

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: *Nyctornis*, *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).

Coraciiformes 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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Todiramphus sanctus **Sacred Kingfisher**

COLOUR PLATE FACING PAGE 1184

Halcyon sanctus Vigors & Horsfield, 1827, *Trans. Linn. Soc. Lond.* 15: 206 — New Holland = New South Wales.

Vigors & Horsfield (1827) considered this species to be allied to Gmelin's (1788) *Alcedo sacra* (now considered a subspecies of the Collared Kingfisher). Both, together with other Pacific kingfishers, were held in superstitious veneration by the natives of Polynesia and believed to have power over the waves and the ocean (Latin *sanctus*, holy, sacred; *sacrum*, holy).

OTHER ENGLISH NAMES Kingfisher; Green, Tree, New Zealand or Wood Kingfisher.

POLYTYPIC Nominate *sanctus* breeds Aust. and e. Solomon Is; in austral winter, Aust. birds migrate to Solomon Is, New Guinea and surrounding islands, Talaud and Sunda Is, Indonesia and Borneo; *vagans* (Lesson, 1826) NZ, Kermadec, Norfolk and Lord Howe Is. Extralimital subspecies: *canacorum* (Brasil, 1916), New Caledonia and Isle of Pines; *macmillani*, Mayr, 1940, Loyalty Is; *recurvirostris* (Lafresnaye, 1842), Western Samoa.

FIELD IDENTIFICATION Nominate *sanctus*: Length c. 21 cm; wingspan c. 33 cm; weight c. 40 g; subspecies *vagans*: length c. 23 cm; wingspan c. 37 cm; weight c. 55 g. Familiar small tree kingfisher with mostly greenish-blue cap and upperparts; buff to white collar, supraloral stripe and underbody; and blackish eye-stripe. Very similar in shape to Forest Kingfisher *Todiramphus macleayi* but slightly bigger; smaller than Collared Kingfisher *T. chloris*, with shorter and much smaller bill. Sexes differ very slightly; female duller and greener above. No seasonal change in plumage but appearance varies greatly with wear, appearing brighter above and more strongly buff below in fresh plumage (in winter), becoming duller and whiter respectively as plumage wears (in late spring–summer). Juvenile separable. **Adult male** Cap, dark greenish-blue, bordered below by contrasting broad black eye-stripe from lores to ear-coverts (where often strongly tinged green-blue), that joins narrow black band round nape. A prominent short orange-buff supraloral stripe extends across upper lores from bill, and ends in narrow line over eye; stripe fades to whitish with wear. Chin, throat, foreneck and broad hindneck-collar, white (collar often washed buff in fresh plumage). Mantle and scapulars, dark green to dark bluish-green, slightly darker on upper mantle; rest of upperbody and uppertail, dark greenish-blue, brightest on rump and uppertail-coverts. Upperwing: secondary coverts, dark greenish-blue, contrasting markedly with duller-greenish saddle; rest of upperwing slightly deeper greenish-blue than secondary coverts. Underbody varies much with wear: orange-buff to buff when fresh, fading to cream or white with paler buff wash on lower sides when worn. Undertail, grey. Underwing: coverts, rich buff, contrasting with light grey remiges. Bill, black with narrow pale stripe along underside of lower mandible. Iris, dark brown. Orbital ring, black. Legs and feet, grey or pink-brown. **Adult female** Similar to adult male but generally duller and greener above, with paler rump and uppertail-coverts; sexes can be difficult to distinguish in field as variation with wear results in considerable overlap. In fresh plumage typically differs from male by: cap, mantle and scapulars duller, bluish olive; rump and uppertail-coverts noticeably paler, dull greenish-blue; uppertail duller, greenish blue with greyish tinge; and upperwing duller and greener, with noticeably duller, bluish-green secondary coverts contrasting less with saddle. **Juvenile** Sexes not separable in field. Very similar to adult female, differing by: feathers of forehead and secondary coverts of upperwing fringed buff, giving slightly scaly appearance to forehead and usually obvious scaly appearance to folded wing; supraloral stripe, neck and underbody strongly suffused with buff; and neck and breast finely mottled to clearly scaled black. Bill at first shorter and weaker than adult, black except for tiny white tip, small pale area at base of lower mandible, and white gape; soon like adult.

Similar species In all plumages, combination of mostly greenish-blue cap and upperparts, buff to white collar, underbody and supraloral stripe, and blackish eye-stripe, should distinguish from congeners. In mangroves, beware confusion with **Collared Kingfisher** (q.v.); see also comments under **Forest and Red-backed** *T. pyrrhopygia* Kingfishers.

Seen singly, in pairs or family parties in wide variety of open habitats, usually near water. Often seen perched on overhead wires. Noisy and can be conspicuous during breeding season; quieter at other times. Often appear rather wary, flighty and nervous, especially adult females and juveniles; during breeding season, males often sit in distinctive posture: upright, with wing-tips pointing downward, and watching or calling to other males. When foraging, sit quietly on branch, post, over-

head wire or other vantage point, occasionally moving head a little or flicking tail upward, while watching for prey; when prey sighted, dive to ground and snatch prey then quickly return to perch, where prey repeatedly bashed against perch before it is eaten; sometimes snatch prey from foliage, tree-trunks or branches, or, rarely, plunge-dive. Flight swift and direct, with rapid shallow wing-beats interspersed with fast stiff-winged glides. Most noticeable call a series of 4–5 loud staccato notes *kek-kek-kek-kek*, repeated monotonously for long periods during breeding season and occasionally at other times of year, and sometimes at night; other calls include rapid Ascending Roll *tucree-tucree-tucree...*, often given by pair together; and short shrieks and screams.

HABITAT Inhabit wide variety of wooded and open habitats.

Aust. Throughout range, often in open sclerophyll forests and tall woodlands (McEvey & Middleton 1968; Roberts & Ingram 1976; Emison & Porter 1978; Boekel 1980; Conole 1981; Jones 1986; Baxter 1989; Ashton 1996; Hall), usually with sparse understorey or ground-cover of grasses, or scattered patches of open ground (Loyn 1980; Porter & Henderson 1983; Gibson 1986; Leach 1988; Baxter 1989; Vic. Atlas). Sometimes in forest regenerating after fire, or in mosaic of logged and unlogged forest (Porter & Henderson 1983; Smith 1984; Kavanagh *et al.* 1985; Loyn 1985b; Turner 1992), though near Orbost, Vic., present in unlogged old-growth forest but absent from adjacent mosaic of logged and unlogged forest (Kutt 1996). Sometimes occur at edges of monsoon rainforest (Thompson 1984); in depauperate temperate rainforest (Recher 1975); in semi-deciduous vine-thickets (Smith *et al.* 1978; Woinarski *et al.* 1988); or in pockets of eucalypts within rainforest (Robertson & McGill 1948), though, in some areas, said to avoid dense closed forests (Thompson 1984; Gosper & Gosper 1996); in Kakadu NP, NT, recorded in all types of monsoon forest except on escarpments (Woinarski 1993). Often near water (Alexander 1921; Sedgwick 1947; Sharrock 1981; see also Chisholm 1934; Hall): in vegetation in, or at edges of, wetlands, such as rivers, creeks, floodplains, lakes, swamps and billabongs (McGill 1944; Hobbs 1961; Missen & Timms 1974; Costello 1981; Gosper 1981; Loyn 1985a; Leach 1988; Baxter 1989). In n. Aust., often among paperbarks *Melaleuca* along rivers and round swamps (Deignan 1964; Johnstone *et al.* 1977; Johnstone 1983; Start & Fuller 1983; Woinarski *et al.* 1988). In study on Howards Pen., NT, in Apr.–May (transition between wet and dry seasons; 46 records), recorded at greatest density (0.20 birds/ha) in tall closed paperbark swamp forest, to 17 m tall, dominated by *Melaleuca leucadendra*, *M. cajaputi* and *M. symphyocarpa*; also recorded in low open mangrove forest ≤ 4 m tall (0.08 birds/ha), low closed mangrove forest ≤ 8 m tall (0.08 birds/ha) and closed semi-deciduous vine-thicket (forest) ≤ 15 m tall (0.08 birds/ha) (Woinarski *et al.* 1988). At Victoria R. Downs, NT, mainly confined to understorey of riverine vegetation during dry season (Boekel 1980). In arid or semi-arid inland areas, mostly confined to watercourses lined with trees, such as River Red Gums *Eucalyptus camaldulensis*, Coolibahs *E. microtheca* and Black Box *E. largiflorens* (Alexander 1923; Jones 1952; Johnstone *et al.* 1977; Boekel 1980; Start & Fuller 1983; Jones 1986; Henle 1989; Hall; Storr 7); also along vegetated bore drains or round waterholes (Church 1925; Liddy 1963; Beruldsen 1969; Sharrock 1982; SA Bird Rep. 1977–81); and recorded in flooded dongas on Nullarbor Plain (Brooker *et al.* 1979). Often in sheltered coastal areas, such as harbours and estuaries with intertidal mudflats or sandflats, and often among mangroves (Hindwood

1935a; Brown 1949; Eckert 1972; Frith & Calaby 1974; Draffan *et al.* 1983; Gosper 1983; Taylor 1987; Baxter 1989; Gosper & Gosper 1996; Noske 1996) or vegetated coastal dunes (Limpus 1973; Roberts & Ingram 1976; Garnett & Bredl 1985). Sometimes on low vegetated sandy or coral cays; rarely on unvegetated sandbanks or reefs (Serventy 1951; Domm 1977; McKean 1980; Smith 1987; Walker 1987). Sometimes in coastal scrub (Recher 1975; Reilly 1981). Rarely in heathland or saltmarsh (Preston 1983; Pyke 1985; Smith 1987; Morris *et al.* 1990; McLean 1993). Also occur in open farmland, often with strips of remnant or roadside vegetation (Marshall 1935; Sedgwick 1984; Loyn 1985b; Leach & Watson 1994; Tas. Bird Rep. 4); grassland (Cooper 1974); and in parks and gardens in built-up areas (Le Souëf & MacPherson 1920; Whitlock 1939; Parker 1971; Paton 1976; Thompson 1984; McKilligan & McKilligan 1987; Sitte & Jones 1994; Collins 1995), especially those with forest nearby (Morris 1975; Gibson 1977). In some areas, show seasonal preference for different habitats, e.g. in winter in e. NSW, more often in open habitats, such as pasture or coastal foreshores (Hindwood 1935a; Gosper 1981; Morris *et al.* 1981; Marchant 1992; Gosper & Gosper 1996; cf. NZ); in tropical NT, throughout eucalypt forests and woodlands during breeding season (Sept.–Mar.), but rare in these habitats in other months (dry season) when more common in wetter habitats (such as along watercourses, in paperbark swamp forests, mangroves and so on) (Curl 1998). Sometimes land on ships out at sea (Alexander 1926; Darby 1970; Qld Bird Rep. 1986). On LORD HOWE I. occur in variety of habitats, including open forests, especially in clearings and round ecotone with open farmland, and on rocky seashores (Hindwood 1940; Fullagar *et al.* 1974; Hutton 1991). On NORFOLK I. mostly inhabit open farmland, and rocky coasts and nearby reefs; do not occur in thick native forest, though may occur in clearings in or at edges of forests; sometimes among riparian vegetation (Smithers & Disney 1969; Disney & Smithers 1972; Schodde *et al.* 1983; Forshaw & Cooper 1985; Hermes 1985).

NZ Often in native forests dominated by Rimu *Dacrydium cupressinum*, beech *Nothofagus*, rata *Metrosideros*, Broadleaf *Griselinia littoralis*, *Podocarpus* and hardwood species; where understorey of forests is dense, inhabit canopy (Secker 1951; St Paul 1977; Onley 1980; Fitzgerald *et al.* 1986, 1989; CSN); often at edges of forest or in clearings within forests (Blackburn 1967; Oliver; CSN). Sometimes in logged forest (Challies 1966; Onley 1980; CSN 19 [Suppl.]), or in plantations of pines *Pinus*, especially along tracks or in clearings (Weeks 1949; Oliver). Sometimes occur in remnant patches of native vegetation, including forest, woodland or scrub dominated by rimu, beech, podocarp or manuka (Kirk & Wodzicki 1943; Sedgwick 1955; Onley 1980; O'Donnell 1981) or vegetation along watercourses, including willows *Salix* (DFNC 1948; Hayes 1991; Moon 1991). Also occur in open farmland, particularly pasture with shelterbelts of pines and cypress *Cupressus*; orchards (Guthrie-Smith 1910; Sedgwick 1955; Gill 1977; Ralph & Ralph 1977; CSN 19 [Suppl.]); and open gardens and parks in settled areas (Stead 1932; Secker 1951; Acres 1960; Guest & Guest 1987, 1993; Day 1995; CSN). Often in sheltered coastal areas, such as estuaries, lagoons, bays, inlets and harbours, especially those with expansive intertidal mudflats or exposed rock platforms (Blackburn 1967; Pierce 1980; Owen & Sell 1985; Hayes 1989; Robertson 1992; Oliver; CSN); also shores of fiords (CSN 19 [Suppl.]) or narrow shingle beaches (Forshaw & Cooper 1985). Sometimes in coastal sand-dunes (Wodzicki 1946; CSN 25; *contra* Bell & Brathwaite 1964) or dunes round lakes (CSN 37). Some seasonal variation in use of habitats:

usually in forests during summer, moving to more open habitats, including shores and farmland, in winter (Secker 1951; Taylor 1966; Ralph & Ralph 1977; Dawson *et al.* 1978; Edgar 1978b; Owen & Sell 1985; Fitzgerald *et al.* 1986; Hayes 1989; CSN 25, 30; see Movements). On KERMADEC IS inhabit seashores, farmland and edges of forests; sometimes also occur within thick forests (Edgar *et al.* 1965; Merton 1970).

Breed in wide variety of habitats, including along coasts; often near wetlands: within or at edges of native forests or woodlands, including remnant patches; also in urban areas (McGill 1944; Binns 1953; Chinner 1977; Boekel 1980; O'Donnell 1981; Fitzgerald *et al.* 1986; Hayes 1991; Moon 1991; Marchant 1992; NZRD; CSN; NRS). In hollows: excavated or partly excavated in branches or trunks of living or decaying trees, including mangroves and *Pisonia* trees on coast, and in exotic trees in suburban reserves; or excavated in soil of banks, cliffs of roadside cuttings, including sandbanks or cliffs near high-tide mark along coasts; or excavated in arboreal termitaria (Campbell & White 1910; MacGillivray 1926, 1928; Mayo 1931b; Sandland 1931; Cooper 1948; Edwards 1955; Hindwood 1959; Ford 1965; Storr 1965; Wheeler 1967a; Reed 1976; Gosper 1981; Jones 1981; Forshaw & Cooper 1985; McKean 1985; CSN 3). Sometimes nest in hollows in buildings (Hutton & Drummond 1904; Stone 1912) or old mine workings (BFNC 1976). Some regional variation in habitat preference: in n. and e. Aust. and NZ, breed in trees, banks and termitaria, but in WA, said to nest almost invariably in hollows in trees (Serventy & Whittell; *contra* Storr 1965); similarly, on Lord Howe I., only recorded breeding in rotting trunks of native vegetation (Basset Hull 1909; Sharland 1929; Hutton 1991); on Kermadec Is, only recorded breeding in roadside banks (Edgar *et al.* 1965; Merton 1970); on Norfolk I., nest in both banks and native trees, including tree-ferns and Norfolk Island Pines *Araucaria heterophylla* (Basset Hull 1909; Hermes 1985; Hermes *et al.* 1986).

Most food taken from ground. Usually in open, often grassy, areas including floors of open forests and woodlands, and open farmland (e.g. Chisholm 1924; Stead 1932; Austin 1950; Wakelin 1968; Disney & Smithers 1972; Fleming 1976; St Paul 1977; Forshaw & Cooper 1985; Ford *et al.* 1986; Baxter 1989; Hutton 1991; Moon 1991; Oliver); also on mudflats or sandflats exposed at low tide on shores of sheltered coastal embayments, harbours and estuaries, taking prey from surface of mud, at edge of water, or in remaining shallow pools (Alexander 1926; Hindwood 1935a; Austin 1950; Draffan *et al.* 1983; Taylor 1987; Baxter 1989; Hayes 1989, 1991; Hall; CSN); sometimes also forage on exposed sandy beaches (Brown 1949). Also forage on outer foliage of trees or shrubs, both in open or within forests or woodlands, especially forest with dense undergrowth that hinders foraging on ground (Chisholm 1924; Stead 1932; Disney & Smithers 1972; St Paul 1977; Child 1984; Fitzgerald *et al.* 1986; Moon 1991; Curl 1998; CSN 1, 38). On Lord Howe I., recorded probing rotten trunk of tree (Hutton 1991). Also forage by surface-plunging in shallow water of wetlands, such as rivers, creeks and billabongs (Butler 1907; Smithers & Disney 1969; Fleming 1976; St Paul 1977; Boekel 1979; Conole 1981; O'Donnell 1981; Moon 1991; Tas. Bird Rep. 9; CSN); in artificial ponds and tanks (Hutton & Drummond 1904; Carter 1924; Robbins 1997; CSN 4); at pools on exposed rock platforms or reefs (MacGillivray 1926; Smithers & Disney 1969; Fullagar *et al.* 1974; Hutton 1991). Once fed on fish attracted to stranded krill on beach (Tas. Bird Rep. 15). Take food from surface of water or a few centimetres below surface (Stead 1932; Austin 1950; Oliver). Sometimes feed aerially (Scammell 1922;

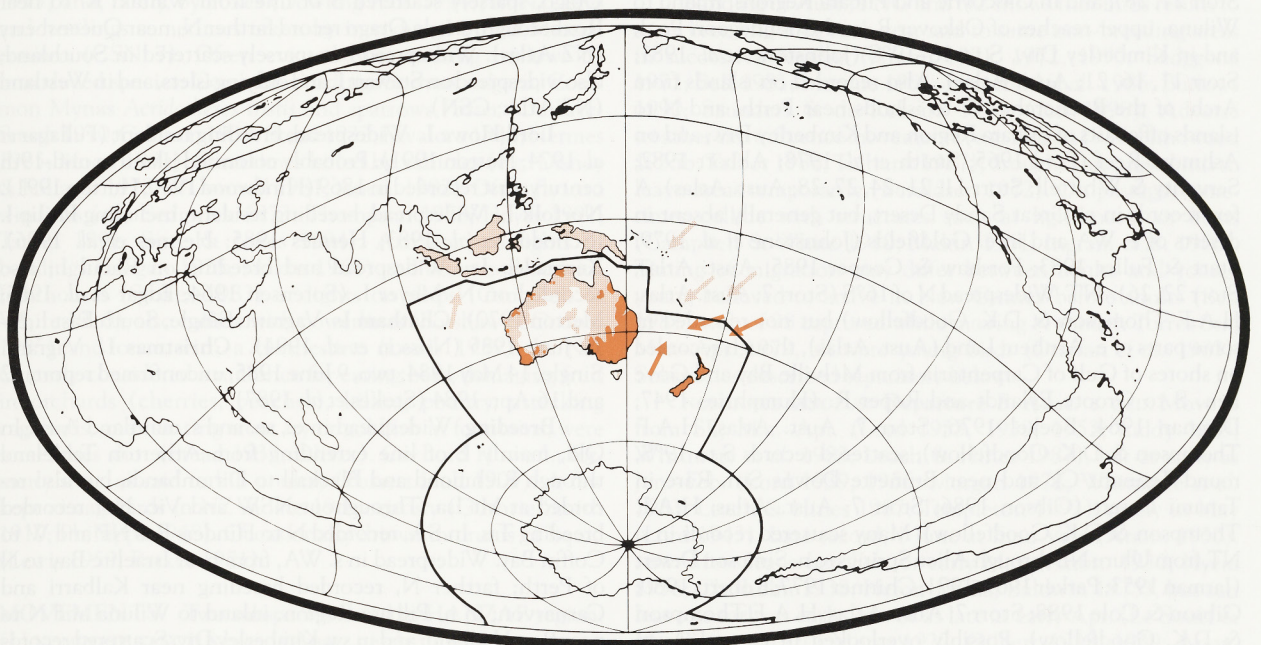
Lewis 1959; Disney & Smithers 1972; Fleming 1976; O'Donnell 1981; Grant 1983; CSN 19 [Suppl.]).

