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The Red Goshawk *Erythrotriorchis radiatus:* A Review

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Summary

The literature concerning the Red Goshawk's morphology, habitat, population status, prey, hunting methods and breeding biology is reviewed and supplemented with field observations and museum data. The Red Goshawk is considered a specialised inhabitant of climax vegetation communities in the biologically richest parts of Australia; it appears sensitive to ecological disturbance. It possibly has specific structural habitat requirements for hunting, and breeds in sclerophyllous vegetation. Nests are placed near water, in mature living *Eucalyptus* or *Melaleuca* trees. It is a bird specialist (preying especially on water birds, pigeons, parrots and large passerines), but also takes some mammals, reptiles and insects. It apparently has a low breeding density, large territory and traditional nest site; a low recruitment rate; and long nestling and post-fledging dependence periods. Although there has been little historical change in the Red Goshawk's gross distribution, it appears to have declined in density and in the size of its breeding population, commensurate with substantial habitat loss and declines in abundance of some of its prey species. It may also have been declining before European settlement, as a result of climatic change and competition from colonising raptor species similar in size and ecology.

Introduction

The endemic Red Goshawk *Erythrotriorchis radiatus* is an uncommon and enigmatic raptor. Compared with other Australian birds of prey it is little known and seldom observed; most encounters with it are brief and rarely made at close quarters. Furthermore, it is an unusual species with uncertain affinities, as evidenced by its past taxonomic history (e.g. North 1912, Brown & Amadon 1968, Amadon 1978). The Red Goshawk appears most closely related to the Chestnut-shouldered (=Burgers') Goshawk *Accipiter buergersi* of New Guinea, despite their present (unsatisfactory) generic separation. The relationship of these two species to *Accipiter* and other accipitrids is obscure, and will be examined elsewhere. Herein, we examine what is known of the biology of the Red Goshawk. Such information may assist in resolving taxonomic problems as well as providing a basis for conservation and management decisions.

Most early accounts of the Red Goshawk were casual observations, often incidental to the collection of eggs and specimens. A review of its oology has appeared recently (Favaloro 1981). The most comprehensive accounts of its biology concern separate observations at one nest in one year, for part of the incubation and nestling periods (Cupper & Cupper 1981, Hollands 1984). In this paper we review and interpret the literature concerning the Red Goshawk, and supplement this with our own field observations (mainly GVC), those contained in the RAOU Atlas of Australian Birds (unusual record report forms) and Bird of Prey Watch schemes, field notes made by colleagues and examination of museum specimens. This is intended as a working base for the RAOU study on the Red Goshawk, and to suggest the sorts of data that observers might report to the RAOU.

Physical characters

Body-weight data for Red Goshawks are almost non-existent. One male weighed 640 g (S.A. Parker); a comparison of measurements and dimorphism indices for

Australian *Accipiter* and the Little Eagle *Hieraaetus morphnoides* (Baker-Gabb 1984) suggests the female to be at least 1000 g, perhaps 1200 g. The Red Goshawk is therefore at least as heavy and powerful as the Little Eagle (male c. 600 g, female c. 1000 g), and sex for sex much larger than the Grey Goshawk *Accipiter novaehollandiae* (male Grey and Brown Goshawk *A. fasciatus* 359 and 311 g respectively). The Red Goshawk is thus the largest of an Australian suite of sympatric accipiter-type hawks ranging upwards in size from the Collared Sparrowhawk *A. cirrocephalus*, and approximates the large goshawks on other continents (cf. Brown & Amadon 1968, Wattel 1973).

The morphometric data in Baker-Gabb (1984) and formula in Cade (1982) give a wing-loading index of 0.37 g/sq. cm for the male Red Goshawk, which is intermediate between the male Brown and Grey Goshawks (0.33 and 0.39 g/sq. cm), similar to the male Little Eagle (0.36 g/sq. cm) and higher than that of the soaring kites (male Black Kite *Milvus migrans* and Whistling Kite *Haliastur sphenurus* 0.25 and 0.33 g/sq. cm). The Red Goshawk's flight performance should therefore be similar to the Little Eagle, less buoyant than the kites and Brown Goshawk and more so than the short-winged Grey Goshawk.

The Red Goshawk is extremely sexually dimorphic in size (Baker-Gabb 1984), which together with the long middle toe suggests bird-catching as its primary ecological role (cf. Wattel 1973, Newton 1979). The middle toe also has a pad on the underside, forming a pincer action with the claw for gripping birds (cf. Newton 1986). [Note that the illustration of the foot in Mathews (1916) is more accurate than that in Campbell (1911)]. The heavy legs and strong feet and claws suggest large prey in relation to its body size, and the female's relatively more massive feet suggest some mammal-eating and the likelihood of prey partitioning between the sexes (cf. Grey Goshawk: Mooney 1982). The long wings suggest adaptation to open habitats and reliance on sustained flight, the emarginated primaries suggest the ability to soar or glide slowly, i.e. low stalling speed, and the pointed wing tips and square tail suggest a fast flight capability (cf. Wattel 1973, Amadon 1978, Cade 1982). The general impression is of a hawk that uses slow searching flight and fast pursuit. Predictions on the Red Goshawk's flight performance from wing loading and wing structure are confirmed by field observations: it can fly rapidly, sail or glide for long periods and soar well in spirals though with more bursts of flapping than the Little Eagle and large kites (Macdonald 1973, Morris 1973, 1976, Hughes & Hughes 1988, GVC, SD).

In size, build and proportions the Red Goshawk bears a superficial resemblance to small woodland hawk-eagles of the genus *Hieraaetus*, e.g. African Hawk-Eagle *H. spilogaster* (cf. photographs in Cupper & Cupper 1981, Hollands 1984, Steyn 1973).

General habits and behaviour

The Red Goshawk's behaviour makes it somewhat difficult to observe and identify. The fragmentary observations available suggest that established resident birds have rather predictable habits, with a regular hunting range that they cover at precise times of the day, often early morning and late afternoon but also at other times when feeding young (see hunting behaviour, below; Cupper & Cupper 1981, Hollands 1984). Its hunting behaviour includes some accipitrine methods and at such times it is secretive and skulking (see below). When not hunting it perches in cover in deep shade for long periods (Morris 1976, Mason 1976), and it often flies below tree-canopy level when it is difficult to distinguish against the background (Passmore 1981, Hughes & Hughes 1988). It is sometimes seen soaring or in high flight in late morning to midday (Czechura 1985); soaring is often at less than 150 m above the ground, and the legs are sometimes lowered (T. Hertog).

There are conflicting reports on the Red Goshawk's reaction to human intruders. It has variously been described as shy (Lord 1952, Passmore 1981), wary (Morris 1976, Favaloro 1981), quiet and confiding (Cupper & Cupper 1981), tame (Campbell & Barnard 1917), and bold and fearless (Barnard 1934). Adults may also defend young against humans (Favaloro 1981). Lord (1952) was able to observe a perched bird from 20 m, B. Wells & G. Hooper (BOPWatch) were able to observe a confiding and sluggish female from 25 m whereas its mate was wary and active, and Hughes & Hughes (1988 and pers. comm.) have had wintering adults perching, hunting and feeding around their farmhouse, on one occasion allowing a 6-7 m approach. When flushed from the tree canopy, Red Goshawks usually fly through the trees for 200-250 m and land in the canopy to observe the intruder; at c. 100 m they fly again, usually out of sight so that one often gets a poor view from the rear (T. Hertog). When soaring low overhead, Red Goshawks sometimes seem curious towards human observers rather than alarmed (G. Holmes, C. Giffard).

The above divergent views may represent individual, age and sex variation according to the birds' activities at the time of the observation. Juveniles are likely to be more confiding than adults, and breeding males may be quite wary whereas females may be reluctant to leave eggs or chicks (e.g. Cupper & Cupper 1981, Hollands 1984). A hunting bird may be so engrossed that it fails to notice human observers, or is reluctant to leave a kill (e.g. Barnard 1934), and thus seems bold and fearless. On balance, it seems likely that Red Goshawks normally avoid the close proximity of humans except where hunting or breeding considerations over-ride this.

