

Distribution, status and habitat of the Red Goshawk *Erythrotriorchis radiatus* in Queensland

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Field surveys of the Red Goshawk *Erythrotriorchis radiatus* were conducted in south-east Queensland in 1995 and again in 2001; in northern Queensland in 1999; and on Cape York Peninsula in 2000. In south-eastern Queensland, Red Goshawks were found at 25 localities in 1995, representing at least 10–12 (possibly up to 16) resident pairs; breeding was suspected but not confirmed at one site. In 2001, records representing 15–16 pairs were obtained, with breeding confirmed at one site, reported in prior years at a second site, and confirmed at another site after the survey in 2003. In northern Queensland, Red Goshawks were found or reported at 23 localities in the eastern parts, representing 5–8 pairs (one with a fledgling), and three nests (one active) were found. On Cape York Peninsula, Red Goshawks were found at 20 localities. The records included nine pairs and three active nests; most of these (including the active nests) were in central and eastern parts of the Peninsula. Red Goshawks inhabit biodiverse, extensive, multi-species mosaics of mainly eucalypt-dominated open forests and woodlands, in permanently watered, varied terrain, and nest high (>20 m) in emergent trees with an open limb and canopy structure. The Queensland population is estimated at up to 135–140 pairs (10–30 in the south-east, 30–35 in the north-east, and 60–70 on Cape York Peninsula). Identified key threats include habitat clearance, logging of nesting habitat, and loss or degradation of freshwater wetlands. Recommendations for the species' conservation and management include further survey and monitoring, and ecological research.

INTRODUCTION

The endemic Red Goshawk *Erythrotriorchis radiatus* is listed as *vulnerable* nationally and in the Northern Territory, *rare* in Western Australia, *endangered* in Queensland (Qld), and *critically endangered* in New South Wales (NSW), under relevant federal and state legislation. It formerly occurred south to Sydney, but has all but disappeared from that state, and was historically widespread and fairly frequently encountered in coastal eastern Queensland (e.g. Debus and Czechura 1988; Debus 1993; Debus *et al.* 1993a, b; Marchant and Higgins 1993). It forms an Australasian endemic genus with only one close relative in New Guinea, the Chestnut-shouldered Goshawk *E. buergersi*, and part of an 'old endemic' raptor assemblage not allied to *Accipiter* (e.g. Debus 1998).

The Red Goshawk's ecological requirements in eastern Australia are poorly known compared with the information collected on the species in the Northern Territory and Kimberley region of Western Australia (Aumann and Baker-Gabb 1991; Marchant and Higgins 1993). Previous reviews of the bird's ecology in Queensland describe aspects of its forest or woodland habitat in general terms (Debus and Czechura 1988; Debus *et al.* 1993b; Marchant and Higgins 1993). Findings from our recent study of the Red Goshawk's breeding biology (including nest-site characteristics), diet and foraging behaviour in Queensland are reported elsewhere (Czechura *et al.* 2009). Desktop studies and preliminary habitat modelling in Queensland have also been conducted, for the South Eastern Queensland Bioregion (Ward 2000; Stewart 2006).

In this paper, we report the results of surveys aimed at determining the Red Goshawk's distribution, population status and habitat use in south-eastern and northern Queensland.

STUDY AREAS AND METHODS

Much of this study relied on prior knowledge of the Red Goshawk's broad ecology and occurrence in Queensland (Debus and Czechura 1988; Debus *et al.* 1993a, b; Marchant and Higgins 1993), and consideration of prevailing topography and vegetation. Earlier (private) surveys by GVC and past reliable sightings by credible observers were used to identify priority locations for survey: primarily extensive forested areas with permanent water.

An initial field survey was conducted by GVC (with supporting information from RGH) in south-east Queensland primarily during January–August 1995, supplemented by other Red Goshawk sightings obtained between September 1994 and February 1996. Surveys were conducted across the area bounded by Mackay in the north (Central Mackay Coast Bioregion), Dalby in the west (Brigalow Belt South Bioregion) and the New South Wales border in the south (South Eastern Queensland Bioregion; Thackway and Creswell 1995) – see Figure 1. Priority was given to regions where human impact was great (to identify remnant Goshawk populations or important habitat), or where local conditions and topography provided vantage points. Selected sites ($n = 23$ locations) were then visited for 2–3 days each, with observers stationed at observation points. One suspected nesting area, occupied by a pair, was visited regularly during the breeding season