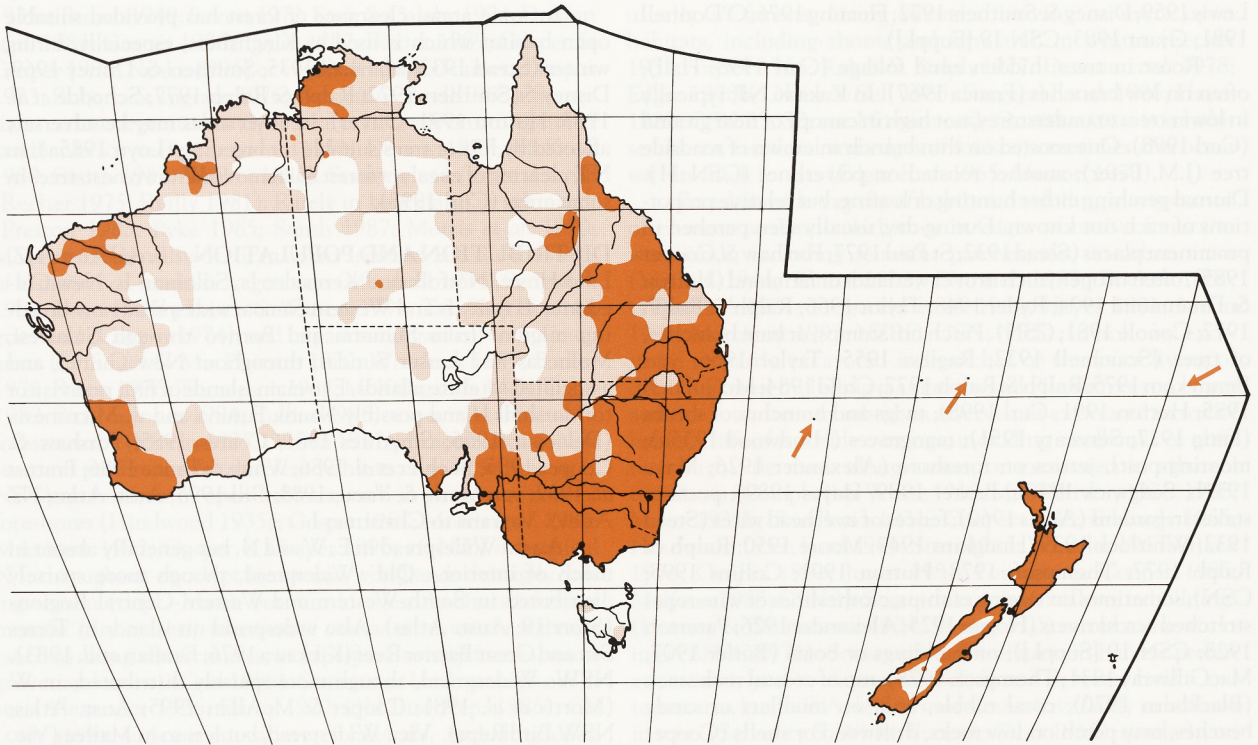
Roost in trees; hidden amid foliage (Curl 1998; Hall); often on low branches (Frauca 1967). In Kakadu NP, typically in lower trees or understorey, not high in canopy or near ground (Curl 1998). One roosted on thin branch in crown of roadside tree (J.M. Peter); another roosted on powerlines (CSN 31). Diurnal perching either hunting or loafing, but relative proportions of each not known. During day, usually seen perched in prominent places (Stead 1932; St Paul 1977; Forshaw & Cooper 1985), often in open, such as over wetlands or farmland (Hutton & Drummond 1904; Ryder 1948; Taylor 1966; Ralph & Ralph 1977; Conole 1981; CSN). Perch on: stumps, or bare branches, of trees (Scammell 1922; Ragless 1955; Taylor 1966; van Bennekom 1975; Ralph & Ralph 1977; Child 1984; McCulloch 1985; Hutton 1991; Curl 1998); twigs and branches of shrubs (Lang 1927; Serventy 1951); mangroves (Hindwood 1935a); mooring-posts, jetties on foreshore (Alexander 1926; Mayo 1931b; Sedgwick 1940b; Baxter 1989; Hayes 1989); posts or stakes in gardens (Acres 1960); fences or overhead wires (Stead 1932; Whitlock 1939; Hodgkins 1949; Moore 1950; Ralph & Ralph 1977; Thompson 1978; Hutton 1991; Collins 1995; CSN); sometimes on rigging of ships, clotheslines or wire ropes stretched across rivers (Hogan 1925; Alexander 1926; Paterson 1928; CSN 19 [Suppl.]); on buildings or boats (Butler 1907; MacGillivray 1931; Thompson 1978); top of coastal rock stack (Blackburn 1970); coral rubble; and, on mudflats or sandy beaches, may perch on low rocks, driftwood or shells (Cooper 1948; Edgar 1978a; Draffan *et al.* 1983; Gosper 1983; Hayes 1989; McLean 1993; CSN); once on goalpost on football field (Stead 1932); also on rain-gauge (Stead 1932). Perches usually >2 m above ground (Guthrie-Smith 1910; Smithers & Disney 1969; Recher & Holmes 1985; see Food); in Kakadu NP, 3–5 m (Curl 1998); but in some open habitats may perch only a few centimetres above ground (Cooper 1948; Edgar 1978a; Draffan *et al.* 1983; Gosper 1983; Hayes 1989; McLean 1993; CSN); rarely perch on ground (Gosper 1983; Hayes 1989). Once sought refuge on boat during a storm (Barrett 1910).

In some areas, clearance of forest has provided suitable open habitat which is used by Kingfishers, especially during winter (Stead 1932; Marshall 1935; Smithers & Disney 1969; Disney & Smithers 1972; Ralph & Ralph 1977; Schodde *et al.* 1983; Hutton 1991; Oliver). In other areas may be adversely affected by loss of trees suitable for breeding (Loyn 1985a); in NT, clearing of eucalypt forest has removed known nest-trees in some areas (Curl 1998).

DISTRIBUTION AND POPULATION Breed Aust., NZ, Lord Howe, Norfolk and Kermadec Is, Solomon Is, New Caledonia, Loyalty Is and Western Samoa; widespread non-breeding migrant from Sumatra and Borneo through Sulawesi, Moluccas and Lesser Sundas; throughout New Guinea and associated satellite islands, E to main islands of Fiji; rare visitor to Marshall Is and possibly Nauru, Futuna and w. Micronesia (Delacour 1966; Smythies 1981; Coates 1985; Forshaw & Cooper 1985; Beehler *et al.* 1986; White & Bruce 1986; Pratt *et al.* 1987; van Marle & Voous 1988; Gill 1995; Aust. Atlas; NZ Atlas). Vagrant to Christmas I.

Aust. Widespread in E, W and N, but generally absent in much of interior. **Qld** Widespread, though more sparsely distributed in South-Western and Western-Central Regions (Storr 19; Aust. Atlas). Also widespread on islands in Torres Str. and Great Barrier Reef (Kikkawa 1976; Draffan *et al.* 1983). **NSW** Widespread, though more sparsely distributed, in W (Morris *et al.* 1981; Cooper & McAllan 1995; Aust. Atlas; NSW Bird Reps). **Vic.** Widespread, but less so in Mallee (Vic. Atlas). **Tas.** Regular non-breeding visitor in small numbers. Most records in SE, from Triabunna and Maria I. S to Bruny I. and Cockle Ck (Aust. Atlas; Tas. Bird Reps); rare elsewhere, such as on n. coast at Perkins I. and mouth of Mersey R. (Tas. Bird Reps 1, 19). Recent records from islands in Bass Str. include singles on: King I., at Egg Lagoon, 25 Mar. 1975, and Currie, 30 Mar. 1990 (Tas. Bird Reps 5, 20); Deal I., 2 June 1982 (Gray *et al.* 1987). **SA** In NE, rare in s. Simpson Desert and L. Eyre Drainage Basin; scattered records from middle reaches of L. Eyre Drainage Basin, S to n. Flinders Ras (to 30°S). Wide-





spread but sparse from n. Flinders Ras, S to coast from near Port Macdonnell to e. and s. Eyre Pen. Scattered records farther W, from near Streaky Bay to Yalata Aboriginal Reserve (Jenkin & Waterman 1965; Eckert 1972; Cox & Pedler 1977; Badman 1989; Paton *et al.* 1994; Stove 1994; Hall; Aust. Atlas; SA Bird Reps 1976, 1977–81). **WA** Regularly recorded in small numbers at a few scattered sites on Nullarbor Plain (Brooker *et al.* 1979; Congreve & Congreve 1985; Storr 27; Aust. Atlas). Widespread in SW, S of line from Israelite Bay to Kalbarri (Saunders & Ingram 1995; Serventy & Whittell; Aust. Atlas; Storr 27, 28); and in Gascoyne and Pilbara Regions, inland to Wiluna, upper reaches of Oakover R. and Coondegoon Pool; and in Kimberley Div., S to 18–19°S (Johnstone *et al.* 1981; Storr 11, 16, 21; Aust. Atlas). Also recorded on islands from Arch. of the Recherche, W to islands near Perth, and N to islands off coasts of Pilbara Region and Kimberley Div., and on Ashmore Reef (Ford 1965; Smith *et al.* 1978; Abbott 1982; Serventy & Whittell; Storr 11, 21, 24, 27, 28; Aust. Atlas). A few records in n. Great Sandy Desert, but generally absent in deserts of e. WA and in e. Goldfields (Johnstone *et al.* 1979; Start & Fuller 1983; Forshaw & Cooper 1985; Aust. Atlas; Storr 22, 26). **NT** Widespread N of 16°S (Storr 7; Aust. Atlas; H.A.F. Thompson & D.K. Goodfellow) but not recorded in some parts of e. Arnhem Land (Aust. Atlas), though recorded on shores of Gulf of Carpentaria from Melville Bay and Gove Pen. S to Groote Eylandt and Roper R. (Humphries 1947; Deignan 1964; Boekel 1976; Storr 7; Aust. Atlas; H.A.F. Thompson & D.K. Goodfellow); scattered records S to 19°S, round Tennant Ck and near Brunette Downs Stn. Rare in Tanami Desert (Gibson 1986; Storr 7; Aust. Atlas; H.A.F. Thompson & D.K. Goodfellow). Many scattered records in s. NT, from Uluru NE through Alice Springs to n. Simpson Desert (Jarman 1953; Parker 1969, 1971; Chinner 1977; Roberts 1980; Gibson & Cole 1988; Storr 7; Aust. Atlas; H.A.F. Thompson & D.K. Goodfellow). Possibly overlooked in central Aust.

because similar to, and possibly misidentified as, Red-backed Kingfisher (Parker 1971; Roberts 1980).

NZ Widespread. **NI** Widespread in all regions from Northland S to Wellington and Wairarapa, though more sparsely scattered in Volcanic Plateau, w. and central parts of East Coast, w. Hawkes Bay and s. Taranaki (NZ Atlas; CSN). **SI** Widespread in Nelson and Marlborough Regions, though more sparsely scattered in s. Kaikoura Ras. Also widespread in Canterbury, particularly along coast, extending inland to Canterbury Plains; a few records farther W along main divide. In Otago, sparsely scattered S of line from Waitaki R. to near Roxborough; single Otago record farther N, near Queensberry (NZ Atlas). Widespread but sparsely scattered in Southland; also widespread on Stewart I. and offlying islets, and in Westland (NZ Atlas; CSN).

Lord Howe I. Widespread, breeding resident (Fullagar *et al.* 1974; Hutton 1991). Probably colonized island in mid-19th century; first recorded in 1869 (Hindwood 1940; Hutton 1991). **Norfolk I.** Widespread, breeding resident, including Philip I. (Schodde *et al.* 1983; Hermes 1985; Hermes *et al.* 1986). **Kermadec Is** Widespread and breeding on Raoul I.; also recorded on N. Meyer I. (Sorensen 1964; Edgar *et al.* 1965; Merton 1970). **Chatham Is** Vagrant. Single, South East I., 9–11 June 1985 (Nilsson *et al.* 1994). **Christmas I.** Vagrant. Single, 14 May 1984; two, 9 June 1985; unconfirmed report, 12 and 16 Apr. 1984 (Stokes *et al.* 1987).

Breeding Widespread in e., se. and s. mainland Aust. In Qld, mainly E of line extending from Atherton Tableland through Richmond and Blackall to Dirranbandi, but also recorded at Mt Isa. Throughout NSW and Vic. Not recorded breeding Tas. In SA, recorded N to Flinders Ras NP and W to Coffin Bay. Widespread in s. WA, from near Israelite Bay to N of Perth; farther N, recorded breeding near Kalbarri and Carnarvon; in n. Pilbara Region, inland to Wiluna and N to near Port Hedland; and in sw. Kimberley Div. Scattered records

in Top End of NT, from Humpty Doo and Kapalga, S to Keep R. and Victoria R. Downs; also recorded farther S, near Tennant Ck and Alice Springs (Curl 1998; Aust Atlas; NRS). In NZ, widely scattered in NI and SI: many records from Hen & Chickens Is, S to Hunua Ras and E to Cuvier I., with records scattered S to Orongorongo R. in Wellington; and from Golden Bay, S to Stewart I. and E to near Dunedin and Christchurch (CSN). Also on Lord Howe, Norfolk and Kermadec Is.

Irruptions Influxes recorded in Vic. at L. Boga, 1909 (Stone 1912) and in Western District, 1971 (Missen & Timms 1974). Minor irruption into Tas. in 1974 (Tas. Bird Rep. 4).

Populations AUSTR.: Recorded at densities of: 0.17–0.19 birds/ha near Armidale, NSW (Ford & Bell 1981); 0.4 birds/ha at Wollombi, NSW (H.L. Bell); 0.8 birds/ha along Hawkesbury R., NSW (Keast 1985a); 0.2–1.7 birds/10 ha near Canberra (Bell 1980); 3–4 pairs in 19 ha near Moruya, NSW (Marchant 1979); 0.31 birds/ha at Jamieson, Vic. (P.N. Reilly); 0.19 birds/ha in mangroves at Palmerston, NT (Noske 1996); 0.4 birds/ha along S. Alligator R., NT (Keast 1985a); 0.08–0.2 birds/ha on Howards Pen., NT (Woinarski *et al.* 1988); 0.2–0.3 birds/ha in contiguous breeding territories in eucalypt forests in Kakadu NP, NT (Curl 1998). In Wheatbelt of WA, said to have declined since 1930s (Saunders & Ingram 1995). NZ: Between Foxton and Palmerston North (32.5 km), mean of 0.61 birds/trip (0.90; 0–4; 56 trips), equivalent to mean of 0.19 birds/km (Gill 1977). From combined roadside censuses from several sites on NI, 7.5 birds/10 km (10.38; 0.35–27.8; eight different roadside counts, total of 429 km) (from CSN 23, 34, 41). Winter census in areas N of Hawkes Bay, 21 June to 12 July 1975: 2.90 birds/10 km (n=229 birds in 790 km); S of Hawkes Bay, 0.63 birds/10 km (n=62 birds in 984 km) (Ralph & Ralph 1977). Total of 63 counted on overhead wires in c. 1.6 km at Clevedon (CSN 1); 25 counted on overhead wires in c. 1.6 km at Oakleigh (CSN 22). Between Nelson and St Arnaud recorded at average of 1.06 birds/10 km (Taylor 1966). On Big Chicken I., eight pairs recorded in c. 125 ha (Skegg 1964). Numbers in NZ said to have increased in 20th century (Oliver).

Often killed or injured by cats (Thompson 1978; Hayes 1991; Dowling *et al.* 1994; Sitte & Jones 1994; NSW Bird Rep. 1993) and, rarely, by Foxes (Dowling *et al.* 1994); in NZ, eggs and nestlings sometimes taken by introduced Stoats *Mustela erminea* (CSN 7). Often evicted from nesting hollows by introduced species: Common Starlings *Sturnus vulgaris*, Common Mynas *Acridotheres tristis* and sparrows *Passer* (Guthrie-Smith 1910; Gannon 1932; Stead 1932; Favaloro 1942; Hermes 1985; Moon 1991). Sometimes killed by vehicles (e.g. Disney & Fullagar 1978; O'Donnell 1981; Anon. 1982). Often fly into windows (e.g. Sedgwick 1973; Thompson 1978; Hayes 1991; Taplin 1991; Sitte & Jones 1994). Attracted to lights in buildings (Hogan 1925; Makin 1961) and often collide with lighthouses (Stokes 1983) or lights on ships (Campbell & White 1910); also collide with powerlines (Forshaw & Cooper 1985) and once with a clothesline (Lewis 1959). In NZ, formerly considered a nuisance for eating bees, damaging fruit in orchards (cherries, peaches), killing poultry, attacking cagebirds, and hunting trout fry or goldfish in fountains; were sometimes shot (Stead 1932; Oliver). On Lord Howe I., formerly shot, as said to kill poultry (Bassett Hull 1909). A few kept as cagebirds in NZ in late 19th century (Guthrie-Smith 1910; Phillipps 1948). Occasionally drown in drums of liquid (Lewis 1959; Parker 1971).

MOVEMENTS Two subspecies breed in HANZAB region. (1) **NOMINATE SANCTUS** breeds Aust.; partly migratory, patterns

of movements differing between n. and s. Aust. In n. Aust., resident or present throughout year in many areas, with maximum numbers Apr.–May and Aug.–Sept., suggesting passage of s. breeding birds through n. Aust.; more common at coastal sites in winter (Crawford 1972; Boekel 1980; Draffan *et al.* 1983; Forshaw & Cooper 1985; McKean 1985; Anon. 1990; Curl 1998; Serventy & Whittell; Aust. Atlas; Storr 7, 11, 16). Recorded on passage in Torres Str., going N, Mar.–May, and S in Sept. (Tubb 1945; Draffan *et al.* 1983; Ingram *et al.* 1986). In s. Aust., most of population migratory, breeding spring–summer and moving N in late summer–autumn to spend non-breeding season in coastal n. Aust., Indonesia and New Guinea region; vagrant Micronesia. Appear to migrate on broad front through Timor and Arafura Seas, Torres Str. and Coral Sea (Serventy 1951; Keast 1957; Storr & Johnstone 1979; Smythies 1981; Draffan *et al.* 1983; Coates 1985; Forshaw & Cooper 1985; White & Bruce 1986; Pratt *et al.* 1987; Fry *et al.* 1992; Serventy & Whittell; Storr 7, 19). In s. Aust., some may migrate through high country of ACT and s. NSW, but migration more noticeable along coast and at sea (Hogan 1925; Gall & Longmore 1978; Taylor 1983; Strahan); in s. WA, some appear to move via small offshore islands (Ford 1965; Storr 28). During winter, some birds remain in s. Aust., along coast, particularly intertidal zones, and less commonly inland, usually near wetlands, where food supply may be more consistent (Keast 1957; Morris *et al.* 1981, 1990; Forshaw & Cooper 1985; McAllan & Bruce 1988; Bamford 1990; Aust. Atlas; Strahan). Times of departure and return vary from year to year (e.g. Cohn 1926; Schmidt 1978; Saunders & Ingram 1995; Vic. and NSW Bird Reps), and patterns of movements in areas where birds on passage and resident populations occur can be difficult to determine, especially in N (Kikkawa *et al.* 1965; Hoskin 1991). Pattern of movement to and from Tas. not clear (Butler 1907; Mathews; Aust. Atlas; Tas. Bird Reps). (2) **SUBSPECIES VAGANS** breeds NZ and on Kermadec, Lord Howe and Norfolk Is; altitudinal migrant in NZ, moving to coast during winter; though also said to be resident with some altitudinal movement; resident on offshore islands (Sorensen 1964; Edgar *et al.* 1965; Turbott 1967; Forshaw & Cooper 1985; Fry *et al.* 1992; Aust. Atlas).

