1966 (Parry 1968a); some used for 5 consecutive years (Hindwood 1947, 1948; Marchant 1992; NRS); one site claimed to have been used intermittently for 60 years (NRS). May nest in same tree as other species of birds, e.g. Galahs *Eolophus roseicapillus*, Australian Ringnecks *Barnardius zonarius*, Crimson Rosellas *Platycercus elegans*, Dollarbirds *Eurystomus orientalis* and Noisy Miners *Manorina melanocephala*. Said to have used old nest dug by Sacred Kingfisher *Todiramphus sanctus*. Nest-holes sometimes usurped by bees and possums (Parry 1973; Ashton 1985, 1987; NRS). **MEASUREMENTS**: NRS data summarized in Table 1. Elsewhere, height of nesting holes, 3–18 m, determined by the structure of trees within breeding territory (Parry 1968a; North; S. Legge), but recorded as low as 20 cm (Campbell; North).

**Nest, Materials** Spherical chamber, with floor roughly level with or slightly below level of entrance to nest. Shape of

**Table 1.** Summary of measurements of nesting hollows (NRS).

NESTS	HEIGHT OF NESTING	HEIGHT OF NESTING	N
	HOLE ABOVE GROUND (M)	SUBSTRATE (M)	
Hollows in live eucalypts	9.3 (7.60; 2–60)	21.4 (12.11; 6–70)	121
Hollows in live non-eucalypts	4.8 (2.40; 2–10)	10.4 (5.81; 2–20)	16
Hollows in dead trees	8.3 (4.20; 3–18)	13.6 (4.23; 7–20)	14
Arboreal termitaria	8.4 (2.73; 5–15)	16.6 (4.40; 10–22)	29
Other sites (see text)	6.6 (3.10; 3–15)	10.6 (6.34; 3–20)	12
ALL SITES	8.4 (6.3; 1.2–60.0)	18.0 (10.5; 3.0–70.0)	203

entrance varies; opens directly into nest-chamber. No nesting material, eggs laid on floor of chamber. Before laying, breeding pair spends time inspecting hole, and both will sit inside for several minutes at a time, but no other preparation unless hole is being excavated or re-modelled (S. Legge); these preliminaries may last weeks before laying begins (Hindwood 1947; Parry 1968a; S. Legge). Both sexes excavate, relieving each other every 10 min or so (North). When excavating termitaria, dive-bomb, bill first, at site, usually from 7–10 m; also cling to mound and peck at inside of cavity (NRS). For description of excavation by captive pair, see Crawford (1986). **MEASUREMENTS** (cm): Diameter of entrance: at least 13 (Parry 1968a); 8–40 (61 nests, 1994–97; S. Legge); 12–15 (4 nests; NRS). Nesting chamber: 30 deep  $\times$  23 high (Parry 1968a); 20–150 deep  $\times$  20–40 high (S. Legge); 30–60 deep  $\times$  25–30 high (NRS).

**Eggs** Rounded to elliptical, oval or pyriform, one end more pointed than other; smooth, slightly textured and luminous white when laid, becoming matt and opaque as incubation progresses (Forshaw & Cooper 1983; Campbell; North). Size of eggs varies more in larger clutches (Forshaw & Cooper 1983); dimensions of eggs usually decrease with laying order (S. Legge). **MEASUREMENTS:** Nominat *novaeguineae*: near Canberra, 44.1 (1.64; 216)  $\times$  35.1 (1.14; 216) (S. Legge); 44.5 (1.6; 42.1–44.8; 10)  $\times$  34.8 (0.9; 33.8–36.7) (Campbell; North); 43.8 (0.93; 42.8–45.4; 6)  $\times$  35.6 (0.98; 34.1–36.2) (Forshaw & Cooper 1983). Subspecies *minor*: 45.9 (4.4; 42.0–51.9; 5)  $\times$  36.0 (1.9; 34.0–38.3) (Forshaw & Cooper 1983).

**Clutch-size** Usually three, but 1–5 (Parry 1968a, 1973a; Forshaw & Cooper 1983; Campbell; North). Throughout range, 3.0 (0.60; 45); C/2  $\times$  6, C/3  $\times$  33, C/4  $\times$  5, C/5  $\times$  1 (NRS); in Dandenong Ras, mean for pairs, 2.5 (n=6), and for groups, 3.0 (n=13) (Parry 1968a, 1973a); near Canberra, mean for pairs, 2.92 (0.49; 25), and for groups, 2.89 (0.49; 56) (S. Legge). Subspecies *minor* may have larger clutches (MacGillivray 1914, but see White 1916). Clutches of five eggs may result from two females laying in nest. In a captive trio, two females laid in one nest-box (Smith 1976). Five nestlings observed in one nest in Vic. (Smith 1992).