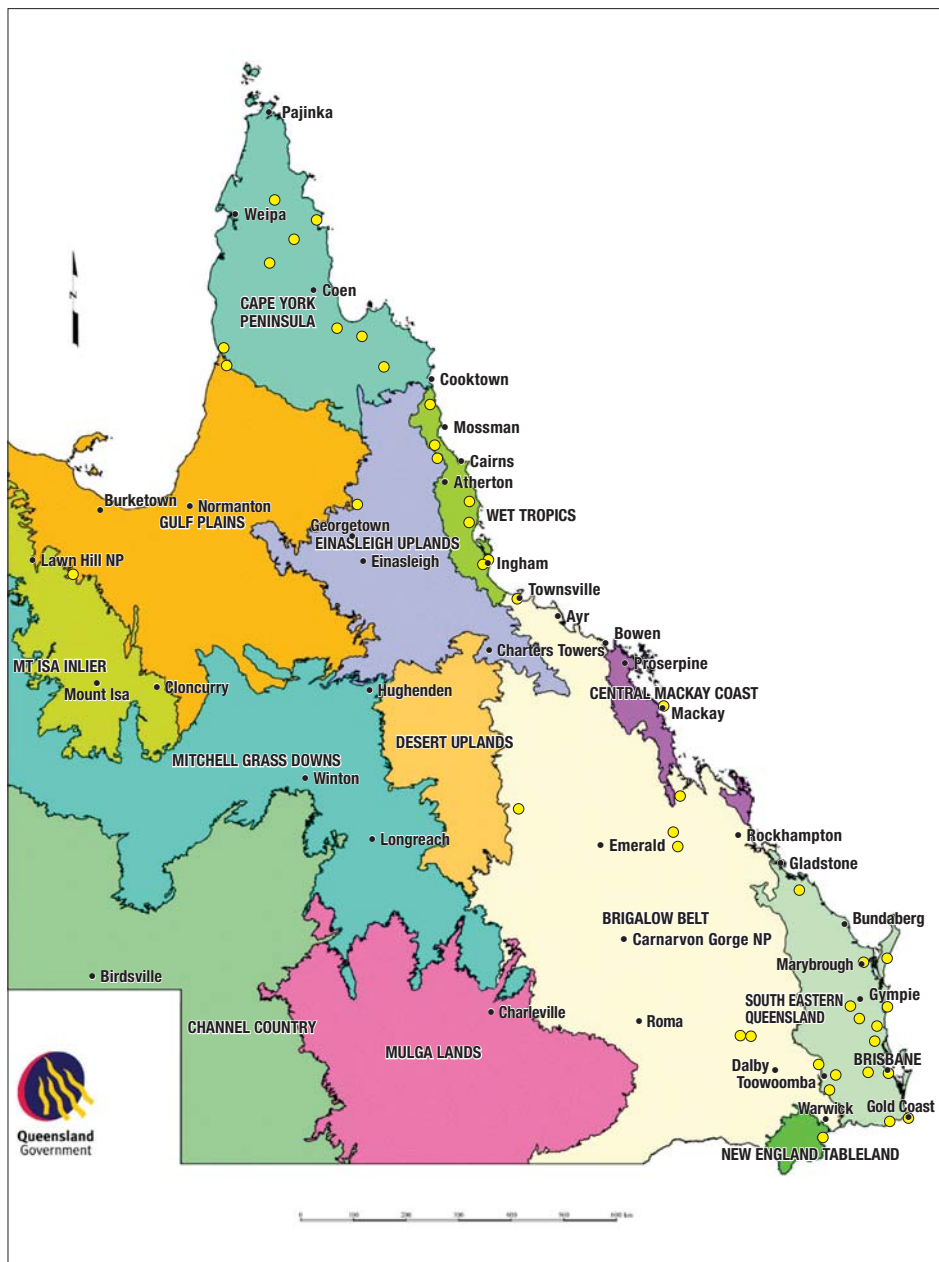


Figure 1. Red Goshawk records in Queensland, incorporating the survey results of this study. Source: Qld DERM Red Goshawk conservation management profile (prepared by S. Ryan, 2006) overlain on the Bioregional Map of Queensland V0001 (courtesy of Qld DERM).

(September 1995–February 1996). Selected volunteer observers were also recruited to the project, for their additional sightings during the survey period.

The field sites surveyed in south-east Queensland in 1995 were re-surveyed in 2001, with the exception that the region was re-defined as the South Eastern Queensland Bioregion. Hence, some of the most northern and inland locations in the 1995 survey (Central Mackay Coast and Brigalow Belt bioregions) were excluded. Field surveys for Red Goshawks (Border Ranges north to Gladstone and Carnarvon Gorge, inland to the Great Dividing Range) were conducted in 2001

via: (i) a search by RGH in February–June ($n = 14$ sites), and (ii) a volunteer-based survey co-ordinated by DAS ($n = 12$ locations, 124 volunteer-days). Volunteers either stayed at vantage points, scanning for Red Goshawks, or drove along roads and tracks through suitable habitat, for at least one day per month through the year, and the survey effort included nest searches in likely habitat ($n = 24$ volunteer-days). A desktop analysis of Red Goshawk records in the bioregion was also conducted by DAS, using the Queensland Wildnet (fauna atlas) database, the results of the 1995 survey, and records from the 2001 survey. After vetting the records, all reliable historical and recent records were mapped (Figure 1).