Banding in Aust., PNG and NZ shows that birds return to same breeding sites each year and to same non-breeding areas in successive seasons (Anon. 1971, 1972, 1990; Bedggood 1972; Bell 1981; Mordue 1981; Fitzgerald *et al.* 1986; Burrows 1990; Saunders & de Rebeira 1993; Curl 1998). Adverse weather can influence movements (e.g. Hogan 1925; Hindwood 1935b; Talbot 1986; Tolhurst 1987); drought can cause birds to leave areas temporarily (Beruldsen 1972). On passage, sometimes collide with structures such as lighthouses or boats (Campbell & White 1910; Makin 1961; Ingram *et al.* 1986). Timing of migration may differ between adults and young: young believed to arrive in New Guinea before adults (Bell 1981) and, of 98 captured while moving N through Torres Str., Mar.–Apr. 1979, all were young birds (Draffan *et al.* 1983). Subspecies described separately below.

NOMINATE SANCTUS: Departure S. Aust. s. QLD: Move N from SE, Mar.–Apr. (Lord 1933, 1939, 1953; Liddy 1963; Whitmore *et al.* 1983; Leach & Hines 1987), but as early as Jan.–Feb. (Lord 1939, 1956; Morgan 1972; Whitmore *et al.* 1983; Leach & Hines 1987; Templeton 1992), rarely in May (Lord 1943). Late record, 1 June at Emu Vale (Anon. 1930). NSW: Most leave late Feb. or early Mar. (Anon. 1930; Hyem 1936; Chisholm 1938; Heron 1973a; Baldwin 1975), but can leave as early as early Feb. or as late as early Apr. (Le Souëf & MacPherson 1920; Morse 1922; Gilbert 1935, 1939; Anon.

1969, 1974; Pratt 1971, 1972; Morris 1975, 1986; Gibson 1977; Gall & Longmore 1978; Marchant 1979; McFarland 1984; Leishman 1994; North; NSW and ACT Bird Reps). Rare reports of earlier or later departures: as early as 30 Dec. (NSW Bird Rep. 1978); Jan. (Althofer 1934; Gregory-Smith 1991); and 10 Jan. (NSW Bird Rep. 1983); one, assumed to have been on passage, found dead at Broken Hill 28 Apr. (NSW Bird Rep. 1981). **vic.:** Most leave Feb. to mid-Mar., some before end of Jan. (Ingle 1910; Belcher 1914; Rowley 1961; Bedggood 1970; Aston & Balmford 1978; Loyn 1980; Thomas & Wheeler 1983; Vic. Atlas); rarely as late as Apr.–May (Graham 1903; Campbell 1905, 1937; Bedggood 1972, 1980; Fleming 1976; Aston & Balmford 1978; Vic. Atlas; Vic. Bird Reps). **sa:** Usually leave Feb. to mid-Mar., some Jan. (Ford & Paton 1976; Rix 1976; Paton & Paton 1980; Ashton 1985; SA Bird Reps). **s. wa:** Leave SW, including Wheatbelt, by early Mar. (Sedgwick 1986, 1988; Serventy & Whittell), most leaving late Jan.–Feb. (Carter 1903; Anon. 1930; Sedgwick 1940a,c, 1942, 1986, 1988; Serventy 1948; Heron 1970; Masters & Milhinch 1974; Talbot 1986; Saunders & Wooller 1988; Saunders & Ingram 1995); rarely, in some districts, as early as late Dec. (Saunders & Ingram 1995); some as late as Apr.–May (van Delft 1988; Ashton *et al.* 1996; Serventy & Whittell; Storr 27). May move N through islands off Dongara–Lancelin, Mar.–May (Ford 1965). **N. Aust. n. wa:** At Broome, passage begins Apr. (Collins 1995). **NT:** Most move N from inland areas, Mar.–May (Parker 1971; Storr 7); at Banka Banka Stn, c. 100 km N of Tennant Ck, last seen in Feb., but pair seen nearby, 27 Mar. (Jarman 1944). In Darwin, evidence of passage, probably to Indonesia, Mar.–May (Crawford 1972; H.A.F. Thompson & D.K. Goodfellow). **N. QLD:** On passage ne. C. York Pen., Mar.–May (MacGillivray 1914, 1918; Beruldsen 1990); in ne. highlands, irregular passage migrant, at Mt Spec and Paluma, Feb.–May; and on coast round Townsville, Apr. (Griffin 1974, 1995; Garnett & Cox 1983). On Willis I., Coral Sea, c. 100 birds recorded on passage on 5 and 12 Apr., stopping on island during day (Hogan 1925; Serventy 1959). Specimens collected Booby I., Mar.–May (Kinghorn 1928; Stokes 1983; Ingram *et al.* 1986); young birds pass through Torres Str., Mar.–Apr. (Draffan *et al.* 1983).

Non-breeding Mostly n. Aust., Indonesia, as far W as s. Sumatra, E to New Guinea and e. Solomon Is, and N to n. Borneo and Talaud Is; rarely, Micronesia (Serventy 1951; Keast 1957; Storr & Johnstone 1979; Smythies 1981; Draffan *et al.* 1983; Coates 1985; Forshaw & Cooper 1985; White & Bruce 1986; Pratt *et al.* 1987; Fry *et al.* 1992; Serventy & Whittell; Storr 7, 19). In BORNEO, a few records: Feb., June, Aug.–Sept. (Smythies 1981). **INDONESIA:** Recorded late Mar. to late Nov., with record from Ambon in Jan. (Mees 1982); recorded s. Sumatra, early June to late Aug. (van Marle & Voous 1988); some birds from WA said to migrate to Timor (Serventy & Whittell); in Sulawesi, Lesser Sundas and Moluccas from Mar.–Dec., mainly Apr. to late Oct. (White & Bruce 1986; Coates *et al.* 1997). **NEW GUINEA:** Generally, recorded mid-Mar. to early or mid-Oct. (Rand 1942; Bulmer 1966; Bell 1967, 1971, 1981; Heron 1975; Aust. Atlas); suggested young birds arrive first (Bell 1981). Begin arriving s. coast, mid- to late Feb., but as early as late Jan.; at Daru I., sudden influx late Mar. (Coates 1985). In N, normally arrive mid-Mar., and common by early Apr.; at Lou I., Manus, departed late Aug. (Silva 1966); and at Jacquinot Bay, New Britain, numbers fell in late June (Keast 1957); at Wahgi Valley in Apr.–May (Rand & Gilliard 1967). Generally leave late Sept. to late Oct. but, rarely, a few remain during breeding season. (Coates 1985); two males, Balim R.,

Irian Jaya, 14 Dec. (Rand 1942). **SOLOMON IS:** Migrants from Aust. augment resident breeding population (Forshaw & Cooper 1985). Aust. migrants recorded Feb.–Mar. to Sept.–Oct. (Mayr 1945); recorded New Georgia, July–Aug. (Blaber 1990), and on Santa Isabel, Apr.–Sept. (Webb 1992). **N. Aust. n. wa:** Appear to be present year-round on coast N from Carnarvon including n. Kimberley Div., and inland, in lesser numbers, N of 28°S (Officer 1974; Howard 1983; Aust. Atlas). **NT:** Considered resident at Keep R. NP and at Victoria R. Downs, where also some seasonal movement (Boekel 1980; McKean 1985). Found throughout year in parts of Top End, though some local movements between habitats (Curl 1998). Rare in Darwin except on passage, but some remain in hinterland all year (Crawford 1972; H.A.F. Thompson & D.K. Goodfellow). At Adelaide R., thought to be winter visitor (Rhodes 1944). Some winter records in central Aust. (Aust. Atlas) **n. QLD:** Large numbers recorded n. coast mainly s. migrants, e.g. recorded C. York Pen., mid-Mar. to early Aug. at Edward R. and on islands in Torres Str. (Draffan *et al.* 1983; Garnett & Bredl 1985) but become progressively fewer farther S (Storr 19); in coastal NE (e.g. Cairns, Townsville and Mackay), mostly present in winter till Oct. (Alexander 1926; Wieneke 1988, 1992; Nielsen 1996; *contra* Hopkins 1948; Lavery & Hopkins 1963), but presence of passage migrants and local breeding birds make precise timing unclear (e.g. Garnett & Cox 1983; Nielsen 1996). Round Atherton, recorded Feb.–Dec., and small numbers breed (Bravery 1970; Nielsen 1996). Present all year in many areas, with numbers seasonally supplemented by passage migrants or breeding birds: e.g. Mt Isa, Innisfail, Three Is and One Tree Is (where may move between islands) (Barnard 1925; Liddy 1963; Gill 1970; Domm & Recher 1973; Horton 1975; Jones 1981; McLean 1993). In Richmond area, unusually absent in winter 1906 (Berney 1906). **S. Aust.** Some remain in winter. **sw. QLD:** Present all year in Idalia NP (Sharp & Sewell 1995). **se. QLD:** Present all year in many areas, with numbers seasonally supplemented by passage migrants or breeding birds, e.g. Rockhampton, Daringa, Maryborough, Cooloola NP and Redcliffe Pen. (e.g. Mayo 1931a; Roberts & Ingram 1976; Longmore 1978; Dawson *et al.* 1991; Bielewicz & Bielewicz 1996). **NSW:** Some present May–Aug., particularly on coast N from Sydney (Gilbert 1935; Keast 1944; Anon. 1968b; Cooper 1971; Haines 1971; Morris 1975; Gibson 1977; Morris *et al.* 1981, 1990; Gosper 1983; McAllan & Bruce 1988; NSW Bird Reps; Aust Atlas); rarely, on s. coast (NSW Bird Rep. 1983). On Hunter R. estuary, maximum numbers late summer to early winter; at Richmond R., most numerous, Feb.–Sept. (Gosper 1981), but some birds considered sedentary (Gosper & Gosper 1996). Inland, a few present during winter; possibly stay in mild seasons in areas where prey abnormally abundant (Irby 1933; Hobbs 1961, 1976; Costello 1981; NSW Bird Reps 1973, 1974, 1984). **vic.:**

Plate 53

Sacred Kingfisher *Todiramphus sanctus* (page 1178)

NOMINATE SANCTUS: 1 Adult male (fresh); 2 Adult male (worn);

3 Adult female (fresh); 4 Adult female (worn); 5 Juvenile;

6 Immature female; 7, 8 Adult male

SUBSPECIES VAGANS: 9 Adult male

Collared Kingfisher *Todiramphus chloris* (page 1201)

SUBSPECIES SORDIDUS: 10 Adult male; 11 Adult female; 12 Juvenile

male; 13 Immature female; 14, 15 Adult male

SUBSPECIES PILBARA: 16 Adult male; 17 Adult female

A few present May–Aug. (Wheeler 1967b); on coast and inland (e.g. Bedggood 1970, 1973; Roberts 1975; Vic. Bird Reps; P.S. Lansley & M. O'Brien). **TAS.:** Most records autumn and winter, usually singly and nearly always on coast; can remain for some months; more rarely occur spring and summer (Butler 1907; Mathews; Aust. Atlas; Tas. Bird Reps). **SA:** Formerly occurred round Adelaide in small numbers in June–July, but now transient only (Brummitt 1933; Jarman 1935; Paton 1976; SA Bird Rep. 1977–81); once at Salisbury, 17 July (Anon. 1951). Some present Lefevre Pen. (Winslet & Winslet 1987); Kangaroo I. (Baxter & Berris 1995); and round Port Wakefield in mangroves (Taylor 1987). Records in Apr.–Sept. at Willunga (Symon 1946) seem at odds with what is considered summer seasonality in that area, though sometimes seen in winter (Ashton 1985). **S. WA:** Present year-round on some coastal islands in SW, such as Rottneest I. (Warham 1955; Saunders & Wooller 1988; Saunders & de Rebeira 1993); occasionally winter in other areas (e.g. Sedgwick 1988; van Delft 1988; Bamford 1990; Saunders & Ingram 1995; Serventy & Whittell); several winter records from coastal habitats (Bamford 1990).

Return Appear to return to Aust. on broad front, from Timor Sea in W to Torres Str. and Coral Sea in E. Usually arrive n. Aust., Aug.–Oct., and s. Aust., Sept.–Oct. **N. Aust.** **N. WA:** On passage at Ashmore Reef, Timor Sea, and at Browse I. and Bedout I. during Oct. (Serventy 1951; Serventy & Whittell); pass through Fitzroy R., Kimberley Div., in Oct. (Whitlock 1925); possibly on passage inland from Shark Bay, Gascoyne Region, Aug.–Nov. (Storr 21). **NT:** Round Darwin, evidence of passage from Indonesia, Aug.–Sept. (Crawford 1972); set up territories widely in Top End during Sept. (Curl 1998). At Banka Banka Stn, arrived Dec., at start of wet season (Jarman 1944). Move S to central Aust. in Sept.–Nov. (Storr 7); first seen round Alice Springs, late Sept. (Parker 1971); some birds found there in Jan. in poor condition, and which later died; said to have been exhausted from adverse weather and extensive travel (Parker 1971; Chinner 1977); one reported 19 Aug. nearby (Cleland 1931). **N. QLD:** Pass S through Torres Str., Sept. (Tubb 1945; Draffan *et al.* 1983; Ingram *et al.* 1986). Arrive or pass through: Mt Isa in mid-Oct. (Liddy 1963); Cooktown, Sept.–Nov. (Storr 1953); near Townsville, Aug.–Nov. (Hopkins 1948; Griffin 1974, 1995; Garnett & Cox 1983). **S. migration** may proceed through Coral Sea and islands of Great Barrier Reef, from near Cairns S to Capricorn Grp, usually late Sept. to early Oct. (Campbell & White 1910; Hogan 1925; Serventy 1959; Makin 1961; Heatwole 1968; Qld Bird Rep. 1986); sometimes collide with lighthouses or boats at night (Campbell & White 1910; Makin 1961). **S. Aust.** **SE. QLD:** Usually arrive Sept., sometimes Aug. (Cohn 1926; Lord 1933, 1943, 1956; Morgan 1972; Perkins 1973; Whitmore *et al.* 1983; Templeton 1992) or Oct. (Liddy 1963; Perkins 1973); once as early as 22 July, near Marburg (Leach & Hines 1987). Numbers increase in spring round Rockhampton (Longmore 1978), presumably passage migrants passing S; one recorded on ship N of Fraser I., 16 Sept. (Alexander 1926). **NSW:** Usually become abundant in second half of Sept. (Chenery & Morgan 1920; Cohn 1926; Anon. 1930; Sullivan 1931; Irby 1933; Gilbert 1935; Hyem 1936; Chisholm 1938; Heron 1973a; Morris 1975; Morris *et al.* 1981; NSW Bird Reps), with many still arriving in Oct., mainly in first three weeks, e.g. in ACT, 1964–83, most arrivals in first week Oct. (Morse 1922; Anon. 1930, 1969; Althofer 1934; Hobbs 1961; Rowe 1970; Wilson 1970; Gibson 1977; Gall & Longmore 1978; Marchant 1979, 1981; Taylor 1985; Morris 1986; Leishman 1994; NSW Bird Reps; ACT Bird Rep. 1986–87). However, return rarely as late as Nov. at some sites (Heron

1973b; McFarland 1984), and as early as Aug. (Perkins 1973; Gregory-Smith 1991; North; NSW Bird Rep. 1982); once on 10 Aug. in SW during flood year (Hobbs 1961). One July record in ACT in mild season may have been early return, as many migrant species returned early that year (ACT Atlas); June record at Inverell (Baldwin 1975) possibly wintering bird rather than early return. **VIC.:** Most arrive Oct., with some in Sept. (Campbell 1903, 1937; Graham 1903; Ingle 1910; Belcher 1914; Howe 1928; Anon. 1930; Shanks 1949; McEvey 1965; Thomas 1969; Bedggood 1972; Fleming 1976; Loyn 1980; Vic. Atlas; Vic. Bird Reps). Return recorded late Aug. in some years (e.g. Bedggood 1970, 1980), or as late as mid-Nov. (Graham 1903; Anon. 1930). **SA:** Usually arrive Sept. to early Oct., sometimes Aug. (White 1908; Mellor 1921; Ford & Paton 1976; Rix 1976; Paton & Paton 1980; SA Bird Reps); can be late Oct. (e.g. Sutton 1923). At Aldinga–Sellicks Beach, mostly return in Nov. (Ashton 1985). **S. WA:** Arrive SW, Sept.–Oct. (Carter 1924; Cohn 1926; Anon. 1930; Jenkins 1931; Sedgwick 1940a,c, 1942, 1949, 1986, 1988; Serventy 1948; Robinson 1949; Heron 1970; Masters & Milhinch 1974; Saunders & Wooller 1988; van Delft 1988; Saunders & de Rebeira 1993; Saunders & Ingram 1995; Storr 27), rarely, Aug. (Heron 1970; Sedgwick 1988). Arrive SE Interior in Oct. (Storr 26) and possibly also at Eyre and Nullarbor Plain, where few records (Vervest 1990; Ashton *et al.* 1996); islands of Houtman Abrolhos, 5 Aug. and 27 Oct. (Storr 24).

Breeding Most of population in mainland Aust., from Oct. to Feb. or early Mar. (cf. Breeding). In Kakadu NP, NT, banded birds regularly sighted or recaptured in same or nearby territories in consecutive years (Curl 1998). A few stay in non-breeding grounds in Wallacea and New Guinea (Coates 1985; Coates *et al.* 1997).

SUBSPECIES VAGANS: **NZ** Partly migratory, birds breeding in forests to at least 700 m asl, Oct.–Jan., then moving to open country and estuaries at lower altitudes in autumn (Guthrie-Smith 1910; Taylor 1966; Turbott 1967; Ralph & Ralph 1977; Fry *et al.* 1992; *contra* Aust. Atlas). Seasonal movements primarily between habitats and secondarily altitudinal (Fitzgerald *et al.* 1986), e.g. some birds breed in forests of Orongorongo Valley, NI, at 120 m asl then move to coast for winter; movement probably related to changes in food supply (Fitzgerald *et al.* 1986). No direct evidence for N–S migration (Fitzgerald *et al.* 1986; *contra* Ralph & Ralph 1977). During Apr.–Sept., most of population on coast or in lowlands (usually <150 m asl), e.g. NI: Coromandel Pen., Clevedon, Te Atatu, Firth of Thames, Levin, Wanganui, Manawatu Estuary, and Porirua Harbour; SI: Nelson, Brooklands Lagoon near Christchurch, Waihopai R., Dunedin and Otago Pen. (Hayes 1989; CSN). On coast round Wellington, Apr.–Aug. (Secker 1951). Mean date of departure from Minginui, NI, 21 Feb. (8–27 Feb.; 15 years) (St Paul 1977). Few or no autumn–winter records at elevated forested sites, such as Mt Bruce, NI, and Reefton, Upper Taramakau R. and Hokitika Gorge in SI, though in some areas of NI, stay at higher elevations, up to 370 m asl, in winter, e.g. Rotorua and L. Taupo (Taylor 1966; Dawson *et al.* 1978; Bull 1983; CSN). Return to elevated areas in spring. At Minginui, NI, mean date of return, 15 Sept. (11–21 Sept.; 15 years) (St Paul 1977). In Nelson area, SI, gradual movement up valleys in spring, arriving Howard Valley mid-Oct. (Taylor 1966). In some other areas at this time (e.g. Southland, SI), disperse over inland farmland, as well as staying on coast; round Manawatu R., NI, thought more abundant inland (Gill 1977; CSN 19 Suppl.). Move from coast round Wellington, after Aug., to nearby forest areas to breed (Secker

1951). May have high fidelity to breeding site: in Wellington area five banded birds recaptured in following breeding season assumed to have returned there after winter absence (Fitzgerald *et al.* 1986). Foraging range up to 2 km in Wellington area (Moon 1989). KERMADEC IS: Considered resident on Raoul I. (Sorensen 1964; Edgar *et al.* 1965). LORD HOWE and NORFOLK IS: Sedentary (Aust. Atlas).

Banding NOMINATE *SANCTUS*: Of 3937 banded in Aust. and New Guinea, 1953–96, 485 recoveries (12.3%): 473 (97.5%) <10 km from banding site; 5 (1.0%) 10–49 km; 7 (1.4%) ≥100 km. Long-distance recoveries: Kenmore, se. Qld, to Wewak E., Sepik Province, PNG (2825 km, 337°, 3 months, Dec.; 1+); Munghorn Gap, NSW, to Trobriand Is, PNG (2639 km, 3°, 19 months, Jan; 1+); Chain of Ponds, SA, to Tuart Hill, WA (2165 km, 272°, 39 months, Dec.; P); Norahville, NSW, to Agincourt Reef, Qld (1991 km, 341°, 38 months, Nov.; 1+); Guildford, NSW, to Ayr, Qld (1623 km, 346°, 3 months, Mar.; J); Scheyville, NSW, to between Ayr and Home Hill, Qld (1588 km, 346°, 46 months, Dec.; 1+, M); Beerburum, Qld, to Mackay, Qld (770 km, 328°, 42 months, Mar.; J). Longest lived, 96 months (Anon. 1968a, 1970; ABBBS). Of 40 banded at Pulau Dua, w. Java, Indonesia, 1968–70, recoveries were few and near banding site, with one 'repeat record after one year' (McClure & Leelavit 1972; McClure 1974).