Habitat

Without source data, Brown (1976) stated the Red Goshawk to be a resident of tropical savannas (its preferred habitat) and an occasional resident of subtropical woodlands and mountains, two of the world's biologically richest habitats. With some qualification this seems a reasonable summary, as the general consensus in the literature (e.g. references in Table 1) and ornithological data banks (see introduction) is that the Red Goshawk inhabits coastal and subcoastal tropical savannas, woodlands, open forests, gallery forests along watercourses and wetlands, and the edge of rainforest. Proximity to permanent water (rivers, lagoons) seems important. It apparently does not inhabit dense forest (rainforest, tall open forest) except as a drought refugee (Bravery 1970) or where there are clearings (e.g. watercourses, logging roads: Czechura 1985), and perhaps hunts over rather than inside such forests as suggested by individuals in flight over a rainforest canopy (R. Radnell/Atlas; see also hunting behaviour, below). Observations from a light aircraft (GVC) reveal that potential prey (birds) flying over the tree canopy are easily visible against the green background; a closed canopy may make it difficult for flying prey to reach cover. [At this point we correct a misquote in Debus (1982): four out of six, not all six, of T. Lindsey's Red Goshawk sightings were of birds over subtropical rainforest].

Red Goshawks are perhaps most likely to be encountered where several of the above elements combine to create a diverse environment supporting a large and varied bird population, for instance a mosaic of woodland, riverine vegetation and lagoons. In areas frequented by pairs of Red Goshawks in south-east Queensland and north-east New South Wales, we have been impressed by the patchwork of vegetation types juxtaposed and/or the abundant and diverse bird and reptile fauna; permanent water is also a feature. One observer (W. Filewood) remarked that a Red Goshawk was seen in such an area in north-western Australia where native pigeons were very common. Similar connections between the biological richness of an area and the presence of Red Goshawks are also evident in northern and north-eastern Australia (Campbell

& Barnard 1917, Barnard 1925, Lord 1956, Gunn et al. 1972, Schodde 1973, Cupper & Cupper 1981, Hollands 1984).

There are few detailed descriptions of structure and floristics for the habitats in or over which Red Goshawks have been observed. In eastern Australia the Red Goshawk inhabits Blue Gum *Eucalyptus saligna* and Lemon-scented Gum *E. citriodora* forests with a scrubby understorey to two-thirds the height of the tree trunks (Morris 1973); eucalypt woodland, open forest, tall open forest and complex notophyll vine forest in rugged country (Czechura 1985 and unpubl.); Hoop Pine *Araucaria cunninghamii* vine scrub, subtropical rainforest, Spotted Gum *E. maculata*/ironbark *Eucalyptus* sp. open forest and eucalypt/*Acacia* regeneration bordering farmland (Hughes & Hughes 1984, 1988); and tropical mixed eucalypt woodland with five co-dominant species and thickets of tea-tree *Melaleuca* (?) (J. Ford/W.A. Museum). In the Northern Territory it inhabits wooded and open habitats on sandstone escarpments and plateaux including rainforest, inland waters and fringing forests, eucalypt woodland/open forest and broad-leafed scrub; it apparently avoids the most flat and open terrain and the most enclosed habitats (Schodde 1973, Barnett 1980). Specific details are available on some of these vegetation formations: sandstone woodland-open forest consists of five or so eucalypt species 12-15 m high, with a discontinuous understorey of shrubs and small trees 1.5-4.5 m high and a grassy ground cover; sandstone scrub consists either of figs *Ficus* and other rainforest trees 7-9 m high with a rainforest shrub layer 1.5-4.5 m high, or a sclerophyllous shrub/low tree layer 2-5 m high with occasional eucalypt and *Terminalia* emergents to 10 m, both with a diverse grassy and herbaceous ground cover (see Schodde 1973).

An apparently important and hitherto unremarked habitat is paperbark (*Melaleuca*) swamp sclerophyll forest. Several reports mention Red Goshawks occurring in or breeding in melaleucas (Hill 1911, White 1917, Barnard in Favaloro 1981, S. Garnett/Atlas, S.A. Parker); such forests are prolific nectar producers and support high densities of nectar-feeding birds (S. Gilmore pers. comm.), so they may be expected to attract bird-eating raptors.

There are a few brief descriptions of the general habitat in which nests have been found, and only one detailed account; recorded nests have all been in (climax?) sclerophyllous vegetation communities (Table 3). Nests are placed in living trees, usually (invariably?) near permanent water. Nest trees recorded are all sclerophyllous species (*Eucalyptus* and *Melaleuca*, Table 3). The nest site recorded by H.A. Nix (Table 3; further described under Land Unit 36 of Gunn et al. 1972) is in an area of predominantly eucalypt- and melaleuca-dominated grassy woodlands or low woodlands with rainforest on sheltered slopes and some permanent water; it is floristically diverse with many plant communities juxtaposed. The area is faunistically rich with 35% of Australian land bird species and over half the native pigeon species, and is among the least disturbed coastal habitats in eastern Australia.

Many of the habitats within the Red Goshawk's range have been significantly altered since European settlement. At least half the area of forest and woodland in eastern Australia has been cleared (Goldstein 1977, Keast et al. 1985). Much of the remaining area is subject to forestry practices which reduce the abundance and diversity of bird communities (e.g. Fisher 1975, Keast et al. 1985), or to grazing and annual burning which may cause subtle degradation (e.g. changes to water supply and vegetation communities: Barnard 1925, Coblentz 1978, Czechura & Covacevich 1985) as well as more obvious changes such as thinning of tree cover and removal of understorey and ground cover. Locally, little or no original vegetation remains or it has been so modified that it is now difficult to determine the original structure and floristics (Speck

1968). In the north, grazing by stock and feral animals and annual burning have degraded ground cover and prevented regeneration in woodlands and monsoon forests (Frith 1982). In the north-west, severe overgrazing is causing desertification along some of the rivers (Davies 1987). Wetlands are also seriously affected: in the east, paperbark swamps and other coastal wetlands have been (and are still being) cleared and drained; in the north, those wetlands that have not been drained have been degraded by cattle and buffalo, which destroy the edge vegetation by grazing and wallowing and exclude native fauna from the remaining cover (Frith 1977). It seems reasonable to conclude that the Red Goshawk has lost considerable areas of habitat.

Population status

There are conflicting estimates of the Red Goshawk's abundance. Some authors consider it rare and/or declining everywhere (e.g. Slater 1978, Storr 1973, 1977, 1980, 1984, Price-Jones 1983, Hollands 1984). Others consider that it has contracted from the south-eastern portion of its range but is still moderately numerous in northern coastal areas (e.g. Mason 1976, Morris 1976, Pizzey 1980). There are no measures of abundance and few data upon which to assess population trends. The bird's unobtrusive behaviour, cryptic plumage and occurrence in sparsely inhabited areas all add up to a low probability of encounter, and the difficulty of identification and similarity to other species may result in its being overlooked and under-reported. It is likely that, like other bird specialists, it naturally occurs at much lower density than more generalised raptors (cf. Newton 1979). Nevertheless, a comparison of records from four time periods (Figure 1) may reveal some changes in the Red Goshawk's distribution and abundance, allowing for differences in observer effort. These time periods are:

(a) European settlement to 1950, a time of ornithological exploration (including collecting trips to the far north) when habitats were still reasonably intact;
(b) 1951-1976, a time of accelerated (mechanised) clearing and a number of organised bird surveys in the Kimberley, Top End and Queensland (Kirkpatrick 1967, Lavery 1968, McEvoy & Kirkpatrick 1971, Gunn et al. 1972, Schodde 1973, Hall 1974, Frith & Calaby 1974, Lavery & Grimes 1974, Lavery & Seton 1974; Storr et al. 1975, Broadbent & Clark 1976, Kirkpatrick & Amos 1977, Kirkpatrick & Searle 1977, McEvoy et al. 1979, Ford et al. 1980, Johnstone 1983, Johnstone et al. 1977, 1981, Crossman & Reimer 1986);
(c) the RAOU Field Atlas (1977-1981) when 3000 observers systematically covered the country obtaining bird lists for each 1° grid block (Blakers et al. 1984), and the proliferation of field guides improved observers' ability to identify birds;
(d) 1982-1987, a post-Atlas period of casual sightings, and since 1986 an organised Australia-wide road survey of raptors by some 300 observers, with reasonable coverage of the Kimberley, Top End and eastern Queensland (RAOU Bird of Prey Watch).