Field surveys for Red Goshawks were conducted in northern Queensland (Townsville north almost to Coen and west to Burketown and Lawn Hill National Park) in August–December 1999 by GVC and RGH, and on Cape York Peninsula (Georgetown–Mt Surprise north to Pajinka) in September 2000–January 2001 by GVC. Priority was given to areas where sightings had been reported previously, and where vegetation structure and/or floristics were similar to where the species had been found in southern Queensland in 1995. In 1999, surveys focused on the Einasleigh Uplands Bioregion, owing to the proposed expansion of sugar plantations and land-clearing for grazing, and on coastal parts of the Wet Tropics Bioregion where large areas of forest and woodland still extended onto the coastal lowlands from the ranges. Surveys were guided by reliable sightings from credible observers, existing information and the presence of apparently suitable habitat, and by discussions with local observers (notably J. Young, J. Augusteyn, L. Nielsen and staff of the Queensland Parks and Wildlife Service and the Qld Department of Natural Resources). Based on previous experience and information, areas assigned high priority for survey had extensive open forest and woodland, permanent water and varied topography. Selected sites ($n = 155$ sites across 23 areas in 1999, 180 across 13 areas in 2000) were then visited for 1–3 days each (unless sightings were made sooner), with observers stationed at observation points.

Surveys did not achieve total coverage of areas investigated, given that these raptors are difficult to locate and that many areas of habitat were inaccessible (terrain, weather conditions and lack of suitable observation points) at the time of the surveys. It is inevitable that pairs were missed. Consequently, upper estimates of the likely total population size for a given region were reached by calculating the number of pairs recorded in the area surveyed and the total area of suitable habitat available. This relation between pairs and habitat was used to calculate the likely number of undetected pairs present in relation to the extent of suitable habitat in unsurveyed parts of each region. Since these surveys, several breeding pairs were reported from unsurveyed areas of suitable habitat (Cape York and north Queensland).

For Red Goshawk sightings, the location was recorded by GPS, and the topography, water conditions, and vegetation types present within approximately one kilometre of the sighting were recorded. Major vegetation types within five kilometres of sightings on Cape York Peninsula were also identified from vegetation maps (Qld Herbarium's Cape York maps: Neldner and Clarkson in prep.). This latter information was primarily used to gauge the distribution of vegetation types beyond the immediate area of the sightings and to indicate vegetation types likely to be of highest value for Red Goshawks. This process was carried out only on Cape York because of the level of vegetation mapping available for that region. During the north Queensland surveys, all the provinces within the Cape York Peninsula Bioregion were surveyed (25 sites in 1999, 180 in 2000). As well, in 1999 surveys were conducted in the Einasleigh Uplands (6 provinces, 39 sites), Wet Tropics (9 provinces, 58 sites), Gulf Plains (7 provinces, 23 sites), and Mt Isa Inlier bioregions (3 provinces, 10 sites) (after Thackway and Creswell 1995; Sattler and Williams 1999) – see Figure 1.

In all field surveys conducted by GVC and RGH, searches for Red Goshawks were undertaken from suitable elevated viewing points, on foot, by driving along road networks, and

by a combination of these methods. Observations were made with 10 × 40 or 10 × 42 binoculars, and a 25× or a 20–60× zoom telescope. At all survey sites, a record was kept of avian diversity (i.e. potential prey populations) in the form of species lists based on sight records and subjective assessments of abundance and distribution. Habitat classifications followed the structural categories of Specht (1970) and regional ecosystems of Sattler and Williams (1999). As individual Red Goshawks are mobile and wide-ranging (Marchant and Higgins 1993), we consider habitat at the level of vegetation structural type and dominant tree species.

Red Goshawks are difficult to identify, and other reddish-brown raptors (notably the Square-tailed Kite *Lophoictinia isura*, female Swamp Harrier *Circus approximans* and rufous Brown Falcons *Falco berigora*) are often misidentified as Red Goshawks, leading to possible false positive records (e.g. Debus 1998; Czechura and Field 2007). Hence, records from informants and databases were vetted to ensure reliability.