**Laying** Probably lay in morning and afternoon (Parry 1968a). Eggs laid at intervals of: 24–48 h between first and second egg (though once 96 h in one clutch in 1997–98 season in Canberra [S. Legge]), 17–96 h between second and third or third and fourth eggs (n=12 clutches, 10 groups, Parry 1968a; 12 clutches, 12 groups, S. Legge; 1 clutch, 1 group, Hindwood 1947); or at regular 2-day intervals (n=4 nests, NRS). In captivity, intervals appear similar (Seth-Smith 1941; England 1944; Widman & Vorous 1961; Timmis 1968; Weber 1971; Eichner 1987; Pypers 1996), though in one clutch eggs laid at intervals of 5 days (Smith 1976). Apparently only primary female lays, but egg-dumping by female auxiliaries possible (see Clutch-size). Tend to be single-brooded but occasionally raise

two broods in a season (Parry 1968a; *contra* Campbell). Second clutches may be laid after loss of first clutch, nestlings or fledgelings, but not always; of 20 nests lost 1995–97 near Canberra at egg, nestling or fledgeling (<1 week post-fledging) stage, six groups made second breeding attempt (S. Legge). Time taken to lay replacement clutches varies from 1 week after loss of a 1-week-old chick (Parry 1968a) to 2–7 weeks after loss of eggs, nestlings or fledgelings (7 nests; S. Legge). Usually only one brood raised to independence; when two broods reared successfully, laying interval between broods is c. 2 months (two groups, Parry 1968a; two groups, NRS); one unusual record of three broods in same season (NRS).

**Incubation** Start of incubation varies: between first and third egg or on completion of clutch. At one nest, incubation only began upon completion of clutch, but bird sat in hole at night from first egg (Hindwood 1947). At other nests, incubation sporadic between laying of first and second eggs, but fairly certainly started before clutch completed and probably soon after first egg laid (Parry 1968a, 1973a). In five nests near Canberra, incubation sporadic till third egg laid (S. Legge). Hatching asynchronous; usually 2–48 h (usually 24 h) between hatching of each egg (Hindwood 1947; Parry 1968a; S. Legge). In pairs, both sexes incubate; in groups, all members of group incubate. In Dandenong Ras, at six nests, bouts of incubation lasted 26–97 min, averaging 36 min; in four pairs, female incubated for 24% of time, male 43%, and nest vacant for 33%; in two trios, breeding female incubated for 38%, male 28.5%, auxiliary 19.5%, and nest vacant for 14%; in one nest, breeding female noted in nest overnight six times (Parry 1968a, 1973a). Near Canberra, breeding male usually incubates more than breeding female during daytime, and breeding birds incubate more than auxiliaries; no difference between contributions by female auxiliaries and male auxiliaries. In 58 visits to eight nests of pairs, female was incubating for 24% of visits, male 64%, and nest vacant for 12%; in 101 visits to 18 nests of groups, breeding female incubating for 24% of visits, breeding male 59%, auxiliaries 8%, and nest vacant for 9%. Near Canberra, adults occasionally incubate clutches of Australian Wood Duck *Chenonetta jubata* left in hollows, for up to 3 weeks; in some cases, this seems to result in delayed laying by Kookaburras, sometimes because helpers are especially inclined to sit tight on these eggs; in other cases, Kookaburras lay on top, but suffer incubation problems as a result of the extra-large clutch (S. Legge). **INCUBATION PERIOD:** 24–26 days for each egg, including intermittent incubation of early eggs for first day or so (n=24 eggs in 12 clutches, Parry 1968a; 9 eggs in 3 clutches, S. Legge); 25–28 days (4 clutches, NRS); in one clutch of 3 eggs, 25–29 days from laying, incubation not starting till third egg laid (Hindwood 1947). In captivity, 23–26 days (England 1944; Schmidt 1968; Timmis 1968; Anon. 1969; Weber 1971; Smith 1976; Eichner 1987). Unhatched eggs tend to be left in nest with nestlings. After hatching, eggshells may stay in nest, be pushed out of nests, or disappear completely. Adults perform no sanitation of nest (S. Legge).

**Young** Information mainly from 29 chicks observed by Parry (1968a, 1973a) and 201 chicks by S. Legge. Altricial and nidicolous. Can take over 36 h to hatch after first cracks in shell appear (Hindwood 1947; S. Legge). Hatch naked and blind; skin, smooth, fleshy-pink in colour (Parry 1968a; S. Legge; *contra* Hindwood 1947); during first 24 h, have blisterly, watery appearance just under skin. Hatchlings squat on floor of nest, with head balanced on back; surprisingly mobile and move around nest using wings and legs. Pin-feathers visible under skin when c. 4 days old, and emerge between Days 7 and 11