We have omitted a few south-eastern records (Hall 1974, Debus 1982) that were insufficiently substantiated. The results for each time period are perhaps not directly comparable because of differences in the length of each period, the methods and objectives of the observers and the intensity of coverage, but the maps suggest some trends.

The data suggest little change in the gross distribution of the Red Goshawk, with perhaps some contraction coastwards in the east. Despite an increase in observer numbers, effort and ability and greater accessibility of remote northern regions, the number of 1° blocks in which the species has been reported declined slightly from 34 pre-1950 to 30 in 1977-1981; we obtained 37 casual records for 25 blocks since 1982 although there was no centralised recording scheme for most of this time. It apparently

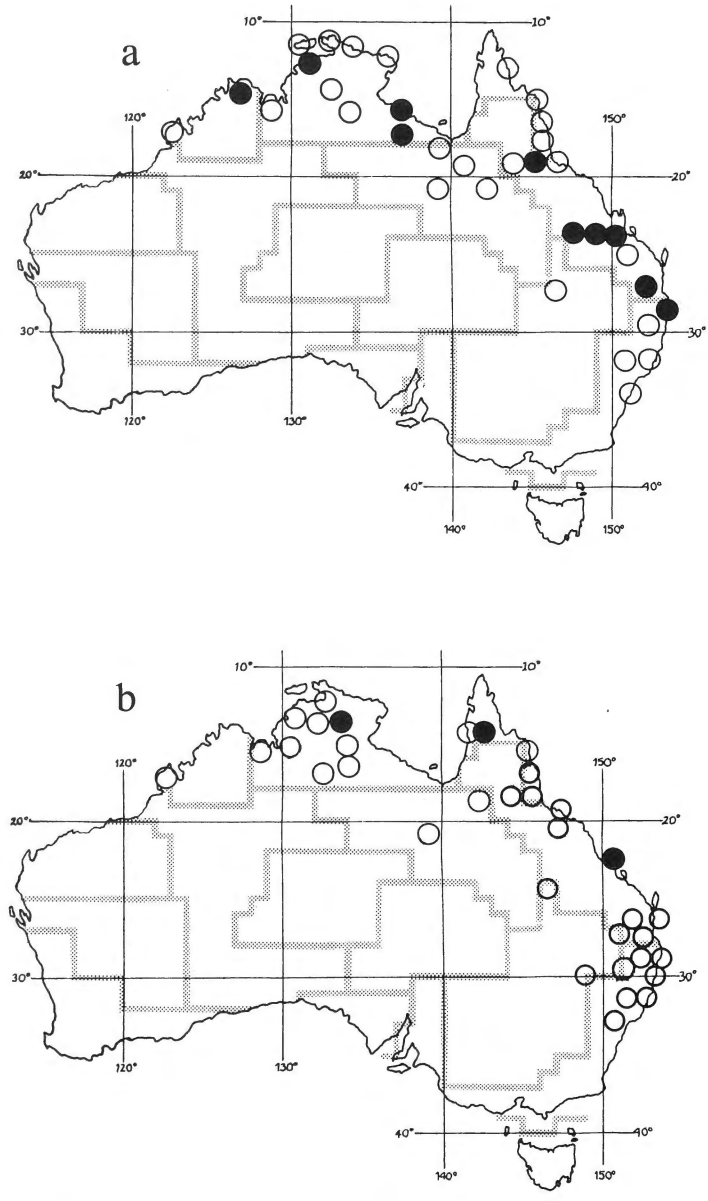
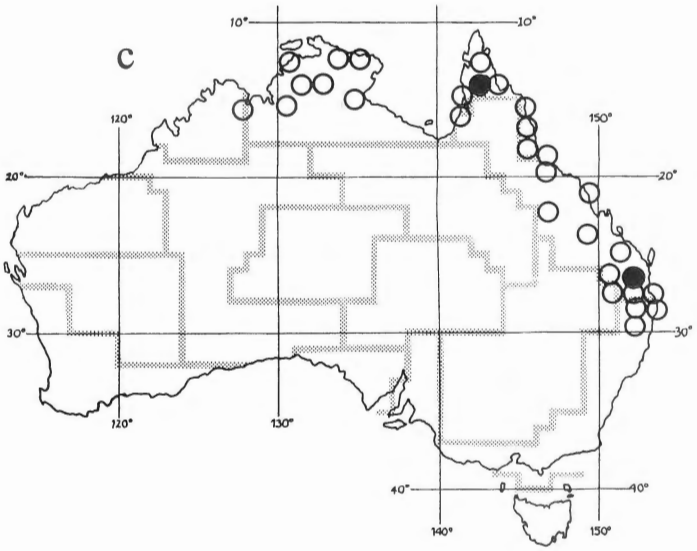
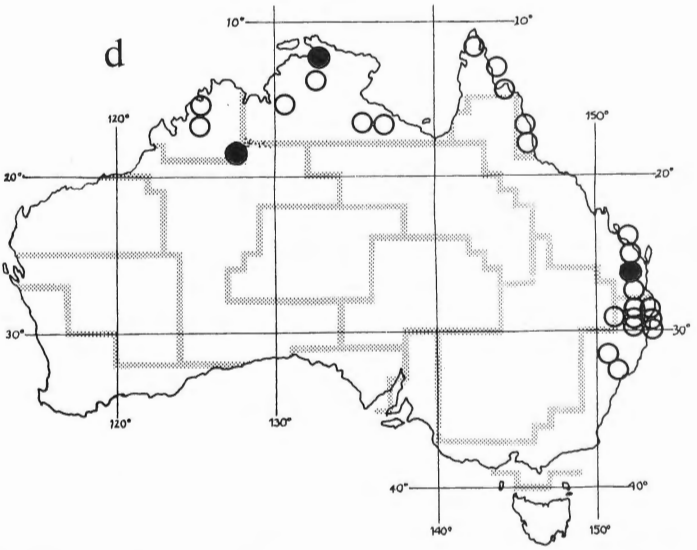


Figure 1. **Sight records and specimens (open symbols) and breeding records, including attempts (solid symbols) of the Red Goshawk in 1° blocks in four time periods: (a) pre-1950, (b) 1951-1976, (c) 1977-1981, (d) 1982-1987. Sources: RAOU Historical and Field Atlases, Museum of Victoria, Australian Museum, Qld Museum, S.A. Museum, W.A. Museum, Condon & Amadon 1954, Deignan 1964, Wheeler**





1964, 1970, Favaloro 1981, Debus 1982, Lindsey 1982, 1984-1986, Stewart 1984, Palliser 1985, Winter & Atherton 1985, Hertog 1986, Maxwell 1986, Hughes & Hughes 1988, J. Reid/BOPWatch, B. Wells & G. Hooper/BOPWatch, N. Aiken, T. Aumann, D. Baker-Gabb, P.A. Bourke, D. Geering, G. Holmes, R. Leggett, T. Kloot, N. Mooney, S.A. Parker, I. Venables, GVC.

Drawing: G.V. Czechura

still breeds near the extremities of its historical range, perhaps even in far north-eastern New South Wales as pairs are occasionally seen there in spring/summer and unconfirmed breeding reports persist. It was last confirmed breeding there in 1917 (G. Holmes). However, there has been a marked decline in the number of breeding records from 15 at 10 sites 1884-1950 to eight at six sites 1951-1987 (three at three sites 1951-1976, only two at two sites during the Field Atlas 1977-1981 and three at three sites 1982-1987). There has also been a decline in the number of specimens collected, from 25+ pre-1950 to four 1951-1976 and two 1977-1987 (one lost, one not retained). Most fauna surveys in the tropics since 1950, each spanning months or years, have failed to record the bird: of the 19 official fauna surveys cited above, only four (21%) recorded it; for Queensland, this is two (15%) out of 13 surveys. In particular, the species seems to be almost absent from the agricultural region in central-eastern Queensland occupied by the Barnard brothers, where it was formerly a breeding resident (cf. Figure 1a-d; Crossman & Reimer 1986).