RESULTS

South-east Queensland

During the first survey in the mid-1990s, Red Goshawks were encountered at 12 localities, and credible reports were received from a further 13 localities. Of these, pairs were recorded at seven, possibly nine, localities during the field survey, and earlier sightings and credible reports added a further three pairs (total 12 pairs). Breeding was not confirmed, but a possible nest (based on the behaviour of the pair) was suspected in remote and inaccessible terrain. Including suspected pairs, there may have been up to 16 pairs detected in the survey region. On the foregoing basis, the population is estimated at somewhere between 10 and 15 pairs. A maximum of 25–30 pairs is indicated in the region surveyed, if the total area of suitable habitat is taken into account.

Red Goshawk records were distributed throughout the region, coastally and inland to the western slopes of the Great Dividing Range. Consistently recorded pairs were associated with permanently watered, rather remote areas of rugged terrain supporting mosaics of tall vegetation, primarily forest (Table 1). All 14 of these pair locations supported at least three different native forest types, and over half of them supported at least four native vegetation types. Nine of these 14 localities supported araucarian notophyll vine forest–araucarian microphyll vine forest (or similar vine scrubs)–open forest mosaics. All locations included riverine habitat, and 10 locations were in dissected terrain. Lowland, temporary freshwater wetlands were used by the Red Goshawks in autumn–winter, around which they appeared to maintain non-breeding home ranges.

Eighty-one regional ecosystems were present across the Red Goshawk localities in the broader south-east Queensland region surveyed in 1995. These were mostly eucalypt-dominated, open forest/woodland types, with common trees being Forest Red Gum *Eucalyptus teretricornis*, ironbarks (notably Narrow-leaved *E. crebra*), bloodwoods *Corymbia* spp. (notably Pink Bloodwood *C. intermedia* and Lemon-scented Gum *C. citriodora*), and Broad-leaved Paperbark *Melaleuca quinquenervia*.

During the second field survey in 2001, Red Goshawks were encountered at four localities, and credible reports were

TABLE 1

Broad habitat features of significant Red Goshawk localities ($n = 14$, representing Goshawk pairs) in south-eastern Queensland: number of Goshawk locations at which each habitat type was present. Vegetation classifications follow the structural types of Specht (1970). Vine Forest and Vine Thicket = subtropical/warm temperate and dry rainforest of Young and McDonald (1987), respectively. Plantations (P) of native and exotic softwoods and Farmland (F) were also recognised. Freshwater was classified as Riverine, Lakes or Dam(s) (= artificial impoundment). Topography = major patterns of relief.

Habitat type	<i>n</i> sites	Habitat type	<i>n</i> sites
<i>Vegetation:</i>		<i>Water:</i>	
Vine Forest	9	Riverine	14
Vine Thicket	10	Lakes	1
Tall Open Forest	10	Dam(s)	5
Open Forest	14		
Tall Woodland	6	<i>Topography:</i>	
Woodland	3	Dissected terrain	10
Tall Shrubland	1	Escarpment(s)	7
Closed Heath	1	Gorges	9
Plantation	1	Rock outcrops	1
Farmland	5	Undulating	4

received from volunteers for a further five localities. Of these, pairs were recorded at three localities and a pair was previously known from a fourth (where a single bird was seen during the survey). A newly fledged juvenile was observed at one of these localities, and a suspected nest, active in prior years, was reported at another (not the suspected 1995 nest). In 2003, an active nest was found in the south of the region.

Survey effort was not equivalent to that of 1995. However, including the desktop records ($n = 283$ historical and recent), clusters of records representing 15 or 16 pairs were identified in the South Eastern Queensland Bioregion. This result is similar to the 1995 findings, after excluding the 1995 records from outside the bioregion. Red Goshawks were again found to be distributed sparsely throughout the bioregion.

Northern Queensland

During the survey in 1999, Red Goshawks were encountered at 17 localities, and credible reports were received from a further six localities, across the Wet Tropics, Einasleigh Uplands and lower Cape York Peninsula bioregions. Of these, pairs were recorded at five localities (including one with a fledgling), and suspected at a further three. Three nests (one active) were found (Einasleigh Uplands and Cape York Peninsula bioregions). No confirmed sightings or nests were obtained for the Gulf Plains and Mt Isa Inlier bioregions (though there were several probable sightings), and few sightings were obtained between Mossman and Cooktown. Otherwise, the Goshawk was widespread in the

eastern part the survey area, with records extending towards the lower west of Cape York Peninsula.

Red Goshawks were recorded in all nine provinces of the Wet Tropics Bioregion, four of six in the Einasleigh Uplands Bioregion, and two of three sampled on the lower Cape York Peninsula Bioregion. The Goshawks were encountered mainly in areas still supporting extensive uncleared mosaics of native vegetation (especially riparian gallery forest, open forest and woodland), on varied topography (Table 2). Most sightings were made along the escarpments and foothills of coastal and subcoastal ranges. Open forests and woodlands that contained a mix of tall (>20 m) ironbark, other eucalypt and bloodwood species appeared to be favoured; Red Goshawks were not found in extensive areas of closed forest despite several survey sites being located in such vegetation types. They frequented well-watered areas where freshwater streams and wetlands were present.