SUBSPECIES VAGANS: Of 127 banded in NZ, 1964–73, 15 recoveries (11.8%) (Robertson 1974). One recovered 11 km from banding site near Wellington (Fitzgerald *et al.* 1986).

FOOD A wide variety of animals, mainly insects, but also earthworms, freshwater crayfish, crabs, spiders, fish, frogs and tadpoles, lizards, birds and their young, and small rodents.

Behaviour Most prey taken from ground, in wide variety of habitats, usually in open; also forage from foliage or flowers of trees and shrubs, or from trunks of trees; or aerially; and plunge-dive in shallow water for aquatic prey (for further details of habitats, and references, see Habitat). **SEARCH METHODS**: When hunting, sit quietly on perches looking for prey (see Habitat). When prey sighted, dart suddenly in direct descending flight, catch prey, sometimes without landing, and usually return to perch, often same one (Hutton & Drummond 1904; Stead 1932; Hindwood 1935a; Forshaw & Cooper 1985; Hayes 1989; Moon 1989; Oliver). **ATTACK METHODS**: (1) **SALLY**: Fly from perch, attack prey, and usually return to same perch; either by: (1A) **SALLY-POUNCE**, where land briefly at end of sally to take prey, such as grasshoppers, beetles or lizards, usually from ground (Alexander 1926; Stead 1932; Hindwood 1935a; Hodgkins 1949; Disney & Smithers 1972; Forshaw & Cooper 1985; Ford *et al.* 1986; Baxter 1989; Moon 1989; Hutton 1991; Curl 1998); or (1B) **SALLY-STRIKE**, where attack without landing, when taking prey such as insects and small birds, from foliage, flowers and trunks of trees and shrubs (Chisholm 1924; Stead 1932; Disney & Smithers 1972; St Paul 1977; Child 1984; Moon 1989; Wagener 1995; Curl 1998), from surface of mudflats (Hayes 1989; Moon 1989), or from air (Scammell 1922; Lewis 1959; Fleming 1976; O'Donnell 1981; Grant 1983). (2) **PLUNGE**: Dive to catch prey in water, either by: (2A) **SURFACE-PLUNGE**, where catch prey from surface, without submerging (Hutton & Drummond 1904; Chisholm 1934; Austin 1950; O'Donnell 1981; Baxter 1989; Moon 1991; Oliver; Tas. Bird Rep. 9, 15); or (2B) **SHALLOW-PLUNGE**, when fully but shallowly submerge to catch prey (Butler 1907; Carter 1924; Tindale 1930; Stead 1932; Selby 1952; Moon 1989). At Opoutere, NI, dived from perches 2 m high into water 0.5–1.0 m deep, catching fish (CSN 22); in n. NI, dived for fish in small ponds; duration of

dive, from time bird left perch to return to perch, only 1.5 s; fish when caught not speared but gripped crosswise with bill (Moon 1989). (3) **PROBE**: Usually into rotten wood for insect larvae (Hutton 1991). In study in Kakadu NP, NT, typical height of perches 3–5 m (54%; 0–12 m; 59); of 133 observations of foraging, 43.6% by sally-pounces to ground (including 5.6% without landing), 55.8% by sally-strikes (40.2% from foliage, 7.8% from tree-trunks, 7.8% sallying into air), and 0.6% by shallow-plunging into water. Success rate for foraging dives 81% (n=89 attempts) (Curl 1998). At Brooklands Lagoon, NZ, fed on crabs *Helice crassa* on mudflats at low tide; flew 2–60 m from perches to catch crabs, without touching mud; success rate 96.6% (n=101 attempts); after catching prey, often returned to same perch (46% of 44 observations) (Hayes 1989). **KLEPTOPARASITISM**: Sometimes steal prey, such as earthworms, from other birds (Acres 1960; CSN 28, 37). **FOOD-HANDLING**: Carry prey crosswise in bill (Moon 1989). Most prey battered against perch (Hayes 1989, 1991; Moon 1991, Stead; Oliver). Food swallowed whole and indigestible parts regurgitated later as pellets (Moon 1989; Oliver); discard chellae of crabs and wings from large insects (Moon 1989). **ADAPTATIONS FOR FEEDING**: Eyesight said to be good, and that birds able to locate prey up to c. 90 m away (Hutton & Drummond 1904; Moon 1989).

Young Fed by both parents; food usually similar to that of adults (Hayes 1991). In n. NI, NZ, birds nesting close to marine habitats occupied restricted foraging range, and most food brought to nestlings consisted of crabs and fish; those nesting at inland sites had to forage over much wider areas; at one nest, parents flew c. 2 km to nearest salt water to bring crabs to nest (Moon 1989). Size of prey fed to young varies: at Kakadu NP, larger prey items fed only to older or larger chicks (Curl 1998); in n. NI, NZ, during first day after hatching, young fed small insects and spiders but as young grew older, also fed larger prey such as cicadas, dragonflies, crayfish, and small fish, and, just before fledging, fed lizards, large fish and whole mice (Moon 1989); in Canterbury, NZ, no significant difference in size of food fed to young of different ages (Hayes 1991). In Canterbury, nestlings fed throughout day; every 20 min during first week, increasing to every 10 min in last 2 weeks before fledging (Hayes 1991). See Breeding for further details.

Adults Near ARMIDALE, NSW (Obs.; ** often eaten; * occasionally eaten; Ford 1985): **SPIDERS***. **INSECTS**: Unident. larv.*; Coleoptera**; Scarabaeidae**; Diptera*; Chrysomelidae*; Hymenoptera: Formicidae*. **REPTILES**: Lizards**.

In E. NSW (contents of nine stomachs; Rose 1973, 1997): **INSECTS**: Coleoptera 67% freq.: Curculionidae 22; Scarabaeidae 11; Hemiptera 11; Cicadidae 11; Hymenoptera: Formicidae 11; Lepidoptera 11; Orthoptera 33; Acrididae 11. **REPTILES**: Scincidae 33.

In KAKADU NP, NT (114 items, direct obs.; Curl 1998): 86% of prey invertebrates, 14% vertebrates. **SPIDERS**: 6.1% no. obs. **CHILOPODS**: Centipedes 4.4%. **INSECTS** 75% (Orthoptera: Acrididae; Tettigoniidae; Coleoptera; Hemiptera: Cicadidae; Odonata; Lepidoptera). **AMPHIBIANS**: Frogs 3.5%. **REPTILES** 10.5% (Scincidae: *Carlia amax*; Agamidae).

Young Single nests at MT COLAH (30 Dec.–7 Jan. 1985) and FORSTER (1–18 Jan. 1987), e. NSW (>115 items; from direct obs. of prey brought to nests, remains below nests, regurgitated pellets, and stomach of one nestling; Rose 1997): **SPIDERS**: Unident. 2.6% no.; Idiopidae: *Dyarcycops fuscipes* 0.8; Lycosidae 1.7. **INSECTS**: Blattodea: Blattidae: Unident. 0.8; *Oniscosoma* 0.8; Coleoptera: Unident. 14.8; Carabidae 0.8; Cerambycidae 0.8; Chrysomelidae: *Paropsis* 0.8; Curculionidae

1.7; Elateridae 1.7; Scarabaeidae: Unident. 9.6; *Anoplognathus viriditarsus* 7.8; *A. porosus* 0.8; *Xylotrupes gideon* 0.8; Hemiptera: Cicadidae: Unident. 2.6; *Cicadetta labeulata* 6.1; Hymenoptera: Formicidae 4.3; *Camponotus* 1.7; Lepidoptera: moth 1.7; Mantodea: Mantidae 1.7; Odonata 1.7; Orthoptera: Unident. 9.6; Gryllidae 1.7; Gryllotalpidae 0.8; Stenopelmatidae 2.6. REPTILES: Agamidae: *Amphibolurus muricatus* 0.8; Scincidae: Unident. 15.6; *Bassiana duperreyi* 0.8; *Lampropholis* 0.8.

At ORONGORONGO VALLEY, NZ (653 items from pellets of nestlings of four nests; Fitzgerald et al. 1986): ANNELIDS: Oligochaetes 0.15% no. items. SPIDERS: Araneidae 1.2; Dipluridae: *Porrhothele antipodiana* 0.6; Agelenidae: *Cambridgea foliata* 1.2. CRUSTACEANS: Decapods: Cambaridae: *Paranephrops planifrons* 0.76. INSECTS: Blattodea: Blattidae: *Parcellipsidion* 0.15; Coleoptera: Carabidae: Unident. 1.5; *Holcaspis vagepunctata* 0.15; *Mecodema simplex* 0.9; *Megadromus vigil* 2.3; *Plocamostethus planiusculus* 3.6; Cerambycidae: *Hexatricha pulverulenta* 1.0; Curculionidae: *Platyomida hochstetteri* 0.15; *Psepholax barbifrons* 0.15; Elateridae: *Corymbites megops* 0.15; *Geranus lineicollis* 0.15; *Ochrosternus zealandicus* 0.3; *Thoramus foveolatus* 0.45; *T. wakefieldi* 0.15; Lucanidae: *Dorcus novaeseelandiae* 0.3; *Lissotes reticulatus* 3.9; Scarabaeidae: *Odontria magnum* 0.9; *O. picipes* 0.15; *Pyronota festiva* 0.15; *Stethaspis longicornis* 6.9; Tenebrionidae: *Artystona erichsoni* 0.15; *Uloma tenebrionoides* 0.15; Diptera: Tabanidae: *Dasybasis opla* 0.15; *D. transversa* 0.15; *Scaptia adrel* 0.15; Hemiptera: Cicadidae: *Amphipsalta zelandica* 47.9; *Kikihia* 1.4; *K. scutellaris* 0.76; Hymenoptera: Aphidae: *Apis mellifera* 1.0; Ichneumonidae: *Certonotus fractinervis* 0.3; Pompilidae: *Salius monachus* 0.15; *S. wakefieldi* 0.15; Lepidoptera: Hepialidae: Unident. 0.15; *Trioxycanus enysii* 0.15; Odonata: Corduliidae: *Procordulia smithii* 0.15; *Uropetala carovei* 11.8; Orthoptera: Stenopelmatidae: *Hemideina crassidens* 0.76; Phasmatodea: Phasmatidae: *Acanthoxyla* 1.5. REPTILES: Gekkonidae: Unident. 0.45; *Hoplodactylus granulatus* 1.2; Scincidae: Unident. 0.6; *Leiopisma* 0.45. BIRDS: Rifleman *Acanthisitta chloris* 0.76; Grey Warbler *Gerygone igata* 0.3; Silvereye *Zosterops lateralis* 0.15. MAMMALS: Muridae: House Mouse *Mus domesticus* 1.2.

At CANTERBURY, NZ (156 items; from remains at one nest and remains and direct obs. of prey brought to three nests; Hayes 1991): ANNELIDS 2.0 % no. items. MOLLUSCS: Gastropods: Helicidae: *Helix aspersa* 0.5. SPIDERS: Araneidae 0.5. CRUSTACEANS: Decapods: Grapsidae: *Helice crassa* 40.0. INSECTS: Coleoptera: Carabidae: *Megadromus antarcticus* 13.0; Hemiptera 0.5; Lepidoptera: Noctuidae 3.0; Odonata 0.5. REPTILES: Scincidae: *Leiopisma* 40.0.

At TAUMARUNUI, NZ (61 items from 14 nestling pellets; O'Donnell 1981): CRUSTACEANS: Decapoda: Parastacidae: crayfish (30–70 mm long) 10.0% no. items. INSECTS: Coleoptera: Carabidae (25) 13.0; Cerambycidae: *Hexatricha pulverulenta* (20) 8.0; Elateridae: *Thoramus laevithorax* (15) 8.0; Scarabaeidae: *Stethaspis longicornis* (25) 28.0; Hemiptera: Cicadidae: *Amphipsalta cingulata* (40) 5.0; Odonata: Corduliidae: *Procordulia grayii* (55) 3.0.

Other records — Aust. adults ANNELIDS³⁵. SPIDERS^{4,15,39,42}. CHILOPODS⁴². CRUSTACEANS³⁵: Branchiopods: Notostracans: *Triops*¹⁵; Decapods: Brachyura^{17,21,26,34,37,41}: *Sesama*²⁶; *Micritysis longicarpus*²⁶; *M. plahycheles*⁴⁷; Parastacidae³⁸: *Parathelphusa*^{39,40,42}; Isopods: *Ligia australiensis*^{20,22,24}. INSECTS ads, larv^{8,16,23,28,38,41}: Coleoptera^{14,17,35,38,39,41}: Carabidae⁶; Cerambycidae⁴²; Chrysomelidae: *Paropsis*¹⁵; Curculionidae³⁹; Elateridae^{15,42}; Hydrophilidae: *Hydrophilus*¹⁵; Scarabaeidae^{2,10,42}; *Anoplognathus*^{9,21,24,46}; Tenebrionidae: *Pterohelaeus*¹⁵; Dermaptera⁴²; Diptera: Calliphoridae: *Calliphora augur*³⁶; Tachinidae: *Rutilia*¹⁵;

Hemiptera: Cicadidae^{10,47}; *Psaltoda moerens*^{36,46}; Pentatomidae⁴²; Hymenoptera¹⁵: Formicidae^{24,25,37,42}; Lepidoptera: ads²⁴, larv.^{5,15,19,23,30,37,42}; Mantodea³⁷; Neuroptera: larv.¹⁵; Odonata^{15,18,30}. Aeshnidae: *Austrophlebia*²⁴; *Telephlebia*²⁴; Orthoptera^{3,5,7,11,19,21,31,34,35,37,38,41}; Acrididae⁴²; *Goniaea*²⁴; *Nomadacris guttulosa*²⁹; Gryllidae³⁰; Tettigoniidae²⁴. FISH^{1,6,10,13,18,21,28,35,38,44,45}: Cyprinidae: *Carassius auratus*³⁰; Poeciliidae: *Gambusia*³⁰. AMPHIBIANS: Frogs^{33,38}, tadpoles⁸. REPTILES: Lizards^{2,9,24,37,38,42,46}; Scincidae³¹: *Lampropholis delicata*⁴⁷; *L. guichenoti*^{26,47}; *Leiopisma entrecaesteauxii*⁴²; *Sphenomorphus tympanum*³²; Snakes³⁷. MAMMALS: Rodents: Muridae: House Mouse^{29,43}. **Aust. nestlings and dependent young** ANNELIDS: Unident. worms⁴⁶. SPIDERS^{12,31,46}. Idiopidae: *Dyarcycops fuscipes*⁴⁶. CRUSTACEANS: Decapods: Parastacidae¹². CHILOPODS³¹. INSECTS: Coleoptera^{12,26,46}; Cerambycidae⁴⁶; Chrysomelidae²⁴; Curculionidae²⁶; Geotrupidae²⁶; Scarabaeidae^{24,26,46}; *Anoplognathus porosus*^{26,46}; *A. viriditarsis*⁴⁶; *Xylotrupes gideon*⁴⁶; Hemiptera: Cicadidae⁴⁶; *Psaltoda moerens*⁴⁶; *Thopha saccata*²⁴; Hymenoptera: Formicidae⁴⁶; *Camponotus*⁴⁶; Lepidoptera⁴⁶; Mantodea: Mantidae⁴⁶; Neuroptera⁴⁶; Odonata^{12,46}; Orthoptera^{12,31,46}; Acrididae: *Chortoicetes terminifera*¹³; Gryllidae⁴⁶; Gryllo-talpidae⁴⁶. FISH¹². AMPHIBIANS: Frogs^{12,46}, tadpoles³⁸. REPTILES: Lizards^{27,46}; Scincidae^{26,31,46}; Snakes³¹.

REFERENCES: ¹ Butler 1907; Mathews ² 1909a, ³ 1909b; ⁴ Iredale 1910; ⁵ Cleland 1911; ⁶ Barnard 1914; ⁷ White 1917; ⁸ Carter 1924; Chisholm ⁹ 1924, ¹⁰ 1934; ¹¹ MacGillivray 1926; ¹² Lang 1929; ¹³ Tindale 1930; ¹⁴ Smith 1931; ¹⁵ McKeown 1934; ¹⁶ Bonnin 1935; ¹⁷ Hindwood 1935a; ¹⁸ Selby 1952; ¹⁹ Watson 1955; ²⁰ Haines 1968; ²¹ Eastman 1970; ²² Rose 1971; ²³ Disney & Smithers 1972; ²⁴ Rouse ²⁴ 1973, ²⁵ 1974, ²⁶ 1997; ²⁷ BFNC 1976; ²⁸ Fleming 1976; ²⁹ Hobbs 1976; ³⁰ Vestjens 1977; ³¹ Milhinch 1980; ³² Conole 1981; ³³ Jones 1981; ³⁴ Forshaw & Cooper 1985; ³⁵ Hutton 1991; ³⁶ Lepshi 1993; ³⁷ Gould; ³⁸ North; ³⁹ Cleland; ⁴⁰ Lea & Gray; ⁴¹ Hall; ⁴² FAB; ⁴³ NSW Bird Rep. 1974; Tas. Bird Rep. ⁴⁴ 9, ⁴⁵ 15; ⁴⁶ NRS; ⁴⁷ T. Saunders.

Other records — NZ adults ANNELIDS: Lumbricidae^{4,7,8,9,12,15}. MOLLUSCS⁴. SPIDERS^{4,14}: Pisauridae: *Dolomedes minor*¹⁴. CRUSTACEANS⁹: Decapods: Brachyura: crabs^{5,6,12,15,20,21}; Parastacidae^{4,5,15,20}: *Paranephrops planifrons*¹⁴. INSECTS^{3,10,12}: Coleoptera^{1,4,9,14}; Cerambycidae: *Prionopsis reticularis*¹⁴; Curculionidae¹⁴; Elateridae: *Metablax acutipennis*¹⁴; *Thoramus wakefieldi*¹⁴; Diptera⁹: Calliphoridae⁷; Hemiptera: Cicadidae^{5,11,12,15,20}; Hymenoptera¹; Lepidoptera: ad. moths and butterflies⁴; Odonata^{12,14,15,20}; Petaluridae: *Uropetala carovei*¹⁴; Orthoptera: grasshoppers^{3,9,20}; Gryllidae^{3,20}; Tettigoniidae^{11,15}; Phasmatodea: Phasmatidae: *Acanthoxyla prasina*¹⁴. FISH^{1,4,5,9,12,15,20,21}: Cyprinidae²⁰; Salmonidae⁹. AMPHIBIANS: Tadpoles^{7,11}. REPTILES: Lizards^{3,4,10,20}; *Mocooa zealandica*⁹; *M. ornata*⁹; Scincidae^{6,7,11,12,15,20}; *Leiopisma*¹⁴. BIRDS: Small ads, young^{1,3,10,11,13}; Pukeko *Porphyrio melanotus* chicks¹⁶; Silvereye *Zosterops lateralis*^{12,18,19,20,21}; European Goldfinch *Carduelis carduelis*¹⁷; Common Redpoll *C. flammea*⁴; House Sparrow *Passer domesticus*⁹. MAMMALS: Rodents: Muridae: House Mouse^{1,4,9,10,11,12,20}. **NZ nestlings and dependent fledgelings** ANNELIDS: Oligochaetes¹². SPIDERS¹². CRUSTACEANS: Decapods¹²: Parastacidae¹². INSECTS ads, larv.¹²: Hemiptera: Cicadidae^{2,12}; Hymenoptera¹³; Odonata^{2,12,13}; Orthoptera². FISH¹². AMPHIBIANS: tadpoles¹². REPTILES: Lizards^{2,12}. MAMMALS: Muridae: House Mouse^{9,12}.