These data suggest that the Red Goshawk may have declined in density and that some areas have become unsuitable for breeding. Local declines have been documented: early this century H.G. Barnard (in North 1912) and C.A. Barnard (1925) remarked that the bird had disappeared from a pastoral region of eastern Queensland where it formerly bred (an area cleared or greatly modified: Barnard 1925, Speck 1968, Hollands 1984); the breeding pair studied by Lord (1952) could not be located during the Field Atlas, after the property had been subdivided and cleared (M. Miles/Atlas). Field Atlas reporting rates indicate that the Red Goshawk is seen much less frequently than other raptors within its range, even the Pacific Baza *Aviceda subcristata* with a similarly restricted distribution (66 records in 28 blocks, 2 breeding, maximum reporting rate 6% versus 1042 records in 92 blocks, 26 breeding, maximum reporting rate 25% for the Baza: Blakers et al. 1984). Admittedly the Baza is more conspicuous and easily identified.

Most of the early collectors' and observers' accounts give the impression that the Red Goshawk has always been rather scarce, with the exception of Macgillivray's (1914) account which may involve misidentified birds, but they at least found a number of nests whereas Cupper & Cupper (1981) and Hollands (1984) only managed to locate one nest between them (in perhaps the remotest part of the bird's range) after years of searching, a publicity campaign and the incentive of a financial reward. It does appear that the Red Goshawk's total population has declined somewhat, and that there are now considerably fewer breeding pairs.

It has been suggested that the Red Goshawk is sensitive to human disturbance (Hollands 1984). However, it has been reported to tolerate human observers near the nest, even appearing to be more curious than alarmed; lay replacement clutches after the nest has been robbed; re-mate and nest again (in the same or a new nest) after one of the pair has been shot; and new pairs have apparently replaced those pairs in which both birds were shot (see Hill 1911, North 1912, Barnard 1934, Cupper & Cupper 1981). One active nest was found within 50 m of a remote highway (R. Leggett), and another was within sight (1 km) of an occupied farmhouse (M. Miles/Atlas).

The Red Goshawk would therefore seem no more sensitive to human disturbance than most other Australian raptors, and perhaps less so than the Marsh Harrier *Circus aeruginosus* and Wedge-tailed Eagle *Aquila audax*. On the other hand, it may be significant that one pair disappeared after a fire had burnt out their nest area (Cupper & Cupper 1981, Hollands 1984) and another pair left their nest site after clearing; their presumed new nest was located 5 km away (M. Miles). It may not be human presence *per se*, or even direct persecution, but the wider effects of land-management

Male Red Goshawk alighting near female

Plate 42 Photo: David Hollands

practices that are most detrimental to the species. The situation in a forestry area in south-east Queensland (Czechura 1985) suggests that there is a threshold above which habitat change will not be tolerated: a pair nests in close proximity to Hoop Pine and Slash Pine *Pinus elliottii* plantations, although extensive native forest remains; the birds hunt in selectively logged areas but not in the (now mature) plantations (GVC).

The Red Goshawk will also apparently respond to favourable habitat and/or prey population changes: a pair have become increasingly regular non-breeding visitors to a farm adjoining forest; cessation of stock-grazing and annual burning has been followed by an increase in ground cover and ground-dwelling birds, including Australian Brush-turkeys *Alectura lathami* which are no longer shot by neighbours (Hughes & Hughes 1984, 1988 and pers. comm.). The presence of the Red Goshawk in forested areas around Brisbane suggests that it can persist in areas where the topography provides a buffer against the amount of disturbance that can take place.

Many skins and eggs were taken by the early collectors, a few specimens have been taken in recent years, illegal egg collection persists, and birds are occasionally seen with injuries (broken legs) consistent with gunshot wounds (Lord 1952, P. Slater pers. comm.). Nevertheless, ecological changes are likely to be more important than direct persecution as factors affecting the Red Goshawk's population level, because the limits to raptor populations are determined by food or nest sites, whichever is in short supply (Newton 1979). If habitat destruction and/or a declining prey base cause the Red Goshawk's numbers to drop to a critical level, then direct persecution could become a significant mortality factor.

Table 1
Species recorded as prey of the Red Goshawk *Erythrotriorchis radiatus*

Species	*Weight (g)*[a] *range (mean)*	*Source(s)*[b]
Mammals:		
Brown Hare *Lepus capensis* ('half-grown')	c. 2000	Miles in Hollands 1984
Unspecified (small)		Mason 1976
Birds:		
Rufous Night Heron *Nycticorax caledonicus*	519-726 (629)	Barnard 1914
Muscovy Duck *Cairina moschata* (ducklings)	c. 100	M. Miles/Atlas
Pacific Black Duck *Anas superciliosa*	805-1400(1070)	Barnard 1925
Maned Duck *Chenonetta jubata*	662-955(808)	E.D. Barnard 1902, H.G. Barnard 1934
Australian Brush-turkey *Alectura lathami* (ad.)[c]	2210-2450(2330)	Hughes & Hughes 1988
Domestic fowl *Gallus gallus* (ad. White Leghorn)[c]	c. 2000	Hughes & Hughes 1988
Helmeted Guinea-fowl *Numida meleagris* (chicks)	⟨100	D. Davidson
'Quail' *Coturnix/Turnix* sp.[d]	⟨100	Deignan 1964
Topknot Pigeon *Lopholaimus antarcticus*[c]	518	Hughes & Hughes 1988
Bar-shouldered Dove *Geopelia humeralis*	105-134(118)	Wheeler 1964
Partridge Pigeon *Geophaps smithii*[d]	171-225(194)	Barnard 1914
Common Bronzewing *Phaps chalcoptera*[d]	293-400	Barnard 1934, Maxwell 1986
Crested Pigeon *Ocyphaps lophotes*	175-230(199)	Morris 1973
Galah *Cacatua roseicapilla*[c]	299-332(313)	Macgillivray 1914/S.A. Museum
Sulphur-crested Cockatoo *Cacatua galerita*[d]	600-975	Barnard 1925
Rainbow Lorikeet *Trichoglossus haematodus*[d]	106-157(128)	Cupper & Cupper 1981, Hollands 1984
Red-collared Lorikeet *Trichoglossus rubritorquis*[d]	102-138(122)	S.A. Parker
Eastern Rosella (nestlings) *Platycercus eximius*	⟨100	Miles in Hollands 1984
Laughing Kookaburra *Dacelo novaeguineae*[c]	273-353(311)	Cupper & Cupper 1981
Blue-winged Kookaburra *Dacelo leachii*	277-391(311)	Cupper & Cupper 1981
Grey-crowned Babbler *Pomatostomus temporalis*	65	Miles in Hollands 1984
Thornbill *Acanthiza* sp(p).	10	Mason 1976
Honeyeater sp(p). (Meliphagidae)	c. 10-100	Schodde & Tidemann 1986
Australian Magpie-lark (nestling) *Grallina cyanoleuca*	⟨100	Lord 1952
Butcherbird *Cracticus* sp(p).	85-114	Lord 1956

Table 1 continued
Species recorded as prey of the Red Goshawk *Erythrotriorchis radiatus*

Species	*Weight (g)*[a] *range (mean)*	*Source(s)*[b]
Australian Magpie (nestling) *Gymnorhina tibicen*	205-296(259)	Lord 1956
Torresian Crow *Corvus orru* (adult and nestling)[c]	430-670(558)	Lord 1956, Miles in Hollands 1984, J. Ford/W.A. Museum
Unidentified passerines[d]	⟨100?	Cupper & Cupper 1981
Unidentified nestlings	⟨100?	N. Aiken/Atlas
Unidentified birds[d]		Barnard 1934, Hollands 1984
Reptiles:		
Frilled Lizard *Chlamydosaurus kingii*	c. 300	Barnard 1934
Red-bellied Black Snake *Pseudechis porphyriacus*	c. 100	Lord 1952, N. Aiken/Atlas
Unidentified snake	c. 100	Wheeler 1964
Insects:		
Grasshoppers (Orthoptera)	2	Barnard 1914, Slater 1978

[a]where possible, weights taken from tropical specimens in Hall (1974), otherwise Rowley (1970), Crome (1975), Frith (1977), Long (1981), Forshaw (1981), Jones (1987), Australian Museum.

[b]some sources, particularly the Barnard brothers and Cupper & Cupper (1981)/Hollands (1984), independently reported the same prey items so only the first such report is listed in each case unless different prey individuals were observed.

