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Grassfinch decline and local extinction of the Crimson Finch *Neochmia phaeton* in the Fitzroy River Basin, Queensland

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Abstract. Many granivorous birds of northern Australia, including several species of grassfinches (Estrildidae), have suffered substantial range contractions in the last 50–100 years, apparently as a result of changes in cattle grazing and fire-management regimes. The Crimson Finch *Neochmia phaeton* was once widespread in woodlands and savannas of north-eastern Australia, including the extensive Fitzroy River Basin, where it was recorded in all the major subcatchments until the middle of last century. However, surveys in 2006–2008 show that it is now confined to a relatively small area in the north-east of the Basin. A tall river grass, Chionachne *Chionachne cyathopoda*, is an important component—for food and cover—of its habitat. Complex braiding of river channels, as at the confluence of rivers, is typical of the area where the Finches have persisted, possibly because it increases the availability of water and food, and reduces pressure from cattle grazing during the wet season. A recent local loss of the species was noted in one area where landholders used riparian fencing to maintain greater grazing intensity throughout the year, leading to suppression of Chionachne seeding. Thus, although generally favourable for conservation management, riparian fencing can also be used detrimentally. The loss of one local subpopulation of Finches following changed management practices demonstrates that cattle grazing alone, in the absence of changed fire management, has the capacity to alter habitat suitability for granivorous species.

Introduction

Worldwide, many granivorous birds show declining trends in population size, particularly in northern Europe where agricultural practices have intensified (Siriwardena *et al.* 2001a,b). In Australia, ~20% of land bird species are granivores, one-third of which have declined (Franklin 1999; Franklin *et al.* 2000). Declines have been most severe in the subtropical and tropical woodlands and savannas of northern Australia, including for five of the 15 endemic grassfinch species, four of which are listed as threatened under Australian biodiversity protection legislation (Franklin *et al.* 2005; Forshaw *et al.* 2012; DSEWPaC 2013). Australia's only extinct mainland bird species, the Paradise Parrot *Psephotellus pulcherrimus*, was a granivorous species restricted to this region (Franklin 1999; Higgins 1999). Paradoxically, these declines and losses amongst granivorous bird species have occurred in an area with one of the most extensive tracts of 'natural' vegetation in the world and in an area with a low level of development (mainly low-intensity cattle grazing) (Franklin 1999; Franklin *et al.* 2005).

Within the extensive Fitzroy River Basin in north-eastern Australia (the second largest ocean-flowing catchment in Australia, with an area of 142 655 km^2), four finch taxa present at the time of European settlement are now locally extinct or very rare (Higgins *et al.* 2006). The Southern Star Finch *Neochmia ruficauda ruficauda* once occurred from Cape York Peninsula, Queensland, to northern New South Wales (Holmes 1996, 1998), but is now possibly extinct (Storr 1984; Higgins *et al.* 2006). The Southern Black-throated Finch *Poephila cincta cincta* was common in the Rockhampton area of Queensland until the 1960s, but has now contracted north to small remnant populations near Townsville and in the western Burdekin River catchment (Storr 1984; NSWDECC & QPWS 2007). The Diamond Firetail *Stagonopleura guttata* occurred across the Fitzroy River catchment, but its range has contracted to the south of this region (Higgins *et al.* 2006). The Crimson Finch *Neochmia phaeton* was recorded from all of the main Fitzroy subcatchments including as far south as the upper Dawson River, but in the last 25 years has been consistently recorded only in small sections of the Isaac–Connors and Mackenzie Rivers in the north-east of the Fitzroy Basin, Queensland (Storr 1984; Wilson 1988, 1990; Holmes 1996; Higgins *et al.* 2006; Boisen *et al.* 2010). As the last representative of this suite of extinct or declining grass-finches in this region, an investigation of the current status and broad habitat requirements of the Crimson Finch was considered important for gaining understanding of the processes threatening it. This information may be useful for generating modified management practices that can help restore some of the finch species within the region, and have relevance to finch declines more generally across northern Australia.

Habitat specialists are thought to be more at risk from modification of habitat than are generalists (Pimm *et al.* 1988; Henle *et al.* 2004). Crimson Finches mostly inhabit eucalypt woodlands with tall grasses near permanent water, especially in riparian vegetation with dense Chionachne *Chionachne cyathopoda* (Dorricott & Garnett 2006; Higgins *et al.* 2006; Milenkaya *et al.* 2011; Houston & Black 2014). Other attributes typical of habitat specialists include their sedentary habits and dependence on grass seeds (Woinarski *et al.* 2000; Todd *et al.* 2003; Milenkaya *et al.* 2011; Forshaw *et al.* 2012).

As in northern Europe, changes in land management are thought to be involved in declines in granivorous species of northern Australia. Because most of the declines in this feeding guild pre-dated extensive clearing in northern Australia, it is thought that changed land-management practices associated with fire and grazing regimes caused changes in habitat suitability such as vegetation structure, composition and availability of food resources (Braithwaite

& Muller 1997; Franklin 1999; Franklin *et al.* 2005) but few studies have been able to distinguish the effects of fire from those of grazing alone. The aims of this study were to confirm the restricted distribution of the Crimson Finch and to add to the knowledge of its habitat requirements and threats to survival.