Sixteen of the 17 locations supported at least three different native forest or woodland types, and over half of them supported at least five native vegetation types. All locations included riverine habitat, and 11 locations were in dissected or rugged terrain (Table 2). Red Goshawks frequented many regional ecosystem types that have been extensively cleared. Seventy-eight regional ecosystems were present across the Red Goshawk localities in north-east Queensland. These were mostly eucalypt-dominated, open forest/woodland types, often multi-species stands with several eucalypts and others (e.g. *Melaleuca*, *Lophostemon*). Common trees there included red gums, ironbarks and a variety of bloodwoods.

The Red Goshawk survey encounter rate suggests that it is an uncommon to rare breeding species mainly in the eastern parts of northern Queensland. On the basis of the survey results, and the total area of suitable habitat (from estimates of vegetation cover by Keto and Scott 1986), the population is estimated to be in the order of 25–30 pairs in the Wet Tropics and Einasleigh Uplands bioregions.

Cape York Peninsula

Red Goshawks were encountered at 20 localities, including nine pairs and three active nests (including the nest observed during the 1999 north Queensland survey). One sighting was made in the Wet Tropics Bioregion, two in the Einasleigh Uplands Bioregion and 17 in the Cape York Peninsula Bioregion. Sightings were made on the coastal plains of both eastern and western sides of the Peninsula, and along escarpments and foothills of ranges. Most records were from central and eastern Cape York Peninsula, an apparent 'core' area, and almost all of these were from two provinces: the Coen-Yambo Inlier and the Laura Lowlands, with one from the Battle Camp Sandstones. However, areas farther north were not adequately surveyed, owing to the early onset of the wet season, but they support apparently suitable habitat (especially the Weipa Plateau). A recent record from suitable habitat near Weipa (F. Mikula pers. comm.) confirms the Goshawk's presence in this province.

Red Goshawks were generally encountered in areas supporting extensive uncleared mosaics of native vegetation, consisting of riparian forest, tall woodland, woodland, open woodland and shrubland (especially vegetation dominated or co-dominated by Darwin Stringybark *Eucalyptus tetrodonta*, Molloy Red Box *E. leptophleba*, bloodwoods *Corymbia* spp.

TABLE 2

Broad habitat features of Red Goshawk localities in north-eastern Queensland (1999 survey, $n = 17$) and Cape York Peninsula (2000 survey, $n = 17$): number of Goshawk locations at which each habitat type was present. Vegetation classifications follow the structural types of Specht (1970), with the addition of Riparian to indicate local, distinctive vegetation types associated with watercourses and wetlands, and Disturbed to indicate areas cleared for farms, plantations and housing.

Habitat type	<i>n</i> sites		Habitat type	<i>n</i> sites	
	1999	2000		1999	2000
<i>Vegetation:</i>			<i>Water:</i>		
Closed Forest	7	5	Rivers, creeks	17	17
Low Closed Forest	2		Lakes	1	7
Tall Open Forest	3		Swamps, marshes	4	4
Open Forest	8	1			
Tall Woodland	1	7			
Woodland	17	17			
Low Woodland	9	2	<i>Topography:</i>		
Open Woodland	2	12	Mountainous	2	
Low Open Woodland		13	Escarpments, foothills	6	5
Shrubland		2	Dissected terrain	7	9
Open Heath		2	Undulating	12	8
Tussock Grassland		5	Plains	5	8
Sedgeland		2			
Riparian	16	7			
Disturbed	6	3			

or paperbarks *Melaleuca* spp.). Nesting habit appeared to be tall woodland dominated by Darwin Stringybark, often with bloodwoods, especially Clarkson's Bloodwood *C. clarksoniana*, Melville Island Bloodwood *C. nesophila* and Hyland's Bloodwood *C. hylandii* var. *peninsularis*. Red Goshawks were recorded in well-watered areas with freshwater streams, lagoons and wetlands. All localities had varied topography; however, relatively more sightings were made in plains country (i.e. coastal plains) than elsewhere in Queensland (cf. Tables 1, 2).

All of the 17 locations supported at least three different native forest or woodland types, and two-thirds of these supported at least five native vegetation types. All locations included riverine habitat, and 10 locations were in dissected terrain (Table 2). Red Goshawks frequented many of the regional ecosystems on Cape York Peninsula ($n = 45$ types across the Red Goshawk locations): mostly eucalypt-dominated woodland and tall woodland types, sometimes with *Melaleuca*; common trees included Darwin Stringybark and a variety of bloodwoods.