[c]taken by female goshawk.

[d]taken by male goshawk.

Table 2
Size class, taxonomic group (passerine vs non-passerine) and main foraging zone (ground/understorey vs canopy/aerial) of avian prey species of the Red Goshawk *Erythrotriorchis radiatus*, **Grey Goshawk** *Accipiter novaehollandiae* **and Brown Goshawk** *Accipiter fasciatus* **in sympatry. Summarised from Table 1 (Red Goshawk), Czechura et al. 1987 and Olsen et al. in press (Brown and Grey Goshawks).**

Dietary parameter	*Avian prey species (%)*		
	Red Goshawk	*Grey Goshawk*	*Brown Goshawk*
Size class (g):			
⟨100	32	30	41
100-250	21	35	38
250-500	18	15	15
⟩500	29	20	6
Taxonomic group:			
Passerine	26	32	44
Non-passerine	74	68	56
Foraging zone of prey:			
Ground/understorey	71	53	65
Canopy/aerial	29	47	35

Prey

The Red Goshawk eats mainly birds; mammals, reptiles and insects are also taken (Table 1). Species taken include water birds and gallinaceous birds (29% of avian species), native pigeons (18%), hollow-nesters (Maned Duck *Chenonetta jubata*, kookaburras *Dacelo* spp., parrots: 29%) and passerines up to crow and magpie size (26%). Red Goshawks have also been observed attacking or pursuing a Black-shouldered Kite *Elanus notatus* (Lord 1952), adult Brush-turkey (Hughes & Hughes 1988), Dusky Moorhen *Gallinula tenebrosa* (D. Richards), Spinifex Pigeon *Petrophassa plumifera* (R. Wyatt/Atlas), Rainbow Lorikeet *Trichoglossus haematodus* (Diggles 1875), Yellow-rumped Thornbills *Acanthiza chrysorrhoa* (N. Aiken/Atlas) and House Sparrows *Passer domesticus* (Slater 1978). GVC has observed an apparent attack that flushed a number of Torresian Crows *Corvus orru*, Australian Magpies *Gymnorhina tibicen*, Pied Currawongs *Strepera graculina*, Australian Magpie-larks *Grallina cyanoleuca*, Noisy Miners *Manorina melanocephala*, Crested Pigeons *Ocyphaps lophotes* and Bar-shouldered Doves *Geopelia humeralis*.

Prey range up to at least twice the female Red Goshawk's body weight (adult Brush-turkey, immature Hare *Lepus capensis*), or can inflict damage during self-defence (Sulphur-crested Cockatoo *Cacatua galerita*, killed by male Red Goshawk of similar or somewhat lower body weight). These observations are consistent with the Red Goshawk's leg and foot morphology (see above), i.e. 'sparrowhawk' foot for catching birds and heavy legs and feet for quickly subduing large and/or dangerous prey. The maximum prey size recorded for each sex (Table 1), and the delivery of different-sized prey to a nest by the male (mainly lorikeets) and female (kookaburra: Cupper & Cupper 1981, Hollands 1984), suggest prey partitioning by size; the hare was probably also taken by a female.

There is no support for early claims that the Red Goshawk eats carrion. Lucas & Le Souef (1911) claimed that the Red Goshawk could be attracted to freshly killed animals, but their account of its plumage and distribution refers to the juvenile Black-breasted Buzzard *Hamirostra melanosternon*. Other claims, for instance that the Red Goshawk scavenges dead fish, were based on confusion with the Whistling Kite (Mathews 1916, Debus 1982). GVC has investigated a similar misidentification involving a juvenile Brahminy Kite *Haliastur indus*. A Red Goshawk did not avail itself of a fresh poultry carcass, although it killed a domestic fowl for itself and returned over two days to consume a Brush-turkey kill (Hughes & Hughes 1988 and pers. comm.).

The avian diet of the Red Goshawk includes both abundant and declining species. The former include Maned Duck, Crested Pigeon, cockatoos, magpies and crows (see Blakers et al. 1984), and the latter include waterfowl and tropical ground- and fruit-pigeons (Frith 1977, 1982); the hole-nesters are vulnerable to land-use practices that remove hollow trees. The non-avian diet shows a similar pattern: hares are now common in grasslands and woodlands in the south-eastern part of the Red Goshawk's range (Strahan 1983); all of the reptiles recorded in the Red Goshawk's diet are declining or locally extinct over some parts of their range (Czechura & Miles 1983, Shine & Covacevich 1983, Czechura & Covacevich 1985).

Large Australian goshawks (Red, Grey and Brown) prey mainly on birds in northern Australia (cf. Czechura et al. 1987, Olsen et al. in press). As they overlap in size (Baker-Gabb 1984) and could potentially compete with each other, one might expect some prey partitioning between them where their ranges overlap. Table 2 provides a breakdown of avian prey species according to size, taxonomic group (passerines vs non-passerine) and main foraging zone (ground/understorey vs canopy/aerial). The

data show an increasing proportion of prey species in the larger size classes with an increase in hawk body size, the Red Goshawk taking relatively more species in the 250-500 g and >500 g classes. There is a similar relation between hawk species and taxonomic group of prey species, both Red and Grey Goshawks taking relatively more non-passerine species than the Brown Goshawk. The Red Goshawk also takes relatively more ground/understorey species than the other two goshawks.

Such partitioning may be further enhanced by differences in hunting methods and habitat, for instance the Grey Goshawk inhabits dense forest and takes many foliage-feeding birds (Morris 1973, Olsen et al. in press). Nevertheless, the Red Goshawk shares 54% of its native prey species with the other two goshawks in sympatry (cf. Czechura et al. 1987, Olsen et al. in press). Comparisons would be more valid if based on the number of prey individuals (rather than species) in each weight, taxonomic or foraging-zone class.

Hunting and feeding behaviour

Little has been recorded on the Red Goshawk's hunting behaviour, but it appears to use several methods to locate and capture prey. It hunts by stealth, skulking in cover, working from tree to tree to tree and dashing or gliding out to seize prey on the ground, on perches or in the air; it also hunts on the wing by soaring, slow flying or gliding over vegetation, or fast flight at low levels (Morris 1973, 1976, Mason 1976, Schodde & Tidemann 1986, observations below). Here we employ the terminology of Baker-Gabb (1980) to categorise the various search and attack methods.

The following searching methods have been recorded, but there are no data on their relative frequency of use.

(a) Perch hunting: the Red Goshawk usually waits on a concealed perch in or under the canopy, towards the centre of a fairly dense tree, but occasionally on an exposed perch (Mason 1976, Schodde & Tidemann 1986, Hughes & Hughes 1988, S.A. Parker). It has been observed perching in one position for up to two hours or more (Hughes & Hughes 1988), which suggests 'long-stay' perch hunting rather than the short-stay perch hunting of small sparrowhawks (cf. Newton 1986). Some reports indicate regular perch hunting near known sources of terrestrial prey (reptiles, Brush-turkeys, domestic fowl: Lord 1952, Hughes & Hughes 1988).

(b) Quartering: the Red Goshawk sometimes circles low over the tree canopy, drifting downwind while searching (Morris 1973, 1976). On several occasions a bird progressed in a series of circles (diameter 30 m) very slowly, almost at stalling speed, c. 10 m above a bloodwood open forest for a distance of at least 300 m (C. Giffard); another bird circled just over the canopy of a tall Spotted Gum *Eucalyptus maculata* forest for 15 minutes (D. Geering); and another circled low over open areas in a eucalypt forest, with much flapping, while peering intently downwards (S. Blaber/Atlas). Birds have been observed quartering a river, a large shallow swamp and an urban/rural interface (H. Officer/Atlas, I. McDonald/Atlas).

(c) Transect hunting: there are many observations of Red Goshawks flying or sailing low over or through the vegetation canopy, often that fringing watercourses or roadways (Forshaw & Muller 1978, Maxwell 1986, N. Aiken/Atlas, P. Munday/Atlas, C. Corben, F.T. Morris, S.A. Parker, GVC). One bird travelled very slowly 5-6 m above low bloodwood regrowth (3-5 m), parallel to a road, for 300-400 m before veering off (C. Giffard); another flew slowly with continuous flapping, between the crowns of riverine trees, following the course of the river (G. Holmes).