REFERENCES: ¹ Hutton & Drummond 1904; ² Guthrie-Smith 1910; ³ Moncrieff 1929; ⁴ Stead 1932; ⁵ Hodgkins 1949; ⁶ Bigwood 1950; ⁷ Lewis 1959; ⁸ Acres 1960; ⁹ Turbott 1967; ¹⁰ St Paul 1977; Moon

¹¹1979, ¹²1989, ¹³1991; ¹⁴O'Donnell 1981; ¹⁵Moon & Lockley 1982; ¹⁶Onley 1982; ¹⁷Grant 1983; ¹⁸Child 1984; ¹⁹Wagener 1995; ²⁰Oliver; ²¹CSN 22.

Intake At Brooklands Lagoon, NZ, mean handling time for crabs, before swallowing 11.0 s (5.98; 77), larger crabs taking longer; mean size of crabs eaten (carapace width), 9.1 mm (3.07; 3–15), but preferred larger, particularly male, crabs with carapace width >10 mm (Hayes 1989). At Orongorongo Valley, NZ, food offered to nestling 10–90 mm long with modal length 10–20 mm (Fitzgerald *et al.* 1986).

SOCIAL ORGANIZATION Detailed study in Kakadu NP, NT (Curl 1998), but otherwise poorly known, though many anecdotal observations. Pairs considered normal social unit (Fry *et al.* 1992). Throughout range, form pairs during breeding season, and mostly seen in pairs at this time (e.g. Gosper 1981; Aumann 1991; Curl 1998; Hall), though sometimes seen singly (e.g. Crawford 1972); some sightings of single birds are possibly of off-duty member of breeding pair (Forshaw & Cooper 1985). Sometimes seen in small groups at end of breeding season and in non-breeding season; probably family groups or birds on passage (e.g. Crawford 1972; Gosper 1981; Aumann 1991). In non-breeding season, more often seen singly than in breeding season (e.g. Hindwood 1935a; Hobbs 1961; Gosper 1981; Forshaw & Cooper 1985; Aumann 1991; Gould; Serventy & Whittell; NSW Bird Reps), but still also seen in pairs (e.g. Gosper 1983; North) or small groups (e.g. Crawford 1972; Gosper 1981; Aumann 1991); pairs may stay together in non-breeding season (see Bonds). On passage, seen singly or in groups, in some cases family parties (Gilbert 1935); on Willis I., once more than 100 present for 1 day, with all gone next morning (Hogan 1925); in NZ, may sometimes move in flocks (Moncrieff 1929). In extralimital wintering areas, sometimes at high densities, e.g. at one site in PNG, in May, 80–100 birds in 4–5 ha (Forshaw & Cooper 1985). In AUST., usually seen singly or in twos, probably often pairs (e.g. Whitlock 1939; Ford 1965; Storr 1965; Morris 1975; Gibson 1977; Longmore 1978; Costello 1981; Morris *et al.* 1990; Hall; Storr 11); sometimes seen in groups of three or more (Longmore 1978; Gosper 1981; Hall; NRS). In NZ, often seen singly, especially when birds hunting from overhead wires (e.g. Hodgkins 1949; Ralph & Ralph 1977; CSN), but often recorded at quite high densities (Buller 1888; Bell & Brathwaite 1964; Ralph & Ralph 1977; CSN 1, 22; also see Distribution), e.g. 20–22 birds within radius of 200 m (CSN 38), 27 in c. 0.8 ha (Stead 1932); sometimes in small parties, e.g. of eight (Potts 1870) or >25 (Oliver); rarely, in flocks (St Paul 1977). In Aust., said that often seen in company of Forest Kingfisher (Eastman 1970).

Bonds Probably breed as monogamous pair. In Kakadu NP, maintain bond for consecutive breeding attempts within same season and sometimes for consecutive years (Curl 1998). Possibly long-term monogamous, with pair migrating and staying together year-round (Fry *et al.* 1992); some evidence of maintenance of pairs during winter (Guthrie-Smith 1910; Bell 1981; Gosper 1983; Forshaw & Cooper 1985; North); but often seen singly in non-breeding season (see above). In Aust., nesting starts soon after birds arrive in breeding areas (Lord 1956); in WA, one pair chose nest-hole and laid just over 2 weeks later (Milhinch 1980). In Kakadu NP, active calling and displays by males began Aug.–Sept., with allofeeding or mating observed from 16 Sept. to 7 Jan. (1987–93); pairs often re-nest soon after first brood has fledged (Curl 1998). In NZ, mating displays seen for c. 1 month before nesting starts (Falla *et al.*

1979); courting seen in late Aug.–Sept. and late Nov. (Potts 1873; Hayes 1991); near Nelson, NZ, have formed pairs by late Sept. (Taylor 1966). No evidence of auxiliaries or of cooperative breeding as in some related kingfishers; usually occur at a sufficiently high density that new bonds form quickly if one bird dies (Curl 1998). Once, presumed female of pair disappeared (probably died) during incubation and presumed male appeared to remain faithful to site: at first he called constantly, leaving nest-area for long periods and seeming to desert eggs; after 1 week, returned to nest with potential mate and, after this, old eggs were found broken on ground; after another 2 weeks or so, potential mate had left; in another 2 weeks, second potential mate arrived but only for a few days; c. 1 week later, again two birds attended nest before it was finally deserted (Lord 1953). If one adult disappears at nestling stage, other parent can raise young to fledging (Hayes 1991; NRS). **Parental care** Both members of pair incubate, feed nestlings and fledgelings, and defend nest (e.g. Potts 1873; Guthrie-Smith 1910; White 1922; Lang 1929; Stidolph 1925; Lord 1953; Eastman 1970; Merton 1970; Frauca 1973; Rix 1976; Milhinch 1980; McKean 1985; Shephard 1989; Hayes 1991; Hutton 1991; Saunders & de Rebeira 1993; Curl 1998; North; Mathews; NRS). After fledging, young typically remain near nest at Kakadu NP (Curl 1998) but may follow parents to feeding areas (Potts 1873; Campbell; Mathews); siblings stay close when being fed and roost together (Fracua 1973), though often in different trees (D.A. Curl). Parents feed young for 7–10 days after fledging, then young begin to catch food for themselves (Moon & Lockley 1982; Hayes 1991). In Canterbury, NZ, groups of 4–5 young from two or three families commonly feed together when young several weeks old and becoming independent (Hayes 1991). At Kakadu NP, young can continue to beg for longer than this, but young, especially from first broods, may be chased away, usually by male (Curl 1998); young of first broods seem to disperse before or during start of next breeding attempt (Fracua 1973), and captive adult male became aggressive toward young c. 1 month after they fledged (Goudswaard 1990). Suggested that fledgelings of single broods or second broods stay with parents in nesting area until they all disperse (Buller 1888; Stead 1932; Lord 1953), or, in NZ, till start of next breeding season (Guthrie-Smith 1910). However, in Kakadu NP, different distribution of adults and young at end of breeding season and on passage suggests that they may disperse independently or that young may stay in or near natal territory after adults have left (Curl 1998).

Breeding dispersion As solitary, territorial pairs. At Kakadu NP, typically nest as pairs, exploiting seasonal flush of food, in contiguous, mutually exclusive and all-purpose territories (Curl 1998). Some estimates of breeding density: 19 pairs in 16–20 ha near Brisbane along with six or seven other breeding pairs of other species of kingfishers (Miller 1937); usually 12–30 birds every 1.6 km along Leichhardt R., Qld, during breeding season (Liddy 1963); three or four pairs in 19 ha near Moruya, NSW (Marchant 1979); 0.2–1.7 birds/10 ha in Canberra during breeding season (Bell 1980); five nests in c. 0.4 km near Eltham, Vic. (Sharland 1929); 13 birds, including at least three pairs and two nests, in 2 km of Goulburn R., Vic. (McCulloch 1993); three nests within radius of 3.2 km of Yarra R., Vic. (Lang 1929); 25 breeding pairs on Rottneest I., WA (Saunders & de Rebeira 1993). On Big Chicken I., NZ, eight pairs in c. 125 ha (Skegg 1964).

When nesting in termite mounds, each mound has only one active burrow, but a second pair may excavate a new burrow after first pair has finished nesting; number of breeding pairs

said to be related to number of termite nests in area (Frauca 1973). Pairs may excavate many holes before choosing final nest (e.g. Potts 1873; Stead 1932; Frauca 1967). Some sites used year after year (e.g. Guthrie-Smith 1910; Stead 1932; Roberts 1941; Chaffer 1946; Fitzgerald *et al.* 1986; Mathews), some for nearly 20 or so years (Lord 1956; Oliver), and one termite mound said to be used for 30 years (Eastman 1970); at least sometimes used by same birds each year (Moon & Lockley 1982; Curl 1998). May breed near other species of kingfishers (see Breeding). **Territories** Territorial during breeding season, pairs aggressively defending nest-site (e.g. Ford 1918; St Paul 1977; Forshaw & Cooper 1985; Saunders & Wooller 1988; Hayes 1991; Saunders & de Rebeira 1993); exclude conspecifics, and other adults rarely seen near nest (Forshaw & Cooper 1985; Hayes 1991; NRS) though will tolerate intruding juveniles (Hayes 1991). Also attack many other species of birds near nest (see Relations within family group). Nest-holes sometimes usurped by other nesting species such as sparrows *Passer*, even if they have been repeatedly threatened by Kingfishers (Gannon 1932; Favaloro 1942); Kingfishers evicted from nests by Common Mynas (Moon 1991) and Common Starlings (Guthrie-Smith 1910; Stead 1932). Nest said to be focus of territory (Frauca 1973) but may also defend surrounding foraging area (Saunders & Wooller 1988); at Kakadu NP, defend all-purpose territories, of c. 4 ha in eucalypt woodland (Curl 1998); one pair defended nearby feeding ground on beach, attacking even trespassing waders (MacGillivray 1928); in another area, no disputes seen among hunting birds (Frauca 1973). Near Bundaberg, territories established at start of breeding season, and few territorial disputes by time birds have laid (Frauca 1973). Some evidence that migratory birds return to same territories each year, and that some birds that do not migrate remain within their territories all year (Saunders & Wooller 1988; Saunders & de Rebeira 1993). However, at Kakadu NP, do not remain in territories all year (Curl 1998). During winter, sometimes appear territorial (Bell 1981), defending feeding areas (Aust. Atlas), but at one feeding area in NZ, birds not aggressive, sometimes sitting side by side (Hayes 1989). After fledging, young noted roosting near nest (Frauca 1973) and being fed c. 700 m from nest (Rix 1976); but also said to stay near nest for only a few days (Milhinch 1980). Near Wellington, NZ, likely that haunts of single birds range over 'several miles' (Wodzicki 1946). In or near feeding areas, said to often have favourite branches for extracting prey or perching (Potts 1871; Hindwood 1935a).

Roosting At night, in trees, amid foliage (Frauca 1967; Curl 1998; Hall; J.M. Peter); sometimes on powerlines (CSN 31); some sites used repeatedly (Potts 1871; Curl 1998). After hatching, both parents roost outside nest (Guthrie-Smith 1910). Sometimes roost as family or small group (Frauca 1973; Hall). Some crepuscular activity (Curl 1998; Strahan). Migration said to occur commonly at night, when birds in flight may call (Irby 1933; Gilbert 1935; Hindwood 1935b; Forshaw & Cooper 1985). Calling at night also noted by others (see Voice). Seen resting on ships or boats (e.g. Alexander 1926; Barrett 1910; Campbell). During daylight, seen resting and preening high in tree for 0.5 h (McCulloch 1993); regularly rest on foraging perches during afternoon (Curl 1998).

SOCIAL BEHAVIOUR Detailed study in Kakadu NP, NT (Curl 1998) and study of calls of wild birds taken into captivity (Sitte & Jones 1994). Rather easy to observe at start of breeding season because inhabit rather open habitats, calling males and nest displays highly visible, and birds usually hunt from exposed

perches; during breeding season, presence often indicated by call (e.g. Buller 1888; Taylor 1966; Ralph & Ralph 1977; Forshaw & Cooper 1985; Saunders & de Rebeira 1993; Curl 1998; Campbell; North; Mathews). However, generally more wary than other kingfishers, females especially so (Eastman 1970; Curl 1998), and difficult to observe during incubation period, when shy and quiet (Moon & Lockley 1982; Marchant 1992) and in non-breeding season (Curl 1998). When perched, occasionally bob head or move it backward and forward; or flick tail, more quickly when excited (Stead 1932; Forshaw & Cooper 1985; Curl 1998); when landing on perch, often stretch body out and point tail down and forward under perch (Stead 1932). Bathing similar to that of other kingfishers and Laughing Kookaburra: dive repeatedly from same perch into water, beating wings a few times in water, then flying off or returning to perch to preen (Vellenga 1965; Boekel 1979; Falla *et al.* 1979; McCulloch 1993; Curl 1998). In captivity, often dive into shallow water (Shephard 1989).

Agonistic behaviour Very aggressive when breeding (see Territories, and Parental anti-predator strategies). Calling from prominent perches said to be territorial (Saunders & Wooller 1988; Keast 1993; Sitte & Jones 1994) and to deter intruding conspecifics from nesting area (Saunders & de Rebeira 1993); Staccato Calls given regularly by male throughout breeding season, often in response to calls of neighbours (Keast 1993; Curl 1998); birds, apparently breeding, are often seen calling loudly (e.g. Potts 1873; Le Souëf & MacPherson 1920; Saunders & Wooller 1988; Oliver); sometimes call monotonously all day (Keast 1985b; Hutton 1991) but more so in morning (Keast 1993). On arrival at start of breeding season: birds call as fly between trees, using more fluttering and direct flight than seen at other times (Stead 1932); as pair sets up territory, often give Staccato Call and occasionally dispute with conspecifics (Taylor 1966; Frauca 1973; Marchant 1992); at one site in NZ, single bird arrived in area, called often and appeared to fly round edge of territory (CSN 22). Said usually to be silent when not breeding or during winter, but in some areas continue to call sporadically throughout year (Iredale 1910; Stead 1932; Merton 1970; Falla *et al.* 1979; Forshaw & Cooper 1985; Saunders & de Rebeira 1993; Oliver; Serventy & Whittell). In presence of conspecifics or other threats, male often adopts **AGONISTIC POSTURE** on perch: plumage sleeked, body upright, head craned toward threat, and folded wings brought forward, exposing rump, and held stiffly and vertically with wing-tips pointing down and carpal joints near neck of bird; tail often flicked up and down (Curl 1998). Both sexes dive-bomb wide range of intruders, including ground-foraging birds, people and predators as well as conspecifics, typically giving Attack Screech on passing over head of intruder (Curl 1998). Intruding conspecifics chased out of territory, usually by male (Hayes 1991; Saunders & de Rebeira 1993; Curl 1998; NRS). **Fighting** At Kakadu NP, particularly at start of breeding season, male may fly at rival on perch, both birds locking bills on contact and then parachuting toward ground, with wings partly outstretched, sometimes hitting ground; both soon fly up to nearby perch (Curl 1998). In captivity, quiet and non-aggressive (Shephard 1989); when male introduced to group with resident male, both gave Scream Whistle (Sitte & Jones 1994). Often mobbed by other birds, e.g. Common Blackbirds *Turdus merula*, Song Thrushes *T. philomelos*, Grey Fantails *Rhipidura fuliginosa*, Leaden Flycatchers *Myiagra rubecula*, Grey Warblers and Common Chaffinches *Fringilla coelebs* (Chisholm 1934; Jones 1937; Acres 1960; Child 1984; CSN 42). **Alarm** At times, fairly confiding when approached by people, but if sitting in exposed position may fly

to shelter (Forshaw & Cooper 1985); more wary than other kingfishers (Curl 1998); on Kermadec Is, unapproachable, and more retiring than on mainland NZ (Merton 1970). May bite when handled by people or captured by cats (Buller 1888); or scream and give **THREAT POSTURE**: ruffle feathers, particularly of head, spread wings and open bill. With increasing threat, scream more often. When handled, stop calling after a few minutes but maintain Threat Posture (Sitte & Jones 1994). When mist-netted or when handled, may roll on back and remain motionless (Frauca 1967).

Sexual behaviour At start of breeding season males very vocal, often giving Staccato Call incessantly to advertise presence and location both to mates and rivals (Curl 1998). Before nesting begins, chasing and other sexual displays accompanied by loud Ascending Roll or Shriek (Buller 1888; Falla *et al.* 1979; Moon & Lockley 1982). Some birds may be paired on return to breeding area. Call when excavating nests or inspecting sites (e.g. Potts 1873; Stidolph 1925); in captivity, mates seem to communicate with quiet calls (Goudswaard 1990). In Kakadu NP, NT, active calling and Nest Displays by males begin Aug.–Sept., with courtship feeding and copulation observed from 16 Sept. to 7 Jan. (1987–93), with pairs often re-nesting soon after first brood has fledged. **NEST DISPLAYS**: Most obvious feature of start of breeding season: males perch opposite potential nest (e.g. 3–6 m away) and fly to and from it with dipping flight and giving Judder call in flight and Click on landing at nest and back at perch. May dive repeatedly in quick succession, initiating excavation of potential nest, especially if female sighted or heard nearby. If female lands near male, one or both may give Ascending Roll, often repeatedly. Male will often continue Nest Displays till female joins in; they may then alternate dives at nest-hole. If excavation of hole begins in earnest, female usually appears to do more work, and male's visits to nest are noisier and appear to be more for show. Pair may investigate several nest-sites over many days before settling on suitable nest. Ritualized diving at nest-like marks on trunks observed in juvenile males at end of breeding season (cf. kookaburras, in which displays have become ritualized as part of territorial encounters) (Curl 1998). When mate disappeared, one presumed male called constantly and, for rest of breeding season, appeared to return spasmodically to nest-site with prospective mates and both would call as they attended to nest, but did not bond (Lord 1953). **Courtship feeding** Begins before laying, at same time as Nest Displays begin; male feeds female (Potts 1873; Milhinch 1980; Curl 1998); also seen during incubation (Oliver; NRS) and after young fledge (Hayes 1991). Male approaches female calling loudly and holding food in bill; both birds make purring noise and move toward each other, then male gives food to female; after feeding may then face each other in ritual (Milhinch 1980). At first, female continues to forage actively and gives Chew (food-begging) calls only occasionally (Curl 1998); closer to laying date, female does less foraging and seems to perch quietly in nest-tree waiting to be fed, sometimes giving Chew call (Milhinch 1980; Curl 1998); one female continually begged at feeding grounds when feeding alongside several birds (Potts 1873); in final 1–2 days before laying, female may follow male around to be fed (Curl 1998). Male may give single Staccato Call and female may give Descending Shriek to locate each other; Ascending Roll calls may be given when close together (Curl 1998). If female incubating, male arrives outside nest-hole with prey, calls to female and female flies out to receive item (Hayes 1991; NRS), though once at Kakadu NP, on first day of incubation, female did not leave nest when male was outside offering food (Curl

1998). **Allopreening** Not observed (D.A. Curl), though once male observed caressing female with bill (Potts 1873). **Copulation** Copulation seen while nest being prepared (NRS), 1–2 weeks before laying (Milhinch 1980), and when with nestlings (Hayes 1991). Usually preceded by courtship feeding (NRS), sometimes before female has swallowed food, though it appears that female will only accept male when she has received several food items in succession (Curl 1998); one male gave female four items in 1.5 h before mating with her (Hayes 1991). Male sidles along branch to female, and, if receptive, female crouches low and horizontal, and male hops onto her back; usually lasts for no more than a few seconds. Often followed by preening (Curl 1998), or birds fly off in different directions (Hayes 1991).