The Red Goshawk survey encounter rate suggests that it is an uncommon to rare species in the region. On the basis of our survey results, and assuming a mean of 20 kilometres between neighbouring pairs in the Coen-Yambo Inlier and Laura Lowlands provinces (using data from Aumann and Baker-Gabb 1991 and Czechura *et al.* 2009), the total breeding population is

provisionally estimated to be in the order of 65–70 pairs on Cape York Peninsula. This estimate was reached by using vegetation maps to identify areas of Cape York Peninsula containing a similar mix and distribution of vegetation types to those found in the immediate area of the known nests (i.e. 1 km radius from nests), and assuming that a similar density of breeding pairs to that observed in the Coen-Yambo Inlier and Laura Lowlands existed in these areas. However, it is likely that this approach has underestimated population size by excluding alternative habitat mixes and breeding densities. For example, inter-nest distances elsewhere in the Tropics have been revised down from approximately 20 kilometres to approximately 10 kilometres, following new data from recent surveys (Baker-Gabb 2005). The Peninsula is clearly a stronghold for this species in eastern Australia.

Population status

The upper estimates of breeding population size indicated by this survey, 10–30 pairs in South Eastern Queensland Bioregion, 25–30 pairs in the Wet Tropics and Einasleigh Uplands bioregions, 65–70 pairs on Cape York Peninsula Bioregion and possibly five pairs in the Mt Isa Inlier Bioregion, suggest that up to 135–140 breeding pairs remain in Queensland. This estimate is lower than a probably conservative estimate of 180 breeding pairs historically in Queensland (Aumann and Baker-Gabb

1991). Comparison of these figures suggests that a population decline (>20%) is likely to have occurred in recent times. The extent of this apparent decline cannot be fully assessed, because parts of the Red Goshawk's historical range (i.e. Central Mackay Coast hinterland, Brigalow Belt including the Great Dividing Range and associated spur ranges, and most of the Gulf Plains) have yet to be fully surveyed.

DISCUSSION

South-east Queensland

The field surveys and credible records indicate that the Red Goshawk is still broadly distributed across southern Queensland, including in many areas where it has been recorded since the 1950s (cf. Debus and Czechura 1988; Debus *et al.* 1993a, b). However, its population density appears to be lower than in northern Australia, with pairs more scattered: a situation probably attributable to extensive past and continuing habitat fragmentation in southern Queensland. The Red Goshawk's past, and perhaps even current, distribution appears to be somewhat broader than predicted by BIOCLIM analysis (cf. Aumann and Baker-Gabb 1991). That is, it may extend farther inland to the western slopes of the Great Divide, at least in the north of the region (cf. Debus and Czechura 1988; Debus *et al.* 1993; this study). There is insufficient information to assess the extent of the Red Goshawk's population decline in the region, but it was clearly once more abundant around Brisbane and the coastal lowlands than it is now (cf. Debus *et al.* 1993a, b). The few remaining pairs on the coast are in large reserves protected from extensive clearing.

The four known breeding sites of the Red Goshawk in the region are widely dispersed, in the Border Ranges, Lockyer Valley, Conondale Range/Mary Valley (Favaloro 1981) and Great Sandy coast. Thus, breeding still occurs, if sparsely, in the bioregion south to the New South Wales border.

Northern Queensland

The Red Goshawk's distribution, population status and habitat in northern Queensland, as inferred from this study, are in general agreement with previous interpretations (Debus and Czechura 1988; Aumann and Baker-Gabb 1991; Debus *et al.* 1993a, b; Marchant and Higgins 1993). If the Red Goshawk occurs as a resident breeder in the Mt Isa Inlier and Gulf Plains bioregions, it is less abundant there than in the eastern bioregions (Wet Tropics, Einasleigh Uplands and Cape York Peninsula). These results suggest: (i) a possible break in distribution around the Gulf of Carpentaria (with perhaps mainly dispersing Goshawks occurring there); (ii) the species is rare and localised in the Mt Isa Inlier; and (iii) an apparent break in distribution along the Wet Tropics coast, possibly related to habitat clearance (cf. Cogger *et al.* 2003), and (iv) may reflect very low sampling effort in the Gulf Plains (no systematic fauna surveys conducted in a bioregion that is largely inaccessible, especially during the wet season).