(d) Listening: a bird transect hunting circled once to investigate when the distress cry of a rabbit was imitated (G. Holmes). Partial dependence on hearing during stationary or low, slow searching methods is consistent with the facial ruff (prominent ear coverts).

(e) Soaring and prospecting: the Red Goshawk may soar for other reasons besides hunting, e.g. display, long-distance movements. Soaring may be an energy-saving means of travelling to hunting areas, for instance by circling up from a valley to a high pitch and then setting off on a long, slanting glide several kilometres to the next valley (G. Holmes, GVC). Nevertheless it may sometimes soar to hunt, as some attacks are initiated from high in the air (C.A. Barnard 1925, H.G. Barnard 1934, Lord 1952, Hughes & Hughes 1988).

(f) Fast contour hunting: there are a few observations of Red Goshawks in rapid level flight, along the length (500 m) of a narrow cleared valley in forest, along the edge of mangroves, along a road through rainforest and low (5 m) along a rocky, timbered creek, in the last instance returning in 10 minutes with prey (Morris 1976, R. & C. Cooper/Atlas, S. Garnett/Atlas, J. Strudwick/Atlas, G. Maywald, GVC).

(g) Flushing from cover/mediated flushing: two reports of the same incident (North 1912, Barnard 1934) suggest that the Red Goshawk may on occasion flush prey into flight or take advantage of prey flushed by a human observer. Slater (1978) reported a pair of Red Goshawks catching grasshoppers flushed by a grass fire, and one bird has been observed aggressively trying to flush a Dusky Moorhen from bulrushes along a creek (D. Richards).

Some of the above and other observations suggest that the Red Goshawk makes use of ecotones, e.g. 'patrolling' the edge of an escarpment, sailing along a rainforest/eucalypt forest interface, flying up from a wet sclerophyll/cleared paddock interface, gliding over patchily cleared eucalypt forest with dry rainforest on adjacent slopes, perching in the top of a roadside tree in rainforest, and launching an apparent attack flight along an open forest/paddock interface (E. Finley/Atlas, M. Miles/Atlas, G. Holmes, G. Maywald, GVC).

In addition to active hunting methods the Red Goshawk also takes nestling birds, returning to harvest a known supply of food on successive occasions in the same or subsequent breeding seasons (Lord 1952, 1956, Miles in Hollands 1984, N. Aiken/Atlas).

Much hunting appears to be done at dawn and dusk, and most is apparently done away from the vicinity of the Red Goshawk's own nest (Lord 1952, Cupper & Cupper 1981, Hollands 1984, Hughes & Hughes 1988 and pers. comm., N. Aiken/Atlas). Observations in south-east Queensland support this view, as birds often appear to move several kilometres between presumed hunting areas and roost/nest sites (GVC). Several observations suggest a regular hunting range visited at similar times each day, for instance hunting at a site in the mornings and evenings and departing in the same direction each time, sometimes carrying prey (N. Aiken/Atlas); quartering low on the same flight path, in mid morning on two occasions over several days (C. Giffard).

In some areas Red Goshawks make hunting visits intermittently, within a broader seasonal pattern or at varying intervals over several years (Hughes & Hughes 1988 and pers. comm., N. & C. Aiken, M. Passmore). This suggests a large home range with different parts used in rotation.

There are few observations of attacks on prey, but some of the prey species recorded (ducks, pigeons, lorikeets: Table 1) suggest that the Red Goshawk is capable of bursts

of swift flight. Descriptions suggest that prey is taken in surprise attacks or by direct pursuit. The following attack methods have been recorded.

(a) Glide attack: used in conjunction with perch hunting to take terrestrial prey, in one case along a track through shrubs and then pursuit (on foot?) through thick undergrowth (Hughes & Hughes 1988).

(b) Direct flying attack: used in conjunction with perch hunting, soaring and presumably fast contour hunting to take prey on the ground, on a perch or in the air (Mason 1976, Schodde & Tidemann 1986). GVC has observed a Red Goshawk circle up from a valley and launch what appeared to be a shallow flying attack on a group of birds.

(c) Tail chasing: because of its bulk the Red Goshawk is probably not a tenacious tail-chaser, but there are several descriptions of it chasing birds (Diggles 1875, Slater 1978, Favaloro 1981, N. Aiken/Atlas). Perhaps (short?) tail chases develop if the prey is alerted to one of the above attack methods.

(d) Dive attack: used in conjunction with quartering or transect hunting to take prey on the ground or in vegetation. A bird circling in a gorge made a 'pass' at a Spinifex Pigeon on a ledge (R. Wyatt/Atlas), and a bird gliding 50-60 m above ground dived quickly into a dense patch of eucalypts below (G. Holmes).

(e) Stooping: used in conjunction with soaring and prospecting to take flying birds. Prey are sometimes struck down in the manner of a falcon (C.A. Barnard 1925, H.G. Barnard 1934); a Red Goshawk soaring high over rainforest stooped and seized one of a flock of Topknot Pigeons *Lopholaimus antarcticus* flying over the canopy (Hughes & Hughes 1988).

The above search and attack methods are consistent with the Red Goshawk's morphology; it appears to use more aerial search methods than the Grey and Brown Goshawks which are primarily perch-hunters (e.g. Wattel 1973, Schodde & Tidemann 1986).

Prey is plucked and eaten either on the ground (E.D. Barnard 1902, H.G. Barnard 1934, Hollands 1984, Hughes & Hughes 1988) or on a tree perch (Lord 1952, Cupper & Cupper 1981, Maxwell 1986), often in thick foliage (Morris 1973). One bird returned 4-5 times per day over two days to feed on the ground on prey too large to carry, dragging it farther under a sheltering tree in the process (Hughes & Hughes 1988 and pers. comm.). In the incident reported by Maxwell, a Wedge-tailed Eagle tried to steal the prey whereupon the goshawk dropped it into long grass and returned to finish it on the ground, after the eagle failed to find it and had departed (W. Filewood pers. comm.).

Courtship and advertisement displays

Little has been recorded on the Red Goshawk's displays. Morris (1976) mentioned a deep, harsh chatter uttered in territorial or advertisement contexts, presumably from a perch, and Price-Jones (1983) mentioned soaring over forest at the start of the breeding season. Hertog (1986) reported a single bird performing an undulating aerial display like that of the Torresian Imperial-Pigeon *Ducula spilorrhoa*, further described (pers. comm.) as follows: the bird gave 6-8 shallow wing beats to gain altitude, then about 10 m above its original line of flight it partly closed its wings and dropped back to its former height before repeating the process; the upward part of the display was much shallower than that of Australian *Accipiter*. Lowering of the large yellow legs while soaring at moderate height (<150 m, T. Hertog) may be a ritualised display of 'armament' as in some other raptor species (Barnard & Simmons 1986), but more information is needed on the context of this behaviour.

Pairs of Red Goshawks have been observed circling upwards together, sometimes in opposite spirals like Wedge-tailed Eagle pairs and sometimes calling repeatedly in series of four notes (Hughes & Hughes 1988 and pers. comm.; J. Hobbs/Atlas; J. Duranti, A. Cartwright & R. Edwards, field notes). On one such high soaring flight the male repeatedly dived with closed wings at the female, which adroitly avoided contact (Hughes & Hughes 1984). Courtship provisioning has been recorded: during the nest-building period a male brought food to the female while she was on the nest (Barnard 1934). Nothing has been recorded on mating, but excited calling and ritual mounting have been observed when a male delivered prey to a female during the incubation period (Cupper & Cupper 1981, Hollands 1984).

Breeding biology

There are no measurements of breeding density, but available data suggest two territories on a property of 442 sq. km, two pairs in an area of 370 sq. km and probably only one pair in 50 sq. km, all in south-east Queensland (Barnard 1925, Lord 1956, M. Miles/Atlas, Czechura 1985). The nests of two neighbouring pairs were 6.5 km apart (M. Miles). Apparently each pair of Red Goshawks occupies a large territory, hunting at least 3 km from the nest and possibly much farther. In forested range country in south-east Queensland, the birds have been seen flying between ridges several kilometres apart (GVC).