(Parry 1968a, S. Legge), sometimes as early as Day 6 (Hindwood 1947). Emergence of pins accompanied by much shedding of flaky skin. Sheaths of pin-feathers of body split between Days 17 and 22; those of head, remiges and rectrices between Days 22 and 27; and those of cere between Days 27 and 31 (Parry 1968a). Remiges and rectrices still have remnants of sheaths near bases at Days 32–34 (S. Legge). Similar development noted by Hindwood (1947). Rate of development of feathers varies between chicks; last-hatched chick typically slower than first-hatched chick (Parry 1968a; S. Legge). Eyes open after Day 10; eye-slits may begin opening independently up to 2 days apart, but both fully open by 18 days old (Hindwood 1947; Parry 1968a; S. Legge). **Growth** Mean weight at hatching, 28.5 g (n=14) (Parry 1968a); 23.6 g (3.0; 99) (S. Legge). Maximum weight, >370 g (Parry 1968a); 393 g (S. Legge). Mean weight at fledging (>32 days old): just under 300 g, c. 90% of adult weight (no N) (Parry 1968a); 288 g (34.1; 129), 87.3% of mean adult weight (n=75) (S. Legge). Growth-curves in Parry (1968a). Mean length of wing-chord of 1-day-old chicks, 13.6 mm (0.69; 98) (S. Legge); mean length of wing at 32–36 days (when about to fledge), 144 mm (17; 127) (S. Legge). For development in captivity, see England (1944), Gerrits (1958), Timmis (1968), Weber (1971), Smith (1976), and Eichner (1987). **Parental care, Role of sexes and members of group** All members of group help care for chicks; they feed, brood and defend them. Brooding can last up to 3 weeks; pairs tend to brood intermittently after a while, and stop earlier than groups (Parry 1968a). In four nests, brooding bouts lasted 21–92 min, with female brooding 32% of the time, male 36%, auxiliaries 16%, and nest vacant 16% (Parry 1968a). Usually one bird near nest even if chicks not being brooded. Food passed either directly to chick or to brooding bird, which passes it on. Food delivered whole; no regurgitation. Near Canberra, in detailed analysis of 34 nests, groups did not deliver more food than pairs; rate of feeding increased with age of chick to 18 days old, then declined, and at 32 days similar to that at 4 days old. Contribution to feeding by each member of group increased with increasing size of brood but decreased with increasing group-size; primary males feed young significantly more often than primary females (a very unusual pattern in birds); both parents feed young more often than auxiliaries; male and female auxiliaries feed young at equal rates; auxiliaries made 19–61% of feeding visits (S. Legge). In Dandenong Ras, observations of six nests found that groups fed young at same rate as pairs; feeding rate did not change as brood grew (1.2–8.6 items/h), but size of items delivered increased (Parry 1968a). Chicks become very active between Days 10 and 25, and beg constantly (S. Legge). In captivity, rates of feeding increase up to Day 25, then decrease again (Packe 1960; Timmis 1968). Adults perform no nest sanitation (cf. England [1944] who suggested that adults eat chicks' faeces). Chicks will try to expel faeces out entrance of nest when they are older, but often miss (see Thomson 1935). By fledging, floor likely to be heaving with maggots and a constant stream of ants (e.g. *Pheidole variabilis*, Hindwood 1947).

**Fledging to independence** FLEDGING PERIOD: 32–40 days (Hindwood 1947; Parry 1968a; S. Legge); 33–38 days (12 broods; NRS). Fledging often occurs asynchronously, with usually 1 day between chicks (Parry 1968a; S. Legge; NRS); once, three chicks took 8 days to fledge (Hindwood 1947). Before fledging, chicks may sit near entrance to nest and stretch their wings. On fledging, birds fly to ground or nearby low perch. Fly only occasionally during first few days, making only short flapping flights. At this stage, tail not fully grown, which

causes difficulties with balance on landing (Parry 1968a; S. Legge). Fledgelings continue to be fed by adults (Campbell); generally take 6–10 weeks before forage independently (Hindwood 1947; Parry 1968a; Timmis 1968; S. Legge; NRS). Even when independent, fledgelings still try to beg for food, for up to 10 months after fledging (S. Legge). Breeding birds can 'adopt' unrelated fledgelings (e.g. Frauca 1967; Packe 1960; Lee 1989), and this behaviour often exploited when trying to rehabilitate abandoned or lost fledglings (Walraven 1990).