The Red Goshawk's distribution in northern Queensland agrees with BIOCLIM analysis (cf. Aumann and Baker-Gabb 1991). However, the species is likely to have suffered a range contraction in north-east Queensland, especially along the highly settled parts of the coast. Extensive deforestation (forest, woodland and riparian forest) along coastal eastern Australia has been identified as a major cause for the decline of Red Goshawks (Marchant and Higgins 1993). The impact of

farming and urbanisation on coastal habitats can be seen in the high percentage of endangered regional ecosystems identified throughout coastal eastern Queensland (Sattler and Williams 1999; cf. Cogger *et al.* 2003). Other factors likely to contribute to the scarcity of Red Goshawks in coastal areas include uncontrolled pre-wet season burning of remaining open forests and woodlands and declines in larger prey species.

Cape York Peninsula

Red Goshawks were recorded over much the same area as in the past (cf. Debus and Czechura 1988; Debus *et al.* 1993a, b; Marchant and Higgins 1993). This pattern broadly agrees with BIOCLIM analysis (cf. Aumann and Baker-Gabb 1991), although breeding was recorded or indicated (by the aerial displays of pairs) in our surveys in several half-degree grids flagged as 'less suitable' by BIOCLIM. Together with our survey results elsewhere in Queensland, this outcome suggests that the BIOCLIM model is either too conservative or too coarse (e.g. unable to identify localised pockets of prime breeding habitat).

Red Goshawks were recorded frequently in the eastern coastal lowlands of the Peninsula, more so than for areas farther south. The high incidence of records in eastern and central Cape York Peninsula, and relatively high breeding density, suggest that habitat quality is high in these areas.

The pattern of historical and recent records suggests that the Red Goshawk population on Cape York Peninsula is stable. In addition, our surveys found Red Goshawks in areas where they had not been recorded previously. None of the regional ecosystems occupied by Red Goshawks in the bioregion is currently at risk, which contrasts with the rest of their Queensland range (cf. Sattler and Williams 1999). However, current fire regimes may change this situation by encouraging invasion of open wooded habitats of the Red Goshawk, and other endangered species such as the Golden-shouldered Parrot *Psephotus chrysopterygius*, by dense woody shrubs (Olsen and Weston 2005; Crowley *et al.* 2009). Following recent vegetation assessments in the Tropics, this 'thickening' of Red Goshawk habitat, owing to the combined impacts of changed fire regimes and grazing, may be a very widespread and important threat that has hitherto not been adequately highlighted by previous work (D. Baker-Gabb pers. comm.).

Habitat

Red Goshawks appear to use areas of varied vegetation for both hunting and breeding sites. Mosaics of different vegetation types, near permanent freshwater, are likely to support a diversity of potential prey species throughout the year, e.g. nectar-feeding, frugivorous or seed-eating birds in various seasons according to flowering and fruiting cycles, and waterbirds in other seasons (although there are only occasional records of waterbirds as prey). Lowland, freshwater wetlands appear to be important foraging habitat in autumn–winter, at least in south-east Queensland (see also Hobson 1992).

Open forest and woodland are suited to the search and attack techniques of this long-winged hawk (Aumann and Baker-Gabb 1991; Marchant and Higgins 1993), and ecotones are likely to be profitable areas for prey that can be ambushed or pursued and captured in adjacent open forest or woodland (cf. Czechura *et al.* 2009). Hence, the threat from habitat 'thickening', as highlighted by D. Baker-Gabb (pers. comm.). Tall trees, with

an open growth form (*sensu* Brooker and Kleinig 1996), in open forest, woodland and riparian forest, provide the Red Goshawk with its preferred high (>20 m) nest sites in emergent trees, with easy access and space for the male to manoeuvre large sticks into the nest (Aumann and Baker-Gabb 1991; Czechura *et al.* 2009). The taller forms of open forest and woodland, riparian or within one kilometre of water, support suitable breeding habitat: notably those types dominated by Darwin Stringybark, ironbarks and other eucalypts, various bloodwoods, and Weeping Paperbark *Melaleuca leucadendra*. Nests are also within 1–2 kilometres of paperbark woodland and riparian foraging habitat.

Too few nests were found to test the predictive models of Ward (2000) and Stewart (2006) for South Eastern Queensland, and indeed Stewart (2006) observed no Red Goshawks during an attempt to ground-truth the model at seven sites in the bioregion in May 2006. A more productive approach might be to use GIS to compare habitat components at a landscape scale (e.g. forest or woodland type and cover, distance to permanent freshwater, ruggedness index), in radii around the Red Goshawk sightings and nests in this study, with those around a random sample of points within their Queensland range.

Threats

Threats or potential threats to Red Goshawks and their habitats, identified during these surveys, included habitat destruction (clearing of open forests and woodlands); logging of potential nesting habitat (especially of tall trees with an open limb and canopy structure near permanent streams); loss or degradation of freshwater wetlands that may reduce prey abundance during winter; fire (pre-wet season burning); effects of grazing by livestock and feral herbivores on ground-feeding prey species (pigeons) in open forest in the South Eastern Queensland Bioregion; decline of open-country and woodland prey species, particularly in the tropical savanna woodlands (Franklin 1999, 2000; Franklin *et al.* 2005); and human disturbance (including birdwatchers and egg collectors).