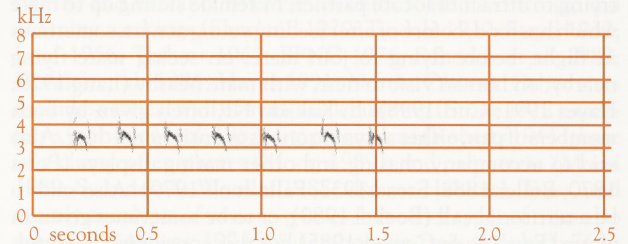
Relations within family groups Both adults feed nestlings and fledgelings (Rix 1976; Hayes 1991; Curl 1998). Nestlings beg with Food-begging Call (e.g. Tindale 1930; Stead 1932; Fitzgerald *et al.* 1986; Hayes 1991; Mathews) which becomes louder as adults near nest (Lang 1929; Frauca 1973), and which changes and is heard less often as chicks grow (Lang 1929; Tindale 1930; Sitte & Jones 1994). In first few days after hatching, young rest heads on ground except when being fed (Frauch 1973). Parent either enters nest with food in bill or stays outside nest, clinging with toes to entrance of burrow, and quickly puts head in hole, passes food to young, and then flies away (e.g. Stead 1932; Frauca 1973; North); one male perched with food in nearby tree for c. 1 h before delivering it (Lang 1929). Items fed whole (e.g. Moon 1991) and passed directly from bill of adult to that of young (Curl 1998). When young 1–2 weeks old, begin to come to entrance of burrow to be fed (Stead 1932; Frauca 1973; Oliver). As young grow, parents call more outside nest (Lang 1929). Fledgelings continue to beg with Food-begging Call and stay together to be fed by parents (Frauch 1973; Sitte & Jones 1994; NRS). Once, one or both members of pair with eggs fed young of Dollarbird *Eurystomus orientalis* nesting nearby, delivering food to young Dollarbird begging at entrance of its nest (van Bennekom 1975). At Kakadu NP, male seen to chase off begging fledgelings 1–2 weeks after fledging; suggested this done to remove begging stimulus from female, so that male can begin courtship feeding again (Curl 1998). **Anti-predator responses of young** When alarmed, stop uttering Food-begging Call (Stead 1932); may give prolonged rasping cry (Buller 1888). When nest examined, nearly fledged young huddled together (Lang 1929); heaviest chick often at back of nest, farthest from grasp of predator (Curl 1998). **Parental anti-predator strategies** Sit tightly on eggs, flushing at last moment or not at all; may not move when eggs inspected by people: may growl, bite hand or sit quietly; once off eggs, do not return quickly (Lang 1929; Sharland 1929; Lord 1953; NRS). May growl when in nest with nestlings (Buller 1888). However, also said to flush easily from nest (Guthrie-Smith 1910), and in Kakadu NP, always leave nest long before any intruder arrives (Curl 1998). Once off nest, in response to people near nest, one or both adults may call (often Shrieks, sometimes Ascending Roll), snap bill, and swoop at intruder, sometimes giving Shriek flying to or from target and usually giving Attack Screech over head of intruder; sometimes strike with bill (Potts 1873; Buller 1888; Guthrie-Smith 1910; Lang 1929; Tindale 1930; Stead 1932; Moon & Lockley 1982; Hayes 1991; Curl 1998; North; Mathews; Oliver; NRS). Also claimed that may lure people away with short distraction flights (Guthrie-Smith 1910). During breeding season very aggressive to all kinds of birds, including White-faced Herons *Egretta novaehollandiae*, South Island Pied Oystercatchers *Haematopus finschi*, Silver Gulls *Larus novaehollandiae*, Pacific Baza *Aviceda*

subcristata, Pallid Cuckoos *Cuculus pallidus*, Laughing and Blue-winged *Dacelo leachii* Kookaburras, Dollarbirds, Black-tailed Treecreepers *Climacteris melanura*, Blue-faced Honeyeaters *Entomyzon cyanotis*, Tuis *Prothemadera novaeseelandiae* (killed), Magpie-larks *Grallina cyanoleuca*, Common Starlings, Common Blackbirds, House Sparrows and Pied Currawongs *Strepera graculina* (Ford 1918; Lord 1953; Wheeler 1959; van Bennekom 1975; Forshaw & Cooper 1985; Hayes 1991; Oliver; NRS). One adult repeatedly flew at Laughing Kookaburra, striking it on neck (NRS). Savagely attack goannas, weasels, stoats, cats or dogs near nest (Tindale 1930; Selby 1952; St Paul 1977; Hayes 1991; Campbell; Oliver). Cats and dogs may be blinded (Oliver) or killed (Buller 1888). Most likely to attack just before (Hayes 1991) or just after (Curl 1998) chicks fledge; one pair was shy and cautious of people near nest till this time (Lang 1929).

VOICE Account compiled by D.A. Curl. Well known from field study in Kakadu NP, NT (Curl 1998; D.A. Curl) and study of wild birds brought into captivity for rehabilitation after injury (Sitte & Jones 1994). Saunders & Wooller (1988) and Sitte & Jones (1994) present sonagrams. Utter wide range of calls, unmusical and harsh (Potts 1871, 1873). Most prominent call is loud Staccato Call, given incessantly by males from exposed perches (Keast 1985b; Hutton 1991; Curl 1998). Short descending Shriek also given often, mostly by females, especially near nest; both members of pair give Ascending Roll, especially when near each other. Other calls also short and simple, ranging from soft to harsh. Many calls accompanied by seemingly agitated flicking of tail, synchronized with call (Curl 1998). In captivity, variety of Soft Calls recognized, audible to less than 5 m: short and long screeches, short and long whistles, and chirps; these calls rarely heard in the field (Curl 1998). **SEASONAL AND DAILY CALLING:** Call much during breeding season; can continue to call sporadically in non-breeding season (winter) (Potts 1871, 1873; Iredale 1910; Stead 1932; Merton 1970; Forshaw & Cooper 1985; Saunders & de Rebeira 1993; Oliver; Serventy & Whittell). At Moruya, NSW, noisy on arrival from migration, but fall silent with start of incubation (Marchant 1992). Staccato Calls given regularly by male throughout breeding season and when establishing territory; often given in response to calls of neighbours (Curl 1998). Sometimes call monotonously all day (Keast 1985b; Hutton 1991), but call more in morning (Keast 1993). In breeding season, first call often given on leaving roost well before sunrise; last call may be given on return to roost at dusk. In Kakadu NP, call more in morning (Keast 1993); most Staccato Calls given between dawn and late morning (c. 06:00 to 11:30) (Curl 1998); brief single calls often given at first light, as distinct from incessant repetitions after sunrise. Occasionally call at night, from perch or in flight (Buller 1888; Hindwood 1935b; Stidolph 1937; Boehm 1950; Campbell; North), though not regularly, and more likely with moonlight (Curl 1998); Soft Calls regularly heard at night from captive birds (Sitte & Jones 1994). **DIFFERENCES BETWEEN SEXES:** Most calls given by both sexes. Staccato Call given predominantly by male, and descending Shriek predominantly by female. **DUETTING:** Both members of pair may give Ascending Roll, sometimes as asynchronous and sometimes as antiphonal duet. **INDIVIDUAL VARIATION:** Individual variation in Screeches audible to human ear (Sitte & Jones 1994). Sonographic analysis of Staccato Calls allowed individuals to be distinguished, with call of individuals being stable over three breeding seasons (Saunders & Wooller 1988). Strong and consistent individual differences audible in several

features of Staccato Call, including quality of sound; such differences detectable both within and between populations (Curl 1998). **GEOGRAPHICAL VARIATION:** No studies, but calls from nw. WA said to be quite different from those elsewhere (North); and calls from sw. WA said to be slightly different (Le Souëf 1908). Suggested that birds on Kermadec Is noisier than those of main islands of NZ (Iredale 1910), probably reflecting differing population densities (D.A. Curl). **SIMILARITY TO OTHER SPECIES:** Staccato Call reminiscent of Staccato Call of Collared Kingfisher, though with more notes per call, and slightly less penetrating in quality and volume. Ascending Roll very similar to Ascending Roll of Collared Kingfisher. **NON-VOCAL SOUNDS:** Shaking of bill, done often after eating or preening, makes sound like soft castanets. When prey carried to perch, sounds of blows to kill or soften it often heard (Potts 1870). Loud *whack* when bill strikes wood when excavating nesting hollow (Stidolph 1925). Bill-snapping while swooping at intruders (Tindale 1930); in captivity, bill-snapping at intruders (Shephard 1989).

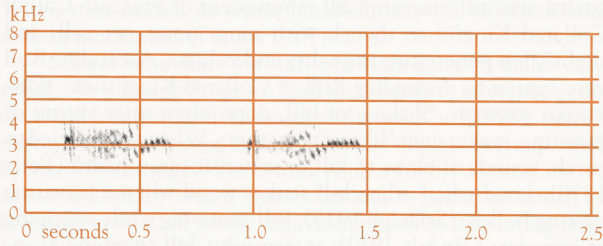
Adult STACCATO CALL (Kek Call in much literature): Short series of sharp forceful staccato notes of same pitch: *kek-kek-kek-kek...*, *tek-tek tek-tek...*, or *kee-kee-kee-kee...* (sonagram A), and with consistent interval between notes. In Kakadu NP, mean number of notes per call was 4.55 (0.92; 2–9; 676 individual calls from 39 birds) and modal number of notes per call ranged from three to seven, typically given at rate of c. 4 notes/s; calls varied in quality from slow, deliberate and methodical to fractious, squeaky or shrill; both rate and quality individually distinct. Individual male from Alice Springs, NT,



A F. van Gessel; Kakadu NP, Nov. 1985; P48

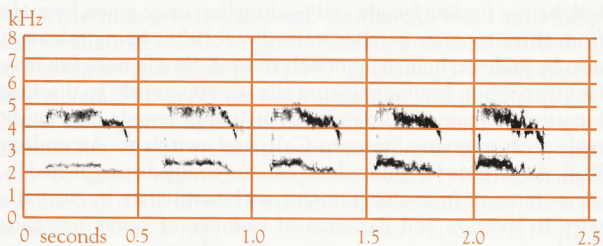
had mean 5.45 notes/call (0.6; 5–7; 20) (D.A. Curl). On Rotttnest I., WA, maximum frequency in a bout of Staccato Calls ranged from 3.04 to 4.31 kHz for different individuals; mean length of note ranged from 0.06 to 0.10 s; and mean interval between notes ranged from 0.14 to 0.19 s (Saunders & Wooller 1988). Given monotonously and for long periods in breeding season, especially at start of season, and occasionally at other times of year (e.g. Stead 1932; St Paul 1977; Mathews). Typically given by male from prominent high perch on bare exposed branch, with body upright and plumage sleeked. Rarely given in flight, but has been heard from males chasing intruders. Given during courtship by male landing on perch with food in bill, before finding female and feeding her; once given by male from three separate perches immediately after being released; also by male on human approach to nest. Single note *kek* may be given when leaving roosting site, or apparently to disclose location to mate. Before nesting, arrival of female may cause male to stop giving Staccato Call, and switch to Ascending Roll. At Kakadu NP, individuals can be readily distinguished by measurements from sonagrams, or, with familiarity, by ear; calls vary in average and variance of number of notes per call, emphasis on different notes, inter-call and inter-note intervals, and, particularly, note quality. **ASCENDING ROLL:** Rapid roll, trill

or churr *tucree-tucree-tucree...*, with pitch of *tu* falling, that of *cree* rising approximately to initial pitch of *tu*; overall effect one of rising inflection (Stead 1932; Curl 1998). Two *tucree* notes shown in sonagram **B**. Also described as low *cree-cree-cree...* (Stead 1932); soft *kee-kee-ee-ee* or *kree-kree-kree* (Forshaw & Cooper 1985; Goudswaard 1990); long, low-toned guttural *klue-e*, *klue-e*, *klue-e...* (Guthrie-Smith 1927); melodious crooning (Lang 1929); purring (Hayes 1991); soft thin *chirrrr* or



B F. van Gessel; Kakadu NP, Nov. 1985; P48

chewirrr (Marchant 1992); and churring (Sitte & Jones 1994). Notes typically repeated several times at intervals of *c.* 1 s, rarely, as many as 20 times. Given regularly by both sexes, usually from perches and especially during breeding season, characteristically as a sort of greeting when near mate or on coming together, and thus often heard near nest-site (Guthrie-Smith 1927; Forshaw & Cooper 1985; Goudswaard 1990; Curl 1998). Given by one or both sexes before courtship feeding or copulation, either when close together or by one bird when trying to attract or locate partner; by female sidling up to male which has food; before or after feeding young at nest, sometimes in flight; before flying to join mate; on seeing mate flying nearby; on human visit to nest, with mate nearby (Lang 1929; Hayes 1991; Curl 1998). In Kakadu NP, often given by both members of pair, either as synchronous or antiphonal duet. Also said to accompany chasing and other mating displays (Potts 1870; Buller 1888; Stead 1932; Falla *et al.* 1979). Also said to be a territorial call (Boekel 1980), or to be sometimes given in alarm (Forshaw & Cooper 1985) but this considered doubtful. Possibly related to Ascending Roll is 'rolling screech' reported from captivity. It is often repeated and varies greatly between individuals; may be uttered at any time of day, often just before feeding, while preening, or for no obvious reason, and may be involved in recognition of individuals within social groups (Sitte & Jones 1994). **SHRIEK**: Shrill descending strained scream or shriek, *c.* 0.3 s in duration; often repeated several times, typically at initial rate of *c.* 2/s, but repeated more rapidly as series continues (Curl 1998). Five repetitions shown in sonagram **C**, with Click at end. Also described as scream-whistle (Sitte & Jones 1994). Appears to be given mainly by female during breeding season. Uttered mostly when perched, but also often in flight. Primary function appears to be to attract attention or alert mate or young, but may also indicate location



C F. van Gessel; Kakadu NP, Nov. 1985; P48

to mate, alert conspecifics to threats, signify danger, and, in case of female, demand food from male. Other shrieks, with notes at same pitch, or ascending, may represent distinct calls, individual variation, or, at least in some cases, subtle differences in rate, quality and pitch of delivery reflecting different circumstances. Given when approaching or near nest, sometimes with food, or when landing after leaving nest; in response to Staccato Call from male; on landing near male; on seeing male fly or land nearby; on seeing male catch prey or land with food for potential courtship feeding, or preceding flight toward male; when 'being ignored' by male; when catching food on ground or in air; by male, before flying up to female at nest (rarely); on human approach to nest, to fledgelings or to adult; on release after banding; when diving at intruder (though Attack Screech [see below] more common in this situation), or more often when returning to perch after swooping at threat; on seeing other birds, e.g. Blue-winged Kookaburras, frogmouths and Sulphur-crested Cockatoos *Cacatua galerita*, flying nearby or emerging from nearby nest-hollows (Curl 1998). Other observations probably referring to same call: loud shriek when chasing intruding conspecific from nest (Hayes 1991); scream accompanying mating displays (Falla *et al.* 1979). **ATTACK SCREECH**: Sudden harsh *ktcha* when attacking predator, intruder (including people), or ground-foraging birds, such as Magpie-lark. Usually given after swift direct flight when just above head of other species (Curl 1998). Shrill or harsh scream when attacking person or animal near nest (Buller 1888; Stead 1932; St Paul 1977), or when surprised by person near nest (Guthrie-Smith 1927), probably same call. **PREDATION SCREAM**: Short harsh scream, sometimes repeated. Typically given when being handled by people or when caught by cats (Sitte & Jones 1994). Screech or scream, perhaps similar call, also given in flight when birds chasing one another (D.A. Curl). **JUDDER**: Soft vibrating, almost buzzing, series of harsh, low-pitched elements *chje-chje-chje-chje...*. Given in flight; most commonly by male diving to and from potential nest-hole, trying to attract female to nest (see Social Behaviour); occasionally given in flight when chasing another bird, or when diving for food. Almost always ends with Click on landing at nest or perch. Described as *chi-rit*, *cli-cli-cli* or low chuckling when about to enter nest (Potts 1873; Guthrie-Smith 1927; Lang 1929). **CLICK**: Sharp abrupt multiple click. Calls attention to bird landing on perch or at nest, though only audible if relatively near. Most often heard at end of Judder in pre-laying Nest Displays; may be given after series of Shrieks (as in sonagram C); sometimes given singly, as if to emphasize location of caller). **CHEW**: Soft and toneless (broad frequency) *chew-chew*. In Kakadu NP, functions as an adult begging or food call. Similar call given by female during week or weeks before laying, in anticipation of courtship feeding by male, and also by older nestlings and fledgelings. Sometimes given singly, but often repeated, especially if conspecific seen catching or approaching with food. Caller, particularly if fledgeling, usually difficult to locate as hidden amid foliage on perch higher than typically used when actively foraging. May also be given by bird with food in bill about to feed young (cf. Squawk of Blue-winged Kookaburra). **SOFT CALLS**: Soft calls rarely audible in field, but the following reported from Kakadu NP: soft *ter-tup*, possibly given before copulation; faint squeak on landing at nest before entering to brood young; squeak when one bird landed next to another (Curl 1998). Rest of description of Soft Calls from study by Sitte & Jones (1994) of wild birds brought into captivity, and refer to calls audible to less than 5 m. Three types: screech, whistle and chirp; uttered at night or at any time when in nest-box. Short

screeches typically of 2–3 single notes, with each note 0.08–0.16 s in duration; long screeches, up to 1 s in duration, consist of simple notes and screech elements in predictable sequence, with characteristic ascending note at start and end. Short whistle is single brief note of c. 0.04 s duration; long whistle typically consists of two descending whistles, with no intervening interval, the whole lasting 0.7–0.9 s. Chirp is 3–6 descending notes, each 0.08–0.12 s in duration, with interval between notes increasing from 0.02 s at beginning to 0.08 s at end. In addition, complex calls combine the screech, whistle and chirp calls and are mainly uttered at night, typically when roosting in nest-box; also occasionally uttered by day, always by birds in nest-box, but consisting only of screeches and whistles. Commonly used in interactions, typical patterns being: (1) short screech and long whistle from first bird, screech from second, modified long whistle from first; (2) short screech from one bird followed by phrase of chirps from the other; and (3) some complex vocal interactions, involving more than two birds, e.g. short screech, long screech with whistling quality, series of chirps, long whistle, and finally a short screech. **Other calls** Loud rasping call when wounded or caught in trap (Buller 1888). Low warning note on approach of intruder, before supposedly luring intruder away from nest by short decoy flight (Guthrie-Smith 1927). Low harsh grating *grrt* from female when about to excavate nest-hole (Marchant 1992). Vigorous purring call notes, possibly a mate-location call (Eastman 1970). Purring noise (Milhinch 1980). Quiet *kree* call in captivity (Goudswaard 1990). Growl (Buller 1888). Piping of Lang (1927) may refer to Staccato Call.

Young FOOD-BEGGING CALL of nestlings: harsh (Goudswaard 1990; Mathews); hissing rasp from older nestlings (Stead 1932). At one nest at Ivanhoe, Vic., chicks 1–2 days old said to take turns in maintaining continuous squawking for food, with all calling more loudly at approach of parent; at 5–6 days old, called incessantly, and call deeper and stronger; by 10 days old, nestlings much quieter; and by 12 days old, called only when parents approached with food; at 22 days old, silent except when handled (Lang 1929). At another nest, in NZ, nestlings reported to call from time sheaths of pin-feathers break (from c. 2 weeks old) (Stead 1932). **ALARM CALL:** Heard to give prolonged harsh rasping cry (Buller 1888). **FOOD-BEGGING CALL** of fledgelings: Described as buzzing and low-frequency pulses, composed of three sub-elements given in different combinations, single call typically lasting 0.8–1.4 s. Thought to develop into 'rolling screech' (Sitte & Jones 1994); see Ascending Roll.

BREEDING Detailed field study in Kakadu NP, NT (Curl 1998); 234 records in NRS to July 1997, most from s. Aust. (s. WA, 41 records; SA, 13; Vic., 48; and NSW, 115). Usually breed solitarily, within contiguous, mutually exclusive territories (Curl 1998). Some information from New Caledonia in Stokes (1980).

Season Throughout range, broadly Sept.–Mar. In s. AUST. (S of 23°S), Sept.–Feb., mostly Oct.–Feb. (Carter 1924; Lord 1939, 1953; Bedgood 1973; Masters & Milhinch 1974; Baldwin 1975; Milhinch 1980; Morris *et al.* 1981; North; Vic. Atlas; ACT Atlas; NRS), though many records of young in Mar. (NRS). Of 77 records of nests with eggs (NRS): Sept. (1, 1.3%), Oct. (11, 14.2%), Nov. (33, 42.9%), Dec. (22, 28.6%), Jan. (8, 10.4%) and Feb. (2, 2.6%); two main periods of laying, early Nov. to early Dec. and late Dec. to late Jan., indicating at least two broods per season. Young, mainly end of Nov. to Feb.; of 147 nests with young (NRS): Oct. (6, 4.1%), Nov. (24, 16.4%), Dec. (63, 42.8%), Jan. (40, 27.2%), Feb. (11, 7.5%) and Mar.