**Success** In Dandenong Ras, of 51 eggs laid over 2 years in c. 20 nests, 33 (65%) hatched, with at least 12 of those not hatched appearing to be infertile; 27 (82% of 33 hatchlings) fledged; and 22 (81% of 27 fledgelings) survived to independence. Overall, 43% of eggs resulted in independent young. On average, nine pairs fledged 1.2 offspring, and ten groups fledged 2.3 offspring (Parry 1968a, 1973a). Of 29 eggs in 10 nests with acceptably complete clutches taken from natural hollows, 27 (93%) hatched, and 18 (62%) fledged, which equals 1.8 fledged young per nest; also from 25 eggs from nine artificial nests (drums placed in haysheds), 18 (72%) hatched, and 10 (40%) fledged, which equals 1.1 fledged young per drum (NRS). From small sample, date of laying does not appear to affect success. Possible that juveniles of pairs more likely to die in first year than juveniles of groups (Parry 1973a), but data unconvincing (S. Legge). Chicks hatched later in brood more likely to die than those hatched earlier: of 39 chicks lost from 32 nests near Canberra, 35 were youngest chick (S. Legge); six of ten juveniles that died were all youngest of their brood (Parry 1968a, 1973a). Near Canberra, of 238 eggs laid over 3 years in 82 nests, 213 (89.5%) hatched; failure to hatch caused mainly by infertility or arrested development, but also by predation or destruction of nest; 143 chicks fledged (67.1% of 213 nestlings), representing 1.7 fledgelings/nest. **Survival and longevity** Long-lived. Smith (1976) kept a bird that lived over 15 years; four birds recaptured 10 years after banding, including one 11 years 5 months (ABBBS). May be severely affected by drought (Barnard 1927; North; S. Legge). Predators of eggs or nestlings include: eagle (Le Souëf 1918), Pied Currawong *Strepera graculina* (S. Legge), Grey Butcherbird *Cracticus torquatus* (Hindwood 1947), Common Brushtail Possum *Trichosurus vulpecula* (S. Legge); and possibly Greater Glider *Petauroides volans*, Common Ringtail Possum *Pseudocheirus peregrinus*, Brush-tailed Phascogale *Phascogale topoatafa* (Parry 1968a), and pythons and goannas (D.A. Curl). Predators known to take adults or fledgelings: owls (Anon. 1903), Powerful Owl *Ninox strenua* (Parry 1968a; Fleay), Masked Owl *Tyto novaehollandiae* (Scarborough 1987) and Whistling Kite (Hobbs 1966). Other possible predators include Barn Owls (White 1916), Wedge-tailed Eagle *Aquila audax* (Parry 1968a), cats and foxes (Parry 1968a), quolls *Dasyurus* (D.A. Curl), and goannas (Chisholm 1924; Mellor 1905). Report of a Nankeen Kestrel attacking a Kookaburra (Cooper 1937) might have been nest-defence by Kestrel. **Parasites, Diseases** Nest-sanitation poor and floor of nest quickly becomes a mass of muscid larvae, especially of genus *Passeromyia* (Hindwood 1947; Anderson 1966; S. Legge). Most are harmless but one, possibly *P. longicornis*, burrows under skin, embedding half of itself in flesh of chick (R. Morrison); not blamed for deaths of Kookaburras, but maggot possibly causes some harm and said that can cause deaths of chicks (Anderson 1966). Louse flies *Ornithomyia avicularia* also common in nest, but probably cause little damage (Hindwood 1947; S. Legge).

**PLUMAGES** Prepared by A.M. Dunn. Fledge in juvenile plumage. Undergo complete post-juvenile (first pre-basic) moult

to adult plumage at c. 14 months old. Thereafter, complete post-breeding moults each cycle produce successive adult plumages with no seasonal change in appearance. While no alternate (breeding) plumage, plumage of adults influenced by social status: Reyer & Schmidl (1988) were able to distinguish primary, and thus breeding, adults and non-breeding auxiliaries mainly on differences in plumage; non-breeding auxiliaries tended to resemble primary adult females but had duller and slightly darker feathers; this difference was consistent in 15 of 16 groups; in one group, one auxiliary resembled primary male but could be distinguished by behaviour. The individual in a group with the brightest lower back and rump was usually the primary, breeding adult male. When examining museum specimens the social status of individuals was not known; the brightest male skins were used for descriptions of primary (breeding) males. Individuals vary greatly in plumage and can differ enough to aid identification of individuals in small groups (see Reyer & Schmidl 1988). Sexes very similar but distinguishable. Can breed at 12 months old (Parry 1970, 1973a). Two subspecies; nominate *novaeguineae* described below.

**Adult male** (First and subsequent basic). **PRIMARY (BREEDING) MALE:** Based on four of the brightest adult male specimens, which were assumed to be primary breeding males. **HEAD AND NECK:** Forehead, crown and ear-coverts show much individual variation. Feathers of forehead usually off-white to light brown (c223D) with dark-brown (121) shaft-streaks and narrow wavy dark-brown (121) barring; whole forehead becomes much paler with wear, and barring becomes very faint. Feathers of crown, dark brown (121) with varying rufous-brown (38) edges and mostly concealed white bases; amount of rufous varies individually, from very narrow edges to most of feather rufous; with wear, rufous fades to off-white. Broad white supercilia (10–20 mm wide) usually extend from above front of eye to join white upper nape, but sometimes extend forward onto sides of forehead; white feathers of supercilia and nape often have one or two narrow wavy dark-brown (121) bars near tips giving faintly mottled appearance. Narrow band of feathers in middle of nape, dark-brown (219) with concealed white bases. Lores grade from white with dark-brown (121) shaft-streaks to feathers near base of upper mandible to dark brown (121) just in front of eye. Eye-ring mostly dark-brown (121), but white at top rear of eye, continuous with supercilium. Ear-coverts mostly dark-brown (c219), but feathers just behind eye often mottled with white and rufous-brown (38); amount of mottling varies individually from little or no mottling to most of lower rear ear-coverts mottled. Dark lores, eye-ring and ear-coverts combine to form broad dark eye-stripe that ends squarely on rear ear-coverts. Malar area, chin, throat, lower nape and neck, white, often with one or two wavy dark-brown (121) bars near tips of feathers of all but chin, centre of throat and foreneck (as supercilium and nape). **UPPERPARTS:** Feathers along upper edge of mantle at junction with hindneck, white or mostly white with dark-brown (c219) tips. Rest of mantle and scapulars, dark-brown (c219) with concealed white bases to feathers; scapulars have narrow white or off-white fringes at tips when fresh. Upper back mostly white with narrow dark-brown (219) barring. Lower back and rump vary much but overall appearance very blue; feathers usually dark brown (219) with broad light-blue (93) tips, but ground-colour can vary from slightly lighter brown (ne) to black-brown, and width of tip ranges from 7 to 15 mm wide; some feathers, particularly at sides of rump, have white barring near bases. Uppertail-coverts, rufous-brown (36–37) with dark-brown (219) barring. **UNDERPARTS:** Most of underparts, white with mostly concealed, faint narrow dark-