In eastern Queensland, clearing has targeted the regional ecosystems frequented by the Red Goshawk, to the extent that one-third to nearly half of these ecosystems are *of concern* or *endangered* (Sattler and Williams 1999). Logging of 'overmature' nest-tree species along permanent streams may reduce nest-site availability or quality (e.g. height, canopy density), and thus lead to lower breeding productivity through nestling mortality. 'Cash sale' logging on private and leasehold land was evident during the north Queensland survey, and selective logging occurred near one of the Cape York lowland nests. Natural freshwater wetlands are subject to drainage, salination, siltation, eutrophication and pollution. Uncontrolled, hot, late dry-season fires in the Tropics threaten Red Goshawk nest trees and nestlings (Aumann and Baker-Gabb 1991), and prolonged smoky fires around the Red Goshawk's nest trees may be a problem. During our Cape York survey, one nest tree (with an active nest) was saved from catching fire only by direct intervention (J. Young pers. comm.). The prevailing fire regime also potentially degrades foraging habitat and reduces prey availability (see Olsen and Weston 2005). Red Goshawks and their nests are subject to intrusion by birdwatchers seeking a rarity, with the potential for nests to be betrayed to would-be egg collectors by the broadcast of nest locations (precise GPS coordinates) over the Internet (e.g. on the Birding-Aus chatline: see Moorhead 2005 and editor's comment). However, some

nests well known to ecotourism operators are effectively under surveillance, thus deterring collectors.

CONCLUSIONS AND RECOMMENDATIONS

Red Goshawks occur at low densities across eastern Queensland, to the western slopes of the Great Dividing Range. Habitat types utilised by Red Goshawks are currently considered secure on Cape York Peninsula, but much less so in south-east Queensland and north-east Queensland. Most Red Goshawk pairs were found in the existing State Forest/National Park reserve system, although it should be noted that extensive clearing was still occurring in the vicinity of most of the significant Red Goshawk sites identified in this study (e.g. Cogger *et al.* 2003), i.e. those areas occupied by resident breeding (or probably breeding) pairs.

The presence of Red Goshawks in areas of high biodiversity suggests that it should be regarded as a potential 'flagship' species indicating the broad biological significance of a given area (further explored by Czechura in prep.). Its present association, in southern and north-eastern Queensland, with rugged terrain may be an artifact of past patterns of habitat clearance, an interpretation supported by the pattern of early records (e.g. Debus *et al.* 1993a, b). Concomitantly, the Red Goshawk's estimated total State population (≤ 140 pairs) appears to be at least 20 percent lower than a conservative historical estimate of 180 pairs.

The Red Goshawk is the subject of several recovery plans and outlines that set out research and management actions for the species (e.g. Garnett and Crowley 2000; Baker-Gabb 2005). Our survey results suggest the following recommendations for further investigation and management in the context of these plans:

- Research on the Red Goshawk's ecology and movements (e.g. by radiotelemetry) in Queensland, as previously conducted in northern Australia (cf. Aumann and Baker-Gabb 1991), including territory dynamics and relationship with seasonal influences and prey populations.
- Investigation of population density and status (e.g. population viability analysis).
- Further surveys in south-east Queensland (e.g. Border Ranges, Main Range, eastern escarpment of the Great Divide; Carnarvon Gorge–Chesterton Range), northern Queensland (Mt Isa Inlier, Gulf Plains, Wet Tropics) and Cape York Peninsula (Coen-Yambo Inlier, Laura Lowlands, Weipa Plateau, Jardine River, Bamaga), to obtain a better estimate of population size and breeding status.
- Resurvey the Goshawk population in the South Eastern Queensland Bioregion after 10 years (i.e. in 2011).
- Conservation and management studies, including investigation and monitoring of hydrological changes in known wintering areas, and monitoring of pesticides in other raptors in intensive agricultural areas near Red Goshawk habitat.
- Adequate pre-logging nest searches in State Forests, similar reserves and leasehold lands that potentially support Red Goshawk breeding pairs, to exclude nesting habitat from logging (alternatively, predicted areas of prime nesting habitat, as identified by survey data and desktop analyses, could be applied).

- Ensure adequate protection of watercourses and riparian forest where large-scale clearing occurs near known or suspected Red Goshawk nests.
- Review fire regimes (especially in reserves) in known or suspected Red Goshawk breeding areas, to reduce impact during the breeding season and encourage fire regimes that maintain open woodland habitat by preventing vegetation thickening.

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