(3, 2.0%). In N. AUST., Sept.–Feb. (Frith & Davies 1961; Lavery *et al.* 1968; Bravery 1970; Gill 1970; Thompson 1984; Aumann 1991; Gosper & Gosper 1996; Curl 1998; Storr 7, 11, 16, 19). In Kakadu NP, males begin prominent calling, Sept.; Nest Displays common Sept.–Jan., especially Sept.–Oct.; courtship feeding and copulation, Sept.–Jan.; from observations at 21 nests, 1987–91: laying, 25 Oct. to 14 Jan.; hatching, 11 Nov. to 31 Jan.; fledging, 6 Dec. to 23 Feb. (Curl 1998). At Alice Springs, male observed giving Nest Display and female feeding a begging fledgeling in early Feb. (D.A. Curl). In NZ, Oct.–Jan. (Stead 1932; St Paul 1977) but mainly Nov.–Dec. (Turbott 1967; Oliver); mating observed early Sept., nest-building, Oct., and eggs laid Nov.–Jan. (Stead 1932); Moon (1989) reported breeding to take place mainly in Sept. or Oct., and second clutches to be laid as late as Feb. On NORFOLK I., breed Sept.–Dec. (Schodde *et al.* 1983; Hermes 1985). On KERMADEC IS, Oct.–Jan. (Iredale 1910).

In Kakadu NP, timing of breeding apparently consistent and unaffected by climate (Curl 1998). In sw. NSW, birds bred in large numbers during flood years, and did not breed in drought years (Hobbs 1961).

Site Nest in burrows; often in hollows of trees, either natural or, more usually, excavated or partly excavated by birds (Barnard 1914; Stidolph 1925; MacGillivray 1928; Sharland 1929; Stead 1932; Hindwood 1940; Chaffer 1946; Cooper 1948; Masters & Milhinch 1974; St Paul 1977; Moon 1989; Hayes 1991; Campbell; North; Oliver; Serventy & Whittell; CSN 42); also excavate burrows in arboreal termitaria (Le Souëf 1903; Barnard 1914; Lord 1953; Jones 1981; Campbell; North) and in soil of river banks, cliffs, roadside cuttings, and old mine workings (Sharland 1929; Tindale 1930; Stead 1932; Lord 1956; Turbott 1967; BFNC 1976; Schodde *et al.* 1983; Hermes *et al.* 1986; Hayes 1991; North; Oliver). Other sites include: vertical wall of mud-brick building (Stone 1912); tree-fens (Schodde *et al.* 1983); staghorn fens (Roberts 1941); base of a clump of epiphytes (Moon 1989); and palm trees (Moon 1989; Saunders & Wooller 1988; also see Habitat). Trees used mainly eucalypts of various species, but other types of trees also used. Of 214 nests: 107 (50%) in holes in trees (of which 76 in eucalypts and 31 in other trees, such as willows, melaleucas, banksias and *Angophora*); 55 (26%) in arboreal termitaria; 10 (5%) in cliffs and banks; 42 records (19%) in trees, but whether in tree-hollow or termitarium not specified (23 were eucalypts). Of 78 nests where position within tree recorded, 42 in main trunk, 36 in side branches (NRS). Tree-hollows used can be natural but more often excavated by members of breeding pair, which bore into rotten wood of dead trees or into broken limbs of live trees where wood is beginning to rot (MacGillivray 1928; NRS). Most nests in termitaria are freshly excavated each year, as termites usually seal holes after breeding finishes (NRS). Near Sydney, often nest in termitaria of *Nasutitermes walkeri* (Hindwood 1959; NRS). In Top End, NT, most nests inconspicuous and in eucalypts, especially Darwin Woollybutt *Eucalyptus miniata*, in small hollows formed where branches have broken off (typically 6–12 m above ground), and requiring varying degrees of excavation; rarely nest in arboreal termitaria (then typically *Nasutitermes graveolus*) (Curl 1998). Selection of nesting site seems to be determined by local availability, with some evidence of regional variability in preferences, such as tunnelling in dead trees in NI, NZ, predominant use of termite nests in central NSW, or selection of tree-hollows in WA, despite availability of alternative sites (St Paul 1977; Forshaw & Cooper 1985; Serventy & Whittell; see Habitat). Nests often re-used for many consecutive seasons, particularly for 2–3

seasons; often re-used for second brood of season (Guthrie-Smith 1910; Marchant 1992; Curl 1998; North; NRS); one particular nest-hole in a termitarium in se. Qld has been used constantly for more than 21 years (Lord 1956); one nest in NZ used for 17 years (Oliver). Often use old nests, or usurp occupied nests, of pardalotes *Pardalotus* (NRS); a few times seen to use only part of nest, leaving other part for pardalote to breed in (Chaffer 1946; Cooper 1961). Once nested in same termitarium as Laughing Kookaburra, each species nesting in its own burrow (Hindwood 1959); once in same arboreal termitarium as excavated in previous and subsequent years by Forest Kingfisher and Blue-winged Kookaburra (Curl 1998); another time nested near nesting Azure Kingfisher *Alcedo azurea* and neither pair interfered with other (Selby 1952). Observed nesting in same tree as Dollarbird (van Bennekom 1975), Noisy Miner *Manorina melanocephala* and Magpie-larks (North). Compete for nesting hollows with House Sparrows (Favaloro 1942); often displaced from excavated holes by Common Starlings (Guthrie-Smith 1910; Hermes 1985) and Common Mynas (Moon 1989, 1991). Nests sometimes infested with fly larvae (Diptera) or moth larvae (Lepidoptera) (Lord 1940). **MEASUREMENTS** (m): Height of nesting hole (all sites), 6.8 (5.5; 0.5–35.0; 215); depth below top of tree or bank, 7.6 (6.3; 0.2–32.0; 118). In eucalypt trees, height of nest-hole, 7.1 (6.2; 0.5–35.0; 99); depth below top of tree, 10.3 (7.4; 2.4–25.0; 42). In arboreal termitaria: height of nest-hole, 7.1 (5.2; 0.75–25.0; 55); depth below top of tree, 7.1 (5.2; 0.25–25.0; 34). In nests in banks or cliffs: height of nest-hole, 1.6 (0.9; 0.2–3.6; 10); depth below top of bank or cliff, 0.44 (0.3; 0.2–1.0; 7).

Nest, Materials An almost spherical chamber at end of usually inclined tunnel (Stead 1932; Moon 1989; Forshaw & Cooper 1985; NRS) excavated, when necessary, by both sexes. Usually no nesting material (Stead 1932; Serventy & Whittell; NRS), though there can be bits of wood or termitarium on floor of nest, along with debris from regurgitated pellets (Curl 1998; NRS): fish bones (North), insect exoskeletons and small bones of reptiles and amphibians (Curl 1998; North); or, on some coastal nests, exoskeleton of crustaceans (Turbott 1967). Claim that some have thin layer of dry grass (NRS) doubtful, but possibly material added earlier by other species. **EXCAVATION OF NEST:** From short distance (e.g. 25–35 m), fly straight at selected spot, striking with bill first and chipping off small pieces of wood or earth; members of pair work alternately; when a few centimetres have been removed, birds then perch on rim of hole and continue excavating with bills (Stidolph 1925; Stead 1932; Moon 1989; Oliver; NRS); bouts of digging usually last 6–10 min and are repeated four or more times each day (Moon 1989); at one nest, building pair made 17 working visits in 20 min (NRS). Tunnelling of a single nest-hole in trees may take c. 2 weeks (Lord 1953; Moon 1989; NRS), or a few days in clay banks (Moon 1989). Often excavate 5–6 holes before choosing one in which to lay (Stead 1932; Turbott 1967; NRS). **MEASUREMENTS** (cm): Mean length of tunnel, 23.0 (9.6; 7–40; 13) (NRS); 30 (Oliver); 90, but as short as 7 (Sharland 1929); diameter of entrance, 5.8 (3.0; 2.5–15.0; 12) (NRS); 5 (Tindale 1930); in Kakadu NP, rarely exceeds 5 (Curl 1998); diameter of chamber, 15 (Stead 1932; Oliver), 12–20 (NRS).

Eggs Spherical or slightly ovate or broadly elliptical; smooth and glossy; white (Forshaw & Cooper 1985; North; Oliver; Serventy & Whittell); those in termitaria often lose gloss (North). **MEASUREMENTS:** AUST.: 25.2 (1.05; 23.5–26.7; 22) × 21.2 (0.68; 19.6–22.3) (Le Souëf 1903, 1908; Campbell; North); in WAM, from one clutch, 27.4 (26.9–28.0; N not stated) × 22.2 (21.9–22.4) (Forshaw & Cooper 1985). NZ: 29.1

(2.1; 26–31; 6) × 23.2 (0.98; 22–25) (Stead 1932); 29.0 (1.2; 27.5–31.0; 5) × 23.5 (0.7; 22.5–24.5) (Oliver). **NORFOLK I.:** From one clutch, one, 28.9 × 23.2, larger than other four, 26.0 (25.3–26.5) × 21.0 (20.2–21.2) (Forshaw & Cooper 1985). **WEIGHTS:** In Kakadu NP, NT, two eggs in clutch of four, 5.9 and 5.8 (Curl 1998).

Clutch-size AUST.: Three to six; mostly four, but five common and three or six rare (Sandland & Orton 1922; Hindwood 1940; Lord 1953; Forshaw & Cooper 1985; Fry *et al.* 1992; Campbell; Serventy & Whittell). From NRS, mean 4.38: C/3 × 1, C/4 × 9, C/5 × 5, C/6 × 1. From Storr (7, 11, 16, 19, 28), mean 4.2: C/3 × 4, C/4 × 12, C/5 × 6, C/6 × 1. In Kakadu NP, rarely three, consistently four, and evidence of five eggs in one out of 30 nests, though fifth egg hatched 4–5 days after rest and possibly laid by another bird (Curl 1998). NZ: Four to seven, usually five (Stead 1932; Moon 1989; Oliver). **NORFOLK I.:** Three to six (Hermes 1985).

Laying In s. Aust., usually rear at least two broods (Chaffer 1946; Lord 1953; Marchant 1992; North, NRS). Eggs laid at intervals of 2 days for first two or three eggs and 1 day for rest of clutch (Oliver; NRS); also said to lay on successive days (Moon 1989); sometimes lay at irregular intervals, usually completing clutch within 7 days (NRS).

Incubation By both sexes, with regular change-overs (Eastman 1970; Frauca 1973; Milhinch 1980; Shephard 1989; Saunders & de Rebeira 1993; Curl 1998), *contra* suggestions that it is mainly (Forshaw & Cooper 1985; Fry *et al.* 1992; Oliver) or only (Lord 1953) by female. Incubating bird not fed in nest, and leaves eggs uncovered within nest-chamber at change-over; adults deposit regurgitated pellets in nest during incubation shifts (Curl 1998). Eggshells usually disappear from nest; said to be thrown out of nest by parents (Tindale 1930), though possibly removed in twilight at end of overnight shift, so difficult to observe (Curl 1998). **INCUBATION PERIOD:** 17–18 days (Forshaw & Cooper 1985; Fry *et al.* 1992; Campbell; Oliver); in one nest, 16–17 days (Milhinch 1980); in NT, typically 17 days from start of full-time incubation to first hatching (Curl 1998). Hatching almost synchronous; at two nests, three nestlings hatched on one day, and rest of clutch hatched in next day or two (NRS).

Young Altricial, nidicolous. At hatching, naked, pink and blind; weight c. 5 g (Curl 1998). Grow rapidly; bristles (first hint of pin-feathers) emerge on wings after c. 3 days; thereafter tracts of spiky feathers in pin emerge in waxy opaque sheaths over entire body and head, giving spiky appearance (Stead 1932; Curl 1998). Usually remain blind till weigh at least 30 g; maximum nestling weight recorded, 50.1 g; nestling weights tend to decrease during final week in nest as last feathers emerge from sheaths; may be heavier than adults on fledging (Curl 1998). **Parental care, Role of sexes** Young apparently not brooded. Both parents feed young, providing similar amounts of food (Rix 1976; Hayes 1991). Fed with dead or stunned food, which is passed directly, bill to bill (Curl 1998). Rate of feeding varies with age of young: in one study in NZ, young fed once every 20 min in first week, increasing to once every 10 min for last 2 weeks in nest, though at nest where one parent died and other continued feeding alone, rate remained at about once every 20 min (Hayes 1991); in study in NT, both adults may feed in quick succession or neither may feed for more than 1 h at any time during fledging period, though feeding rates appeared to decrease in last week in nest, perhaps to encourage fledging (Curl 1998). Rate of feeding also varies with time of day, reflecting foraging patterns of adults: most frequent at dawn, in early morning and at dusk, least often in heat of

afternoon (Moon 1991; Curl 1998). Otherwise young said to be fed at intervals of 5–30 min (Forshaw & Cooper 1985; NRS). One parent can continue feeding young if partner dies (Hayes 1991; NRS). Parents very aggressive, particularly male; intruders attacked and chased from nesting area. Attacks most likely just before fledging (Hayes 1991; Curl 1998; NRS). No evidence for distraction displays (Curl 1998; *contra* Guthrie-Smith 1910). At hatching, eggshells thrown from nest by parents (Tindale 1930). Droppings may surround entrance or accumulate in tunnel and chamber, sometimes reducing its size (Curl 1998; NRS). Despite messy state of entrance and tunnel, nest-chamber said to be clean and dry, and plumage of young unstained (Stead 1932), though in wet weather particularly, entire chamber can become foul with mud and excrement, clogging feathers of birds (Curl 1998), and said that generally nests not clean and have unbearable stench (Oliver).

Fledging to independence FLEDGING PERIOD: 24–29 days (Milhinch 1980; Forshaw & Cooper 1985; Hayes 1991; Oliver; NRS); in NT, typically 25 days (23–25 days) from start of incubation to first fledging (Curl 1998); in NZ, first chick said to leave nest 26 days after hatching, others follow over next 20 h (Moon 1991). In Kakadu NP, young continue to beg for several weeks after fledging, though fledgelings from first brood often evicted from territory by adults after 1–2 weeks; fledgelings may try to catch first food for themselves within 1 week (Curl 1998). In Canterbury, NZ, parents fed young for 7–10 days after fledging; young then began to catch food for themselves (Moon & Lockley 1982; Hayes 1991).

Success FLEDGING SUCCESS: Of 28 eggs in six nests of acceptably complete clutches, 24 (85%) hatched, and 19 (68%) fledged, which equals 3.1 fledged young per nest. HATCHING SUCCESS: Of 62 eggs in 14 nests with acceptably complete clutches but followed to hatching only, 49 (77%) eggs hatched (NRS). In Kakadu NP, 25 of 39 eggs (64%) hatched and fledged; losses included complete loss of clutches or broods through flooding or destruction of nest, failure of eggs to hatch, and death of nestlings (Curl 1998). Said that cats may kill incubating birds (Lord 1953). In Top End, likely predators of eggs and nestlings are Olive Pythons *Liasis olivaceus* and small goannas *Varanus*. Ticks found on one sickly nestling, and mites, seen in other kingfisher nests, may also affect survival (Curl 1998).

PLUMAGES Prepared by A.M. Dunn. Fledge in juvenile plumage. Partial post-juvenile (first pre-basic) moult to immature plumage probably occurs soon after fledging. Then undergo a complete immature post-breeding (second pre-basic) moult to adult plumage, probably when c. 1 year old, but poorly known. Thereafter a complete post-breeding (pre-basic) moult each cycle produces successive adult plumages with no change in appearance, though adult plumages can show considerable change with wear. Much individual variation at all ages. Sexes differ slightly at all ages. Two subspecies in HANZAB region; nominate *sanctus* from Aust. described below.

Adult male (Second and subsequent basic). Pattern and colour of plumage can alter much as plumage wears: in winter, when plumage fresh, birds can look very buff below, with black scaling on sides of breast; can be quite different in late spring-summer, when plumage worn and underparts cleaner and whiter. **HEAD AND NECK:** Forehead and crown, dark blue (ne) to dark greenish-blue (ne); occasionally some feathers of centre of forehead have buff (c123D) edges giving streaked appearance. Feathers at sides of crown just behind eye often appear slightly bluer than rest of crown. Fore-supercilium (or supraloral stripe)

extends from side of forehead to above eye: usually buff (123D) when fresh, fading to off-white with wear. Broad black (89) eye-stripe extends from bill, across lores and through and below eye to join narrow black (89) band round nape; feathers just below and behind eye have bluish or greenish tinge. Single row of white feathers borders upper edge of black nape-band, though these often concealed. Hindneck, sides of neck, chin, throat, foreneck, white, forming broad collar; often have buff (c123D) wash on hindneck when fresh. **UPPERPARTS:** Mantle and scapulars, greenish blue (ne). Back, rump and uppertail-coverts, blue (c168B). **UNDERPARTS:** Much individual variation, probably mostly through wear. Underparts, orange-buff (c118) to buff (124) when fresh, fading to white or cream (c92) with wear. Often have narrow black (89) fringes to feathers at sides of breast in fresh plumage, but these usually lost with wear. Concealed bases to feathers, dark grey (83). **UPPERTAIL:** Dark blue (ne) with concealed dark-grey (83) inner edges to t2–t6. Feathers can darken to black (89) with wear. **UNDERTAIL:** Grey (84). **UPPERWING:** Marginal, lesser and median secondary coverts, greenish blue (ne). Greater secondary coverts, dark blue (ne). Primary coverts and alula have dark-blue (ne) outer webs and grey-black (82) inner webs. Remiges, mostly grey-black (82) with dark-blue (ne) outer edges and concealed white inner edges. **UNDERWING:** Greater primary coverts, buff (c123D) with grey (84) tips. Rest of coverts, cream (92) to buff (124). Remiges, light grey (85) with white inner edges.

Adult female (Second and subsequent basic). Similar to adult male but with duller and greener head, neck and upperparts. Sexes always differ in fresh plumage, but more difficult to separate in worn plumage. Single birds not easily sexed, but it should be possible to sex members of pairs. Differences from adult male: **HEAD AND NECK:** Forehead and crown, bluish olive (ne); appears more olive than adult male. **UPPERPARTS:** Mantle and scapulars appear much more olive; grade from dark olive (c48) on upper mantle to dark bluish-olive (ne) on longer scapulars; base of feathers, brown (c28). **UPPERTAIL:** Usually slightly duller than adult male; greyish dark-blue (ne) with dark-grey (83) inner edges to t2–t6. **UPPERWING:** Lesser and median secondary coverts usually slightly greener; sometimes as male.

Nestling Naked at hatching. Soon attains covering of feathers in pin, which remain sheathed till nestling quite large, giving spiny appearance. Sheaths of pins, whitish (Stead 1932; see Breeding: Young).

Juvenile male Differences from adult male: **HEAD AND NECK:** Forehead and crown, blue with green tinge; feathers of forehead have narrow buff (123D) fringes, giving finely scaled appearance. Feathers below eye more strongly tinged green. Feathers of foreneck, sides of neck and hindneck have narrow black (89) fringes, giving barred or mottled appearance; often have buff (123D) to orange-buff (118) wash. **UPPERPARTS:** Similar to adult male or slightly greener. **UNDERPARTS:** Feathers of breast always have narrow black (89) fringes, giving scalloped or mottled pattern. Much individual variation in amount of fringing: usually broader than in adults, and take much longer to wear away, but occasionally fringing very faint; fringes usually present across whole breast, but sometimes absent from centre of breast. Flanks tend to be more orange-buff (118) than in adult male. **TAIL:** Similar to adult male or slightly duller. **UPPERWING:** Secondary coverts have narrow buff (123D) to orange-buff (118) fringes at tips, giving finely scaled appearance.

Juvenile female Similar to adult female but differs from adult in much the same way that adult and juvenile males differ.

However, ground-colour of forehead, crown, mantle and scapulars slightly browner than adult female. Some probably not separable from juvenile males (most in field), but usually average slightly browner on forehead, crown, mantle and scapulars.