brown (121) to brownish-grey (79) barring near base of feathers. Flanks often appear faintly barred as barring extends closer to tips of feathers. Amount or visibility of barring varies individually, but underparts also appear whiter when more worn. **UPPERTAIL:** Ground-colour of rectrices shows little or no variation, but darker overlying pattern varies much; t1 varies greatly but outer rectrices vary less. Ground-colour of t1 grades from dark-brown (c121A) at base, through rufous-brown (c38) to light brown (c223D) or off-white at tip. Ground-colour of rest of rectrices gradually becomes lighter outward; t6 grades from light rufous-brown (c139) at base to white in middle of feather with distal half white. Darker markings on rectrices vary greatly. At simplest, t1 has complete black-brown (119) barring throughout, bars becoming narrower toward tip. Black-brown barring can be incomplete, broken along centre of feather; or joined along centre of feather by broad shaft-streak of same colour; or most of base of feather can be black-brown with paler ground-colour showing only as speckling; or base of feather mostly pale with black-brown reduced to speckling (see Fig. 1).

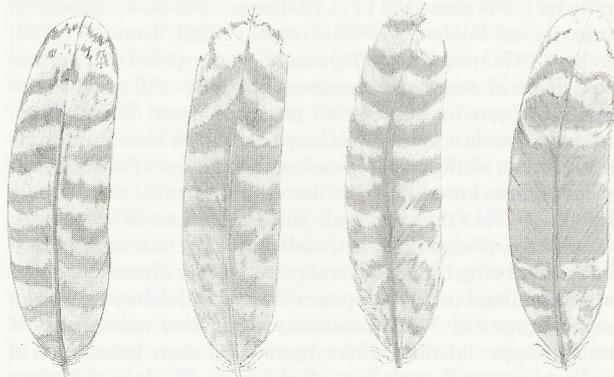


Figure 1 Variation in patterning on tail feathers

Dark patterning on rest of rectrices depends on colour and pattern on t1, but barring becomes narrower and more regular toward t6; t2 like t1 but with more defined barring; t6 with narrow complete bars along length of feather. **UNDERTAIL:** Similar to uppertail, but much paler and duller. Ground-colour grades from light rufous-brown (139) to white. Dark markings, dark brown (c121). **UPPERWING:** Marginal and small lesser secondary coverts near edge of wing, dark-brown (121); a small patch of coverts near carpal joint have narrow white fringes. Larger lesser and median secondary coverts, black-brown (119) with broad light-blue (c93) tips to most feathers; tips usually 7–10 mm wide and can appear white from some angles. Greater secondary coverts, all primary coverts and alula, black-brown (119), often with slightly paler fringes at tips; outermost 2–3 greater primary coverts have bluish sheen to outer webs. Secondaries mostly black-brown (119), each with concealed white base to outer web and partly concealed white base and edge to inner web that joins with white fringe at tip. Primaries mostly black-brown (119) with white bases, which on outer primaries are visible as white patch in middle of outerwing. Size of white patch varies individually: white bases visible on 4–7 primaries, usually extending inward from p9. Inner four primaries (p1–p4) have narrow white fringes at tips. **UNDERWING:** Lesser coverts, most median coverts and greater secondary coverts, white with narrow brownish-grey (79) barring. A few outer median primary coverts, dark brown (121) with 1–2 white bars near tips of feathers. Primaries and secondaries mostly dark grey (c83) with

white bases; secondaries and inner primaries have white extending along inner edge to join white fringes at tips.

**AUXILIARY (NON-BREEDING) MALE:** Based on duller adult male skins. Similar to primary (breeding) males, but lower back and rump usually much duller (like that of adult female; see below). Probably not reliably separable from adult females (see below) on plumage alone, but examination of a large series of skins suggests that a higher percentage have blue tinges on lower back and rump than primary adult females. However, since it was not possible to determine the social status of these skins, it is possible that a number of these males were primary (breeding) males. Field studies suggest they are often duller than primary adult females, with slightly darker feathers (Reyer & Schmidl 1988).

**Adult female** (First and subsequent basic). **PRIMARY (BREEDING) FEMALE:** Based on all adult female specimens. Similar to primary (breeding) adult male, but lower back and rump usually duller: in most birds, feathers of lower back mostly white, grading to rufous-brown (38) on rump, all barred dark-brown (219); some birds also have light-blue (93) tips to some feathers; in a few, lower back and rump mostly dark brown (219) with light-blue (93) tips to some feathers. Never have bright-blue lower back and rump as in primary adult male. Most probably not separable from auxiliary (non-breeding) adults on plumage alone. **AUXILIARY (NON-BREEDING) FEMALE:** Not reliably separable from primary adult females on plumage alone, and most probably not separable from auxiliary (non-breeding) adult males; only behaviour can be reliably used to separate females of different social status. Field studies suggest they are often duller than primary adult females, with slightly darker feathers (Reyer & Schmidl 1988).