Only 66 sightings and two breeding records in five years over its entire Australian range (Blakers et al. 1984) suggest that the Red Goshawk occurs at low density and that nests are difficult to find. There are no observations of a complete breeding cycle, but at one nest parts of the incubation and nestling periods were observed (Cupper & Cupper 1981, Hollands 1984). Together with the early fragmentary accounts, it is possible to build up a composite picture of the Red Goshawk's breeding biology.

The breeding season (months in which eggs are laid, including replacement clutches) appears to be longer in the north, occupying most of the dry season, than in the south where it is restricted to the spring months (Table 3). This is consistent with Wyndham's (1984) hypothesis that in Australia there is an inverse correlation between latitude and the number of months suitable for breeding. Data in Barnard (1914) extend the breeding season given in Beruldsen (1980) for northern Australia, and do not support the notion of discrete autumn-winter and spring laying periods in the north and south-east respectively. Rather, the laying period contracts from May-October in the far north to August-October in the south-east.

Red Goshawks apparently have traditional nesting territories which they use in successive years, renovating the nest used in the previous season or nesting nearby, within 300 m (Lord 1952, Favaloro 1981, Cupper & Cupper 1981, Miles in Hollands 1984). Clearing of habitat caused one pair to leave a traditional site, and a subsequent nest (thought to be their new site) was 5 km away (M. Miles). Pairs attempt to breed annually (Lord 1952); an unpublished photograph shows that the nest observed by Favaloro (1981) in 1974 was the same nest as that observed in 1980 by Cupper & Cupper (1981), so the same site may be used intermittently if not continuously for at least six years. Such re-use may explain the bulk of some nests (e.g. Barnard 1934, Lord 1952), in one case (perhaps unjustifiably) thought to have been built originally by Black-breasted Buzzards (Cupper & Cupper 1981). Although the birds usually build their own nest, there are reports of Red Goshawks renovating nests used previously by Brown Falcons *Falco berigora*, crows and Australian Magpies (Hill 1911, Lord 1952, Hollands 1984).

Adult female Red Goshawk at nest

Plate 43 Photo: David Hollands

There are few observations of nest-building, but in one case a half-built nest took a further three weeks to complete and only the female built it (Barnard 1934). White (1917) referred briefly to a single bird observed building. Both sexes have been observed carrying sticks or adding to a nest (Hill 1911, I. Venables, R. Leggett). The nest is lined thickly with green eucalypt or melaleuca leaves, which are renewed frequently (often at dawn) during the nestling period (Hill 1911, North 1912, Barnard 1934, Cupper & Cupper 1981, Hollands 1984). Nests are usually placed at a considerable height, 9-25 m above the ground (average 19 m, n=11; Table 3), which indicates selection of mature trees for nest sites. Nests are placed well up in the crowns of trees (e.g. Lord 1952), in one case in the framework below the canopy (H.A. Nix); this suggests a requirement for shade over the nest. Other observations suggest a visual requirement for nest sites, e.g. on the highest point of a property, on the flank of a 150 m high hill and half way up the slope at the head of a 100 m deep gorge (M. Miles).

The clutch size is one or two eggs (mean 1.6, n=15), usually two (Table 3; Favaloro 1981, Miles in Hollands 1984). However, although both eggs sometimes hatch (e.g. North 1912), only one young fledges (Miles in Hollands 1984). This indicates a low recruitment rate. There is insufficient evidence for three-egg clutches (see Favaloro 1981).

The incubation period has not been determined, but by analogy with the larger Australian *Accipiter* and hawks of similar size to the Red Goshawk (e.g. kites, Little Eagle), it is likely to be 5-6 weeks (cf. Fleay 1981, Cupper & Cupper 1981, Debus 1984, Hollands 1984). Only the female Red Goshawk has been recorded incubating (Hill 1911, Barnard 1934, Cupper & Cupper 1981, Hollands 1984). At one nest the egg was apparently left uncovered for much of the time, at least during the day, but

Table 3
Breeding parameters of the Red Goshawk

Habitat[a]	*Nest tree species*	*Nest height (m)*	*Month*	*Stage of cycle*	*Clutch/ brood size (n)*	*Sources*
Kimberley:						
			May	building, laying (?)		
			June	egg (pipped 30.6)	1	Hill 1911
	'tall' *Melaleuca leucadendron*	24	July	building (repeat)		
Eucalypt OF around waterhole	riverine *Eucalyptus* sp.	20	July	building		R. Leggett
Top End:						
Melaleuca sp. along watercourse			April	building		White 1917
			May	eggs	2	Favaloro 1981
OW around creek bed	*Melaleuca* sp.	15	Sept	post-laying?		S.A. Parker
Gulf of Carpentaria:						
			Sept	egg (laid Aug)	1	
			Sept	eggs	2	Barnard 1914,
	Melaleuca sp.		Oct	eggs	2	Favaloro 1981
				(repeat)		
Cape York:						
	'large' bloodwood *Eucalyptus* sp.		Aug-Oct	nestling(s)		Campbell & Barnard 1917
			May	eggs		Lavery et al. 1968
	'tall' bloodwood	17	Oct	fledgling	1	Favaloro 1981[b]
Tropical eucalypt OF near gallery RF and lagoons along river	*Eucalyptus gummifera*		Sept	egg	1	Cupper & Cupper 1981[b]
			Oct	nestling	1	
South East Queensland:						
OF near swamp, along creek in hilly country	'large' *Eucalyptus tessellaris*	9	Sept	eggs	2	North 1912, C.A.
OF in range country	*Eucalyptus citriodora*	15	Aug/Sept	eggs	2	Barnard 1925, H.G.
	same nest		Oct	egg (repeat)	1	Barnard 1934, Favaloro 1981
OF in range country	*Eucalyptus citriodora*	21	Oct	hatchlings	2	
	'large' *Eucalyptus* sp. (riverine?)	23	Sept	eggs (laid Aug)	2	Jackson in Favaloro 1981
OF in deep ravine	*Eucalyptus citriodora*	24	Sept	eggs	2	Barnard in Favaloro 1981
OF (?) on hillsides	'large' *Eucalyptus maculata*		Sept	building		Lord 1952, Miles in Hollands 1984
Rugged upper reaches of river, in bed of small dry tributary	'tall tree'	14	Nov	eggs (laid Oct?), 1 hatched?	2	Beruldsen in Favaloro 1981
Eucalyptus moluccana TOF (150 trees/ha, 43% foliage cover), no subcanopy, 80% ground cover of *Themeda* and litter	*Eucalyptus tereticornis* (30 m) in drainage line	25	Sept	eggs?		Gunn et al. 1972, H.A. Nix
North-east New South Wales:						
			Sept	egg	1	S. Ellis per
Swamp sclerophyll forest			Oct	egg	1	G. Holmes

[a]OF=open forest, TOF=tall open forest, OW=open woodland, RF=rainforest
[b]these two accounts refer to the same nest in 1974 and 1980 respectively

the chick survived to hatching (Hill 1911); similarly, minimal incubation leading to successful hatching has been recorded in the Grey Goshawk (Fleay 1981). Hill speculated that the sun provided sufficient warmth during the day (which would apply if the nest was shaded; exposure to the sun may prove lethal to eggs).

The nestling period has not been determined. The nestling studied by Cupper & Cupper (1981) was still mostly downy, with feathers sprouting on the head, scapulars, wings and tail, at five weeks old. This is a much slower growth rate than *Accipiter* species which fledge by five weeks (e.g. Cupper & Cupper 1981, Hollands 1984), and by analogy with the Little Eagle (similar stage of development at five weeks: SD), the Red Goshawk's nestling period would be at least 7-8 weeks as predicted by Cupper & Cupper and Hollands. At five weeks even Black Kites are more advanced than a Red Goshawk nestling, and they may not fledge until six weeks (see photographs in Cupper & Cupper 1981, pp. 46, 203); Little eagles fledge at 8-9 weeks (Debus 1984). An unpublished photograph shows that the fledgling ('brancher') observed by Favaloro (1981) had a virtually fully grown tail; this suggests that young Red Goshawks may leave the nest at a more advanced stage than *Accipiter* (e.g. Brown Goshawks fledge with a half-grown tail: Olsen et al. 1982).