Immature male and female (First basic). Considerable individual variation. When plumage fresh, most probably similar to respective sexes of juvenile, or with slightly brighter upperparts; fringes on wing-coverts appear faded or worn; and possibly have less black fringing on breast. Extent of plumage change from juvenile not certain, but retain at least remiges, upperwing-coverts and rectrices. From about Oct., many become difficult to distinguish from respective adults as fringes of forehead, breast and wing-coverts gradually lost with wear.

Aberrant plumages In NZ, pure white birds and birds that are mostly white with buff underparts and collars have been reported (Oliver).

BARE PARTS Based on photos (Moon & Lockley 1982; Moon 1989, 1992; Hadden 1990; Gosler 1991; Trounson & Trounson 1991; Egerton 1993; Stepnell & Boles Undated; Aust. RD; NZRD; Strahan) and information as cited. **Adult** Bill mostly black (89) with pinkish-white (ne) or off-white undersurface to basal half of lower mandible. Inside of mouth, pink (c108D). Orbital ring, black (89). Iris, black-brown (119) or dark brown (Rogers *et al.* 1990). Legs and feet, grey (c84), dark grey (83), light grey (85) or pink-brown (c221D). Claws, black (89). **Nestling** At hatching, skin, pink. Appears darker later in first week as darker feather-tracts become visible beneath surface of skin (D.A. Curl). Bill and legs pinker than in adult (D.A. Curl). **Juvenile** Bill: at first, black (89) with small white tip, 1–2 mm wide, to both mandibles; has pink tinge to base of lower mandible (D.I. Rogers) not visible in available photos; bill also not fully grown. Description of lower mandible as pale pink with black edges and white tip (Rogers *et al.* 1990) not correct (D.I. Rogers). Soon attain adult coloration of bill; exact timing not known but within first 3 or so months after fledging and probably much sooner (D.I. Rogers). Gape, light grey (85). Orbital ring, grey (84). Iris, black (89). Legs and feet similar to adult or pinkish along rear of legs.

MOULTS Based on examination of 89 adult and 47 juvenile and immature skins of nominate *sanctus* (AM, HLW, MV, SAM), and 69 adult and 39 juvenile and immature skins of subspecies *vagans* (AIM, AM, ANWC, NMNZ). **Adult post-breeding** (Third and subsequent pre-basic). Complete; primaries outward. Moulting usually occurs after breeding (see below), though in Kakadu NP, at least, some can begin moulting during second brood of season (D.A. Curl). Timing similar in *sanctus* and *vagans*, though information presented separately. **SANCTUS**: Few specimens in Mar., Apr. and May, which appears to be main period of moult of primaries; only seven had moulting primaries. Moulting of primaries begins in Jan. (PMS 9 and 20) or Feb. (PMS 4); one in early Mar. had PMS of 19, one in mid-Mar. had PMS of 31, and one in late Mar. had PMS of 42; probably finishes Apr. or May (PMS 46). Moulting of tail appears to begin when primaries well advanced, but probably finishes at about same time; none were moulting tail in Jan.–Feb.; in Mar., one had replaced half of tail and another had nearly finished. Moulting of body occurs over similar period, but probably finished earlier; active moult of body recorded Feb. and Mar. No moult recorded between June and Dec. (n=57). **VAGANS**: Moulting of primaries begins Jan. and proceeds rather rapidly, with up to three growing primaries in each wing; finished May or June; of 23

skins collected Jan.–June, primary-moult recorded: Jan. (PMS 2, 5), Mar. (PMS 23, 34, 38), Apr. (PMS 41.8 [8.58; 27–49; 5]), May (PMS 43, 49), and June (PMS 48, 48). Few skins showed active moult of body; probably begins in Nov. and finishes Mar.–Apr. None of 38 skins from July to Dec. showed any moult. **Post-juvenile** (First pre-basic). Very little information. Partial; extent not known, but probably replace little juvenile plumage. Probably occurs a few months after fledging and involves some feathers of head, neck, upperparts and underparts. Specimens of *vagans* indicated that partial moult occurs in Mar. and Apr.; four of seven in Mar., and two of four in Apr. had active moult of body. Only two dated specimens of *sanctus* showed moult at this time: one in Mar. was replacing feathers of chin, throat and breast, and one in May was replacing feathers of hindneck. Lane (1974) implies that a partial post-juvenile moult occurs before first winter. **First immature post-breeding** (Second pre-basic). Little information. Probably similar in timing and extent to adult post-breeding. Individuals in this moult difficult to identify unless some old juvenile upperwing-coverts with pale fringes still present. Three *sanctus* were finishing moult of primaries but still retained a few identifiable juvenile coverts: two in Mar. had PMS of 30 and 35 and one in May had PMS of 44. All three were still replacing feathers of body, but moult almost finished in May skin.

MEASUREMENTS **NOMINATE SANCTUS**: (1–2) Skins (AM, ANWC, HLW, MV): (1) Adults; (2) Juveniles. (3–5) Adults, live: (3) Aust. (ABBBS); (4) Vic. (K.G., D.I. & A. Rogers); (5) Kakadu NP, NT (D.A. Curl).

	MALES	FEMALES	
WING	(1) 93.8 (2.73; 89–99; 52)	93.9 (2.27; 90–100; 38)	ns
	(2) 91.4 (1.79; 88–95; 18)	92.4 (1.71; 90–96; 16)	ns
	(3) 92.8 (3.59; 83–102; 42)	92.2 (3.45; 87–98; 17)	ns
	(4) 94.9 (2.17; 91–97; 8)	94.9 (2.76; 91–98; 9)	ns
	(5) 90.3 (2.9; 85–95; 10)	89.9 (3.0; 86–94; 8)	ns
TAIL	(1) 59.7 (2.56; 53–65; 51)	59.8 (2.34; 53–65; 39)	ns
	(2) 59.1 (3.01; 52–67; 20)	58.5 (2.80; 55–65; 15)	ns
BILL S	(1) 41.6 (2.48; 37.1–50.6; 51)	42.8 (2.33; 39.8–48.5; 36)	*
	(2) 39.0 (3.44; 33.0–46.0; 19)	40.8 (3.81; 34.6–47.2; 17)	ns
BILL N	(1) 33.0 (2.22; 29.4–41.6; 51)	33.9 (1.91; 31.3–38.0; 36)	*
	(2) 30.4 (3.29; 23.9–36.9; 19)	32.4 (3.46; 25.5–38.7; 17)	ns
BILL D	(1) 10.2 (0.50; 9.0–11.4; 49)	10.4 (0.48; 9.5–11.4; 33)	*
	(2) 9.8 (0.70; 8.4–10.9; 18)	10.2 (0.70; 9.3–11.4; 17)	ns
THL	(4) 68.3 (1.83; 66.7–72.4; 8)	68.9 (2.05; 67.2–72.7; 9)	ns
	(5) 66.7 (2.5; 64–71; 9)	65.6 (2.4; 61–69; 10)	ns
	(2) 14.3 (0.62; 12.7–15.6; 49)	14.3 (0.61; 12.7–15.6; 38)	ns
TARSUS	(2) 14.3 (0.40; 13.6–15.2; 20)	14.1 (0.49; 13.0–14.9; 17)	ns
	(1) 19.9 (1.08; 18.1–22.3; 31)	20.0 (0.79; 19.1–22.3; 17)	ns
TOE C	(2) 19.5 (0.77; 18.4–20.7; 12)	20.1 (0.63; 19.3–21.0; 7)	ns

(6) Vic., unsexed adults, live (Rogers *et al.* 1990).

	ADULTS	IMMATURES	JUVENILE
WING (6)	95.6 (2.01; 92–98; 10)	92.7 (1.99; 88–95; 18)	81
TAIL (6)	60.2 (1.81; 58–64; 9)	59.6 (1.80; 56–64; 18)	57
THL (6)	68.7 (2.03; 66.7–72.7; 10)	64.2 (1.67; 60.1–66.9; 17)	62.0

SUBSPECIES VAGANS: (7–11) Skins (AIM, AM, ANWC, CM, NMNZ): (7) NZ, adults; (8) NZ, juveniles; (9) Lord Howe I., adults; (10) Norfolk I., adults; (11) Kermadec Is, adults.

	MALES	FEMALES	
WING	(7) 100.4 (3.12; 95–105; 17)	102.9 (2.43; 98–105; 12)	*
	(8) 99.8 (2.68; 94–104; 28)	100.1 (2.33; 96–104; 13)	ns

	(9) 100.5 (1.91; 98–102; 4)	–	
	(10) 101.4 (2.30; 99–105; 5)	102	
TAIL	(11) 96.3 (2.75; 92–99; 10)	98.2 (3.86; 94–102; 4)	ns
	(7) 65.2 (3.13; 59–71; 18)	69.6 (2.43; 66–74; 12)	**
	(8) 66.2 (3.14; 60–73; 28)	66.5 (3.18; 62–74; 13)	ns
	(9) 64.7 (3.77; 61–68; 4)	–	
	(10) 65.4 (2.61; 62–69; 5)	66	
BILL S	(11) 65.3 (2.63; 61–71; 10)	64.0 (0.82; 63–65; 4)	ns
	(7) 48.2 (2.75; 43.2–52.3; 17)	48.9 (2.89; 45.4–54.5; 12)	ns
	(8) 44.7 (3.37; 38.6–50.9; 28)	44.0 (2.76; 39.2–48.0; 13)	ns
	(9) 46.7 (1.50; 44.9–48.1; 4)	–	
	(10) 44.4 (2.29; 42.6–48.2; 5)	44.6	
BILL N	(11) 42.8 (3.03; 38.7–46.9; 10)	43.5 (2.25; 40.4–45.3; 4)	ns
	(7) 39.0 (2.29; 34.3–42.5; 18)	39.6 (2.97; 35.7–44.7; 12)	ns
	(8) 36.3 (3.52; 29.8–43.8; 28)	34.7 (2.33; 30.5–37.1; 13)	ns
	(9) 38.2 (1.29; 36.6–39.4; 4)	–	
	(10) 35.8 (2.49; 33.6–39.7; 5)	36.8	
BILL D	(11) 34.2 (2.77; 30.0–38.4; 10)	35.6 (2.90; 31.5–38.0; 4)	ns
	(7) 11.4 (0.52; 10.1–12.0; 16)	11.7 (0.37; 11.1–12.4; 12)	ns
	(8) 11.3 (0.51; 10.5–12.2; 25)	11.0 (0.51; 10.4–12.3; 13)	ns
	(9) 11.4 (0.44; 10.8–11.7; 4)	–	
	(10) 11.3 (0.36; 10.8–11.8; 5)	11.3	
TARSUS	(11) 10.7 (0.34; 10.1–11.2; 10)	10.7 (0.27; 10.4–11.0; 4)	ns
	(7) 14.9 (0.67; 13.6–15.9; 16)	15.4 (0.57; 14.3–16.3; 11)	*
	(8) 15.5 (0.82; 13.7–17.3; 13)	15.3 (0.89; 13.7–16.5; 12)	ns
	(9) 15.8 (0.96; 15.0–17.2; 4)	–	
	(10) 14.1 (0.46; 13.7–14.8; 5)	15.0	
TOE C	(11) 14.3 (0.46; 13.6–14.8; 9)	15.0 (0.50; 14.9–15.0; 4)	**
	(7) 20.8 (1.11; 19.3–22.8; 8)	20.9 (1.77; 17.4–22.6; 7)	ns
	(8) 21.8 (0.87; 19.8–23.4; 13)	22.2 (1.12; 21.4–24.0; 5)	ns
	(9) 23.2	–	
	(10) 21.2, 21.3	21.8	
	(11) 20.0 (0.57; 19.1–20.8; 6)	18.7, 21.1, 21.3	

(12) Orongorongo Valley, NZ, adults, live; Tarsus A = Length of tarsus from posterior point of tibia–metatarsal joint to anterior edge of last undivided scute at junction of metatarsus and middle toe (Roberston *et al.* 1983).

UNSEXED		
WING	(12) 100.0 (3.34; 95–108; 44)	
TAIL	(12) 65.1 (3.07; 59–69; 17)	
BILL	(12) 43.8 (3.91; 37–50; 15)	
TARSUS	(12) 14.9 (0.57; 14–16; 16)	
TARSUS A	(12) 18.4 (0.51; 18–19; 16)	
TOE	(12) 23.0 (2.72; 17–26; 14)	

Additional measurements in Forshaw & Cooper (1985) and Keast (1957).

WEIGHTS *NOMINATE SANCTUS*: (1–2) Aust., from museum labels (AM, ANWC, MV): (1) Adults; (2) Juveniles. (3–5) Adults, live: (3) Aust. (ABBBB); (4) Vic. (K.G., D.I. & A. Rogers). (5) Kakadu NP, NT (D.A. Curl).

	MALES	FEMALES	
(1)	38.8 (5.51; 28–50; 52)	42.6 (6.32; 30–55; 38)	**
(2)	37.4 (6.51; 25–50; 15)	37.6 (6.93; 28–52; 17)	ns
(3)	45.1 (5.36; 30.5–61.4; 71)	45.9 (5.00; 38.5–56.0; 31)	ns
(4)	43.3 (3.65; 38.7–49.0; 7)	46.3 (3.91; 37.5–51.0; 9)	ns
(5)	40.0 (4.7; 34.4–48.2; 9)	41.1 (2.5; 37.7–44.7; 8)	ns

Unsexed, adults, live: (6) Vic. (Rogers *et al.* 1990); (7) Aust. (ABBBB).

	ADULTS	IMMATURES	JUVENILE
(6)	45.0 (3.53; 38.7–50; 10)	45.7 (3.49; 40.3–53; 18)	36.1
(7)	43.7 (5.12; 34.5–62.5; 130)	–	–

SUBSPECIES VAGANS: From museum labels (AIM, AM, ANWC, NMNZ): (8) NZ, adults; (9) NZ, juveniles. (10) Lord Howe I., adults; (11) Norfolk I., adults.

	MALES	FEMALES	
(8)	55.3 (10.88; 35–75; 11)	60.3 (4.75; 51–65; 7)	ns
(9)	57.0 (10.69; 41–73; 16)	51.6 (11.69; 35–64; 7)	ns
(10)	39, 75	–	
(11)	50, 52, 59	57.0	

Orongorongo Valley, NZ, unsexed adults, live (Roberston *et al.* 1983): 64.2 (4.61; 55–75; 45).

STRUCTURE Wing long, narrow and slightly rounded at tip. Eleven primaries: p8 and p9 longest; p10 1–2 mm shorter, p8 0–1, p7 1–3, p6 7–10, p5 12–14, p4 16–19, p3 18–21, p2 21–25, p1 23–27; p11 minute. P7–p9 slightly emarginated on outer webs; p9 and p10 slightly on inner webs. About 14 secondaries, including about four tertials; tips of longest tertials usually fall between p6 and p7 on folded wing. Tail moderately long, with slightly rounded tip; 12 rectrices; t1 longest, t6 5–8 mm shorter. Bill long and heavy; slightly longer than head: upper mandible straight, tapering from base to pointed tip; lower mandible straight and tapering to tip with lower surface slightly convex in profile. Nostrils small and elongated, situated just below culmen ridge at base of upper mandible. Tarsus short and slender; scaling, scutellate in front and reticulate at rear. Tibia fully feathered. Feet syndactylous. Middle toe longest. Outer toe 82–90% of middle, inner 52–64%, hindtoe 50–62%.

GEOGRAPHICAL VARIATION Five subspecies, which vary slightly in size and colour. Two subspecies in HANZAB region: *sanctus* (described above) breeding throughout much of Aust., and partly migratory, spending non-breeding season in Indonesia, New Guinea and Solomon Is; and *vagans* breeding NZ, Kermadec, Lord Howe and Norfolk Is. Subspecies *recurvirostris* from Western Samoa has a dorsoventrally flattened bill and often regarded as separate species (Fry *et al.* 1992); *canacorum* occurs New Caledonia and *macmillani* on Loyalty Is.

SUBSPECIES VAGANS: Largest subspecies. Plumage slightly darker than *sanctus*, especially juvenile plumage. Differences from *sanctus*: **Adult male** Generally darker and greener with more intense buff markings on head and neck. **HEAD AND NECK**: Most of forehead and crown, dark blue-green (ne); often some feathers of forehead have buff (124) edges, particularly in centre of forehead. Ear-coverts and feathers of sides of nape behind eye, dark green-blue (c65), contrasting slightly with greener forehead and crown. **UPPERPARTS**: Mantle and scapulars, blue-green (ne), similar to crown but becoming paler posteriorly. Back, rump and uppertail-coverts, blue (c67) or greenish blue (c65). **UNDERPARTS**: Similar to *sanctus* but in fresh plumage often appear to have heavier scalloping on breast. **UPPERTAIL**: Slightly darker, dark blue (ne). **UPPERWING**: Most coverts, blue (duller than 67). **UNDERWING**: Coverts, yellow-brown (123C); 2–3 outermost greater primary coverts have dark-grey (83) tips. **Adult female** Slightly duller than male, but differences between sexes do not appear as marked as in *sanctus*. **Juvenile** Head, neck and upperparts darker than in adult *vagans*, and also darker than juvenile *sanctus*. Ground-colour of forehead and crown, black-brown (119) with buff (c124) edges to feathers. Feathers of foreneck, sides of neck and hindneck have black (89) fringes and strong buff (123D) to orange-buff (118) wash; black fringes slightly thicker than those on *sanctus* juvenile.

Mantle, black-brown (119), grading into greenish dark-brown (ne) on scapulars. As in *sanctus*, differ from adult in having: broader black (89) fringes to feathers of breast; stronger orange-buff (118) colour on flanks; tail slightly duller; secondary coverts have narrow buff (123D) to orange-buff (118) fringes at tips, giving finely scaled appearance. Sexes probably not separable.

Subspecies *vagans* from NZ mainland significantly larger than *sanctus* in Wing, Tail, Bill S, Bill N, Bill D, Tarsus and Weight ($P < 0.01$).

Birds from Lord Howe I. currently considered *vagans* (Forshaw & Cooper 1985; Fry *et al.* 1992; Schodde & Mason 1997), but have been treated as a separate subspecies, *adamsi*, in the past (Mathews). Population appears similar to that of NZ in both plumage and size. Males on Lord Howe I. showed no significant differences from those in NZ (sample sizes of females were too small for comparison; see Measurements). Possibly colonized the island from NZ in mid-1800s (Fullagar & Disney 1975). Birds on Norfolk I. treated as *vagans* following recent literature (Forshaw & Cooper 1985; Fry *et al.* 1992). Tristram (1885) recognized subspecies *norfolkiensis* on differences in plumage and dimensions of the bill; Schodde *et al.* (1983) list Norfolk I. birds as endemic *norfolkiensis* in species list (p. 33), but refer to it as *vagans* in species account (p. 56). Schodde & Mason (1997) also recognize *norfolkiensis*. Norfolk I. birds similar to birds from NZ in plumage or slightly brighter on head, neck and upperparts; and fore-supercilium said to be shorter, not extending above eye (Tristram 1885), but this was not confirmed on skins. Males significantly smaller than those on NZ mainland in Bill S, Bill N and Tarsus ($P < 0.05$) (sample sizes of females were too small for comparison; see Measurements). Populations possibly differ enough in measurements to allow recognition as separate subspecies, but too little information currently available.

Kermadec Is population currently classified as *vagans*, but, compared with those from NZ, appear slightly bluer above and are significantly smaller in Wing (male $P < 0.01$, female $P < 0.05$), Tail (female $P < 0.01$, male ns), Bill S (both sexes $P < 0.01$), Bill N (male $P < 0.01$, female $P < 0.05$), Bill D (both sexes $P < 0.01$) and Tarsus (male $P < 0.05$, female ns) (see Measurements). Taxonomic status of this population needs examination.

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Sacred Kingfisher *Todiramphus sanctus* (page 1178)

NOMINATE SANCTUS: 1 Adult male (fresh); 2 Adult male (worn); 3 Adult female (fresh); 4 Adult female (worn); 5 Juvenile; 6 Immature female; 7, 8 Adult male

SUBSPECIES VAGANS: 9 Adult male

Collared Kingfisher *Todiramphus chloris* (page 1201)

SUBSPECIES SORDIDUS: 10 Adult female; 11 Adult female; 12 Juvenile male; 13 Immature female; 14, 15 Adult male

SUBSPECIES PILBARA: 16 Adult male; 17 Adult female