**Nestling** Hatch naked (Parry 1970, 1973a; S. Legge). Do not have down (*contra* Hindwood 1947). Pins emerge from skin between Days 7 and 11 (Parry 1967; S. Legge), giving spiny appearance. Pins begin to split between 17 and 22 days (Parry 1968a). See Breeding: Young.

**Juvenile** Sexes alike. At fledging, tend to appear much darker than adults simply because plumage fresh compared with worn plumage of adults; plumage similar to that of adults within 6 months (Parry 1970). Probably not separable from adults when plumage very worn near end of first year. When plumage not overly worn, show following differences from adults: **HEAD AND NECK:** Tend to appear darker; wear to a similar pattern to adults. **UPPERPARTS, UNDERPARTS:** Similar to adult females. **TAIL:** Similar to adult in patterning, but outer rectrices, particularly t6, much more pointed than in adult (see Fig. 2). **UPPERWING:** Pale-blue tips on wing-coverts 4–7 mm wide, usually smaller than on adult. All primaries except p10 have very narrow white fringes to outer edges of tips; very noticeable on p1–p4 (c. 1–2 mm) but narrower on p5–p9 (<1 mm) and lost with wear. Rest similar to adult. **UNDERWING:** Similar to adults.

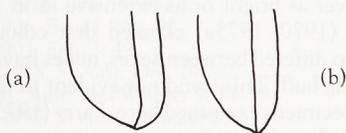


Figure 2 Rectrices (t6) (a) Adult (b) Juvenile

**Aberrant plumage** Albinos and semi-albinos often observed (Haines 1944; Anon. 1987; Beilby 1987; Mitchell 1990); claimed to make up c. 5% of population (Parry 1970). However, not all white birds are necessarily albino, as some with normal

eye-colour (leucistic) occur (Grant & Grant 1976). Melanistic individuals also recorded (Mitchell 1986; Johnstone 1989), and one bird had all white areas of plumage replaced with rufous (Magarry 1982).

**BARE PARTS** Based on photos (Parry 1970; Trounson & Trounson 1991; Egerton 1993; Flegg & Madge 1995; Stepnell & Boles Undated; Aust. RD; NZRD; Strahan). **Adult** Bill: upper mandible, black (89), sometimes slightly paler at tip (but not white as in juvenile); lower mandible mostly buff-yellow (53), pink-buff (121D) or cream (92), with black (89) patch on basal sides extending for 1–2 cm from base. Iris varies individually: brown (33 or 223A or 121C), dark brown (219) or red-brown (32); may also show reddish-brown outer ring (Rogers *et al.* 1990). Orbital ring, brownish grey (80). Legs and feet, cream (c54), light brown (c223C) or light brown-grey (45). Claws, black (89). **Nestling** Bill, grey-black (82); also described as blackish, tipped with small white egg-tooth (Parry 1970). Gape, pink-brown (c219D). Iris, black (89). Orbital ring, blue-grey (ne). Legs and feet mostly blue-grey (ne) but upper tibia, pink (c108D). **Juvenile** Bill mostly black (89) except for white tip (c. 2 mm) to upper and lower mandible round time of fledging; lower mandible gradually pales, attaining adult coloration at c. 3 months old (Parry 1970, 1973a; Rogers *et al.* 1990). Iris very dark at fledging age, black-brown (c119); also described as reddish brown and can show fine brown inner ring (Rogers *et al.* 1990). Orbital ring, light blue-grey (88). Legs and feet, greyish pink-brown (greyish c219D).

**MOULTS** Based on examination of 82 adult and 19 juvenile skins (AM, ANWC, HLW, MV, QM, SAM) and field study in Dandenong Ras, Vic. (Parry 1970, 1973a). **Adult post-breeding** (Second and subsequent pre-basic). Complete; primaries outward. In Dandenong Ras, Vic. (Parry 1970, 1973a), primary adults begin to moult around mid-Dec. or early Jan.; auxiliary adults begin moult earlier than breeding pair, and younger birds usually begin before older ones. Tail replaced first, followed by body, head and wings, with remiges replaced last. Complete moult takes c. 3 months. In Vic. (Rogers *et al.* 1986), moult of adults recorded Oct.–Apr. Only 12 skins showed active moult of primaries, all Dec.–Apr.: moult of primaries begins Dec. or Jan.: one in Dec. had PMS of 4 and one in Jan. had PMS of 6; finishes Mar. or Apr.: four in Mar. had PMS of 37–48, and two in Apr. had PMS of 44 and 47. Moult of primaries rapid; often have three feathers growing in wing at one time. Moult of tail appears to begin when moult of primaries well advanced and probably finished at about same time as primaries; one was over half-way through replacing rectrices in Mar. Very little information on moult of body; in skins, most active moult of body recorded Jan.–Mar.; three skins with slight moult of body recorded Apr. and May. **Post-juvenile** (First pre-basic). Little information. Difficult to separate birds in post-juvenile moult from adults. Probably complete, occurring at end of first year. One skin that was probably in post-juvenile moult was close to finishing moult of primaries in Feb. (PMS 41) and also had active moult of body. Parry (1970) states that juveniles moult into adult plumage when c. 14 months old.