In the breeding cycle, the roles of the sexes are partitioned. During the incubation and early nestling periods the male Red Goshawk calls the female off the nest and she flies to take food at a transfer perch, with much calling ('dismissal' calls?); she feeds away from the nest in the incubation period. The male seldom if ever comes to the nest until the chick is feathered, by which time the female is also hunting; he may then deliver food to the nest although the female still feeds it to the young (Cupper & Cupper 1981, Hollands 1984).

The reaction of adults to human intruders at the nest may vary individually or with the stage of the cycle. During the incubation period the adults are confiding and inoffensive, but they may defend nestlings or fledglings against humans, swooping and calling at an intruder even though the nest tree is not climbed (Cupper & Cupper 1981, Favaloro 1981).

The post-fledging dependence period appears to be long: juveniles remain with their parents until almost seven months old, i.e. 4-5 months post-fledging (Miles in Hollands 1984). Virtually nothing is known about young Red Goshawks, but from the reports of birds some hundreds of kilometres away from known breeding areas it may be inferred that immature or non-breeding birds disperse widely. Records for New South Wales since 1970 (n=24: Debus 1982, Lindsey 1982, 1984-86, G. Holmes) are spread through the year, south to the Hunter River, but most records in spring-summer and the few records of pairs are confined to the extreme north-east corner of the state, north of the Clarence River. Thus there may be some post-breeding dispersal away from possible breeding areas near the Queensland border or known breeding areas just over the border, southwards almost to Sydney. Given the apparently low breeding density and productivity of the species, good dispersal powers may be necessary for vacancies in the breeding population to be filled rapidly by unattached birds of breeding age (as sometimes happened in the past: Hill 1911). Long-distance movements may offer another explanation for the long primaries (cf. Wattel 1973).

Observations in south-east Queensland suggest post-breeding dispersal over short distances: there are apparently no nests on the Blackall Range (adjacent to the Conondale Range where the species breeds), and the few sightings are for June-August (GVC). Movements may involve mainly immature birds, because adults are said to remain in the nesting area all year (Lord 1956, M. Miles/Atlas), although some

observations (Hughes & Hughes 1988) suggest that adults have a regular wintering area (which may represent an expanded home range, as the area adjoins extensive apparently suitable breeding habitat).

Little is known about moult in relation to the Red Goshawk's breeding cycle. Photographs (Cupper & Cupper 1981, Hollands 1984 and unpubl.) show a male and female in active wing and tail moult during the nestling period (late September-early October). Museum specimens and other data (Condon & Amadon 1954, Deignan 1964) and photographs (Qld Museum) show known or presumed adults (n=15, some breeding) in active wing and/or tail moult in March, May-July and September-December, fresh plumage in April and worn plumage in September; and known or presumed juveniles/immatures (n=6) in fresh plumage in March, worn plumage in April, May and June (?) and active wing/tail moult in October. This suggests a more protracted and individually variable moult in adults, spanning the breeding season in the tropics. Primary moult was descendant in all birds examined, but the pattern of tail moult was variable — mostly irregular (no discernible pattern) with a few birds showing the convergent mode (central and outermost rectrices lost first, then working inwards and outwards). In one bird secondary moult was three-centred. In a few birds only the tail was moulting, and in one bird the outer primaries were the newest feathers, so it is not clear whether moult finishes with the primaries or rectrices. It is also not clear whether the Red Goshawk's moult is complete each year, like *Accipiter* (e.g. Newton 1986), or partial like that of eagles (e.g. Little Eagle: SD unpubl.).

Discussion

The data suggest that the Red Goshawk differs from *Accipiter* in many aspects of its biology. These differences will be examined in detail elsewhere, but suffice it to say here that they include adult and juvenile plumages, voice, breeding biology (clutch and brood size, growth rate and development) and some aspects of display.

From the data on its structure, diet and hunting behaviour we interpret the Red Goshawk as a combination of a large *Accipiter* and a small woodland hawk-eagle *Hieraaetus*, particularly tropical bird-eating species such as Ayres' Eagle *H. ayresii* or African Hawk-Eagle *H. spilogaster* (cf. Steyn 1982, Brown et al. 1982). This combination may reflect different niches occupied by the sexes — the male like a large sparrowhawk, taking small-medium birds, the female like a hawk-eagle, taking larger birds and large terrestrial prey, as suggested by Mooney (1982) for the Grey Goshawk (though in the Grey Goshawk's case the resemblance is to short-winged, perch-hunting *Spizaetus* spp. rather than the more aerial *Hieraaetus* spp.). The *Hieraaetus* species soar or fly over the canopy and stoop at birds, or perch hunt and dash out.

From data on its distribution, habitat and diet we interpret the Red Goshawk as a specialised inhabitant of the biologically richest parts of Australia, requiring a large and diverse bird population to support it, and having a large home range and low population density like other top-order predators (e.g. Colinvaux 1978). However, in many raptors population density, home range size and hunting distance from the nest are related to effective food supply, which may be a function of prey vulnerability as well as abundance (Newton 1979, 1986). The evidence for a population decline, the distance at which birds hunt from the nest and the documented declines of many of its prey species (especially pigeons and waterfowl) suggest that the Red Goshawk may be short of food in some areas. Although some of its prey species are common and have increased in numbers since European settlement, habitat changes may have made them less accessible or perhaps it has been forced to switch (somewhat unsuccessfully?) to open-country species. The Red Goshawk may have specific

requirements for hunting habitat, open enough to manoeuvre in but providing enough cover for ambush. This may apply to aerial as well as stationary searching methods, as some observations suggest that birds flying slowly, low over or between tree crowns, use the canopy as cover from which to launch an unseen approach on prey in adjacent open areas.

The Red Goshawk appears to require a specific breeding habitat, of which it has presumably lost considerable areas. Its requirements appear to be similar to those of the Grey Goshawk (Mooney 1987), i.e. mature trees in sclerophyllous vegetation near water, though it possibly needs more open forest or woodland. The breeding data suggest a long nesting cycle (c. 4 months nest-building to fledging), slow maturation and low productivity.

Although the Red Goshawk has evidently declined somewhat in the past 200 years, its position as a top predator and its sensitivity to environmental disturbance do not fully explain its scarcity at the time of European settlement. It has been suggested that the Red Goshawk may have already been in decline before European settlement (Passmore 1981, Hollands 1984). Australia formerly supported a much richer raptor fauna, including several large eagle-like species (Rich & Van Tets 1984); since the mid Miocene, Australia's faunal diversity has declined in response to climatic deterioration and perhaps Aboriginal fire regimes (Archer et al. 1986, Schodde & Tidemann 1986). On a local scale, climatic deterioration has been implicated in the Red Goshawk's disappearance (Barnard 1925). The Red Goshawk may be a relict species that has contracted to the tropics as the continent dried out and its prey base declined. Competition from colonising large *Accipiter* species (Grey and Brown Goshawks), a hawk-eagle (Little Eagle) and most recently the Peregrine Falcon *Falco peregrinus* (which hunts over forest) may have contributed to its decline, as between them these species share 69% of the Red Goshawk's native prey species in areas of sympatry with it (cf. North 1912, Czechura 1984, Debus 1984, Czechura et al. 1987, Olsen et al. in press).

We regard the conservation of the Red Goshawk to be of high priority, particularly if (as the biological data suggest) it should remain classified in an endemic Australasian genus. Until further data are available, it would be inappropriate to recommend specific conservation or management measures. Nevertheless, existing data suggest that the most detrimental influences are mismanagement of tropical rangelands (overstocking, too-frequent burning), extensive destruction of native vegetation and drainage of wetlands.

This paper has summarised existing knowledge on the Red Goshawk at the commencement of the RAOU study of its biology. It remains for that study to obtain the quantitative data needed to confirm or amend our conclusions. The RAOU study will provide a more solid conservation data base than we have been able to assemble, and therefore deserves full support from observers able to assist with data on age and sex criteria (e.g. juvenile plumage), habitat, nest site characteristics, diet, hunting behaviour, displays and breeding biology (density, reproductive success, incubation, nestling and post-fledging dependence periods, and parental roles which may reflect hunting success and hence prey availability, cf. Newton 1979, 1986). After its completion, any subsequent field studies will enhance the bird's survival prospects. The situation will need monitoring in the future if Australia is not to lose a singular member of its avifauna.

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