**MEASUREMENTS** **NOMINATE NOVAEGUINEAE:** (1–2) E. and se. Aust., N to about Cairns, skins (AM, ANWC, HLW, MV, QM): (1) Adults; (2) Juveniles. (3) Dandenong Ras, Vic., adults, live; Tarsus A = Tarsus length but method not specified (Parry 1973a). (4) Canberra, ACT, adults, live; sexed using molecular methods (S. Legge).

	MALES	FEMALES	
WING	(1) 212.7 (8.96; 188–237; 44)	218.7 (8.06; 198–231; 31)	**
	(2) 210.8 (6.67; 198–220; 9)	217.0 (9.38; 200–226; 9)	ns
	(3) 213 (8.45; 59)	218 (9.72; 42)	**
	(4) 218 (5.50; 194–225; 51)	223 (6.03; 210–233; 35)	**
TAIL	(1) 152.2 (10.32; 123–171; 43)	155.1 (7.22; 137–170; 30)	ns
	(2) 151.9 (8.74; 132–159; 8)	156.9 (9.47; 142–171; 9)	ns
	(3) 158 (6.91; 59)	164 (6.48; 42)	**
	(4) 158 (9.71; 138–172; 51)	159 (7.81; 138–172; 35)	ns
BILL S	(1) 68.5 (4.06; 59.5–75.9; 43)	69.2 (4.49; 61.0–77.3; 32)	ns
	(2) 63.7 (3.23; 57.9–69.2; 9)	67.0 (3.44; 61.6–71.6; 10)	*
	(3) 65 (4.61; 59)	66 (3.24; 42)	ns
BILL N	(1) 51.8 (3.40; 44.6–57.5; 43)	51.7 (3.83; 44.4–59.0; 32)	ns
	(2) 46.7 (3.00; 40.5–50.4; 9)	50.0 (3.08; 44.9–53.8; 10)	*
BILL D	(1) 22.8 (1.33; 19.4–25.1; 38)	23.4 (1.54; 19.6–26.6; 29)	ns
	(2) 22.6 (1.88; 20.1–26.1; 9)	23.2 (1.19; 21.4–25.1; 8)	ns
THL	(4) 115 (4.93; 102–127; 51)	118 (4.50; 111–129; 35)	**
TARSUS	(1) 26.8 (1.38; 23.5–31.1; 44)	27.5 (1.37; 25.0–30.0; 32)	*
	(2) 26.5 (1.17; 24.3–27.8; 9)	27.9 (0.99; 26.6–29.3; 9)	*
TARSUS A	(3) 44 (2.04; 26)	45 (1.70; 32)	*
TOE C	(1) 39.2 (1.74; 35.5–42.8; 40)	40.4 (2.04; 37.6–45.7; 25)	*
	(2) 37.7 (1.51; 35.8–40.1; 7)	41.3 (1.82; 38.8–43.5; 6)	**

Juvenile males significantly smaller than adult males in Bill S ( $P < 0.01$ ), Bill N ( $P < 0.01$ ) and Toe ( $P < 0.05$ ). No significant differences between adult and juvenile females. Parry (1970, 1973a) observed that lengths of bill and tail of juveniles appeared shorter than adults till c. 3 months old.

(5A–B) Dandenong Ras, Vic., unsexed juveniles, live (Parry 1973a): (A) Fledgelings, <3 months old; (B) 3–12 months old. (5C) Vic., unsexed adults, live (D.I., K.G. & A. Rogers).

	(5A) <3 months old	(5B) 3–12 months old	(5C) Adults
WING	152 (10.71; 26)	216 (3.39; 8)	223.0 (6.47; 204–237; 29)
TAIL	52 (9.69; 26)	169 (6.22; 8)	163.9 (10.63; 140–190; 22)
BILL S	41 (4.08; 26)	64 (4.52; 8)	–
TARSUS	45 (1.53; 26)	45 (0.85; 8)	–
THL	–	–	116.5 (7.27; 103–144; 28)

Unsexed juveniles significantly larger than fledgelings in Wing, Tail and Bill S ( $P < 0.01$ ). Differences between adults and younger birds not tested.

SUBSPECIES MINOR: C. York Pen.: (6) Adults, skins (ANWC, HLW, QM, SAM).

	MALES	FEMALES	
WING	(6) 195.4 (2.15; 193–199; 7)	187, 194, 194	
TAIL	(6) 135.3 (2.63; 132–139; 7)	133.5 (5.20; 130–141; 4)	ns
BILL S	(6) 62.4 (3.04; 57.2–67.0; 7)	64.3 (2.03; 61.3–65.9; 4)	ns
BILL N	(6) 47.1 (3.00; 43.7–52.8; 7)	47.5 (2.58; 44.1–50.2; 4)	ns
BILL D	(6) 20.8 (0.59; 19.9–21.5; 7)	21.8 (1.26; 20.1–23.1; 4)	ns
TARSUS	(6) 25.2 (0.71; 24.1–26.0; 7)	26.5 (1.48; 24.9–28.5; 4)	ns
TOE C	(6) 38.2, 39.2	38.0, 38.8	

Additional measurements in Forshaw & Cooper (1983) and Keast (1957).

**WEIGHTS** NOMINATE NOVAEGUINAE: (1–2) Aust., from museum labels (AM, ANWC, MV, QM): (1) Adults; (2) Juveniles. (3–4) Adults, live: (3) Dandenong Ras, Vic. (Parry 1973a). (4) Canberra, ACT (S. Legge).

	MALES	FEMALES	
(1)	307.2 (62.71; 196–450; 30)	352.1 (60.55; 245–465; 22)	*
	285.1 (87.02; 101–400; 8)	303.5 (79.70; 190–375; 4)	ns
	325 (30.13; 26)	382 (53.12; 32)	**
	313 (27.07; 248–371; 51)	356 (26.50; 285–417; 35)	**

(5A–B) Dandenong Ras, Vic., unsexed juveniles, live (Parry 1973a): (A) Fledgelings, <3 months old; (B) 3–12 months old. (5C) Vic., unsexed adults, live (D.I., K.G. & A. Rogers).

	(5A) <3 months old	(5B) 3–12 months old	(5C) Adults
	314 (24.47; 26)	365 (32.61; 8)	335.8 (34.8; 283–417; 22)

Unsexed juveniles significantly heavier than fledgelings ( $P < 0.01$ ). Differences between adults and younger birds not tested.

SUBSPECIES MINOR: (7) C. York Pen., adults, museum labels (ANWC): male, 214; females, 196, 270.

From throughout range (subspecies not known), live (ABBBS): males, 343.6 (65.32; 256–575; 29); females 334.6 (74.42; 175–490; 27); unsexed 342.9 (51.85; 208–469; 196).

**STRUCTURE** Wing long, broad and rounded at tip. Eleven primaries: p7 or p8 longest; p10 31–42 mm shorter, p9 5–13, p8 0–2, p7 0–1, p6 1–6, p5 14–19, p4 30–35, p3 40–45, p2 46–50, p1 51–55; p11 minute. P5–p9 slightly emarginated on outer webs, p6–p10 slightly on inner webs. Fifteen secondaries, including about four tertials; tips of longest tertials fall between p4 and p5 on folded wing. Tail long and rounded; 12 rectrices; t1 longest, t6 19–30 mm shorter. Bill long and heavy; about same length as head: upper mandible, straight, broad at base tapering to narrow but rather blunt tip; cutting edge mostly straight but slightly concave near tip; lower mandible straight from base to about half-way along length of bill then tapers with slight upward curve to tip. Nostrils large and elongated; situated just below ridge of culmen near base of upper mandible. Tarsus short and thick; reticulate. Tibia fully feathered. Syndactylous. Middle toe longest. Outer toe 86–91% of middle, inner 61–64%, hindtoe 48–52%. Brood-patches found on primary (breeding) males and females and auxiliary males (auxiliary females not yet checked) (S. Legge), *contra* only females have brood-patches (Rogers *et al.* 1986), though both sexes and all members of group incubate and brood (see Breeding).

**SEXING** Many adults are probably not able to be sexed because primary (breeding) adult females, auxiliary males and auxiliary females all similar. Only birds with bright-blue backs can be confidently sexed as primary (breeding) adult males. Some females can have pale-blue tips to some feathers of back, but these never as bright or as extensive as in primary adult males. Parry (1970, 1973a) claimed that colour of feathers above eye also differed between sexes, males having white and females having buff. This trend not evident in the large series of museum specimens examined here. Parry (1973a) developed sexing criteria based on scores for ten plumage characters for each age, sex and class of social status. These results showed trends in coloration within each group. However, for each plumage character within adults there was at least one exception, and often more, to overall trend. This indicates that plumage characters can be useful in ageing but must be used with caution when trying to determine sex or social status.

**GEOGRAPHICAL VARIATION** Two subspecies that differ in size and, possibly, plumage: *novaeguineae* in se. and e. Aust., N to se. base of C. York. Pen.; and *minor* from C. York Pen., S to about Cooktown. No apparent break in distribution between the two subspecies, but wing and bill measurements show a marked and abrupt change in region just S of Cooktown. Ford (1986) found that the two subspecies separate along the Burdekin–Lynd Divide, between Cooktown and Burra.

*Minor* significantly smaller than *novaeguineae* in Wing ( $P < 0.01$ , male), Tail ( $P < 0.01$ , both sexes), Bill S ( $P < 0.01$  male;  $P < 0.05$  female), Bill N ( $P < 0.01$  male,  $P < 0.05$  female), Bill D ( $P < 0.01$  male) and Tarsus ( $P < 0.01$ , male), though sample sizes of females were too small to compare Wing, Tarsus and Toe, and sample sizes of both sexes were too small to compare weights. *Minor* also appears to differ from *novaeguineae* in slightly darker crown, with less individual variation; all examined had similar pattern of barring to tail (cf. varied pattern in *novaeguineae*).

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Laughing Kookaburra *Dacelo novaeguineae* (page 1122)

NOMINATE NOVAEGUINEAE: 1 Adult male; 2 Adult female; 3 Juvenile; 4, 5 Adult male; 6 Adult female

SUBSPECIES MINOR: 7 Adult

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