Methods

Study area

The Fitzroy River Basin comprises six major subcatchments (Fitzroy, Dawson, Comet, Nogoa, Mackenzie and Isaac–Connors Rivers) in Queensland. It spans the Tropic of Capricorn, extending from 21°1′S to 26°25′S (~590 km) and from 146°35′E in the west to 150°59′E, where it meets the Pacific Ocean. The region has long hot summers and mild winters (mean monthly maxima 22–35°C and minima 7–22°C) and is seasonally wet/dry (Hutchinson *et al.* 2005), with 55–60% of rainfall in summer–autumn (December–March) (mean annual rainfall ~550–900 mm). Most of the land is used for cattle grazing, although coal mining and cropping are also important.

The Connors River is the last unregulated river in the Fitzroy Basin, with major dams or weirs on all the other main rivers. Along the Connors and lower Isaac Rivers, land managers traditionally remove cattle from riparian land bordering the main rivers and tributaries during the wet season (termed 'wet-season spelling') to avoid problems with floods. Fire is not typically used as a management technique in the riparian zone.

Study species

Two subspecies of the Crimson Finch are recognised: Black-bellied *N. p. phaeton* and White-bellied *N. p. evangelinae* (Schodde & Mason 1999). The Near Threatened White-bellied Crimson Finch occurs on central Cape York Peninsula, Queensland, and in the Trans–Fly region of southern Papua New Guinea (Schodde & Mason 1999; Higgins *et al.* 2006; Garnett *et al.* 2011). The Black-bellied Crimson Finch occurs up to 300 km inland from Broome in Western Australia to the western Gulf of Carpentaria, Northern Territory, and in eastern Australia from Cooktown on Cape York Peninsula to north of Mackay, with an outlying population along the Isaac–Connors Rivers (Higgins *et al.* 2006). The Isaac–Connors population, although not morphologically distinct, has developed the unique behavioural characteristic of nesting high in trees where its nests are camouflaged as flood flotsam (Houston & Black 2014).

Crimson Finches are small (13 cm in length), brightly coloured finches with long tails. They mostly eat grass seeds, which are picked from the seedheads or gleaned from the ground. Size of grass seed rather than the species may be more important in influencing seed selection (Dorricott & Garnett 2006). Invertebrates, insects and their larvae, are also eaten, and may comprise a higher proportion of the diet in the breeding season (Todd *et al.* 2003). Late in the dry season, grass seeds become drier, and the need for the birds to drink water is greater (Evans *et al.* 1989).

Crimson Finches are thought to be sedentary, with small seasonal movements to exploit the resources within their home range (Forshaw *et al.* 2012). They mostly live in small flocks (typically <15 birds) and are very rarely found in the large flocks characteristic of many finch species (Higgins *et al.* 2006; Milenkaya *et al.* 2011). Breeding can occur at any time of year, particularly following floods (Houston & Black 2014), but is mostly between January and May, coinciding with the northern wet and post-wet season periods (Todd 2002).

Distribution and evaluation of regional decline

Historical records of sightings of Crimson Finches, mostly from the Queensland Department of Environment and Heritage Protection WildNet database (http://www.ehp.qld.gov.au/wildlife/wildlife-online/), but also from Queensland Parks and Wildlife personnel and local birdwatching groups, were compiled and mapped to show all records in the Fitzroy River catchment. The BirdLife Australia atlas database was also examined but did not provide any additional records (Barrett *et al.* 2003; BirdLife Australia 2013). There were three unconfirmed sightings from the lower Fitzroy River in Rockhampton between 1978 and 1996. The proximity of these sightings to urban areas and lack of adequate suitable habitat suggested that these were avicultural escapees, and they were disregarded. Of the 21 historical sites, 18 were resurveyed (eight in 2008 by Rhys Kellow and the remainder by WH & RB in 2006–2008). Several riparian sites within the historical range of the subspecies were searched as part of other studies (WH unpubl. data), including sites in the Dawson, Mackenzie and Fitzroy River catchments. The only historical locations within the Fitzroy Basin that were not resurveyed were some sites on private properties, one at the headwaters of the Connors River, and two very old records in the Rockhampton region from the late 1800s. There were also some historical records in bordering catchments to the north and south. However, local birdwatching groups in Mackay, Rockhampton and Gladstone (Allan Briggs pers. comm. 25 July 2013; Lindsay Boyd pers. comm. 29 July 2013; Maureen Cooper pers. comm. 2008) reported no recent records of Crimson Finches in any of these districts in Queensland.

Five of the six sites where Crimson Finches had been sighted in the last 25 years formed the starting point for surveys of the species' distribution in the Isaac–Connors catchment: May Downs Crossing and Twin Bridges, both on water reserves, and three on the lower Connors River. These sites were searched in July and August 2006. Subsequently, properties upstream and downstream within a 150-km stretch of the Isaac–Connors Rivers and Funnel Creek, including the lower Isaac River where it joins the Mackenzie River, were surveyed. Following initial property surveys, sites identified as having potential habitat for Finches were searched during both the dry season and the post-wet season periods to optimise the likelihood of finding suitable habitat conditions. Crimson Finches were often found feeding low in the very tall and dense riparian grasses and were often first detected by their distinctive call. Searches of historical sites were comprehensive and undertaken by two observers (usually RB and Leif Black) walking at least 2 km upstream and downstream of the known location, where possible, but sometimes more if required (e.g. on the lower Connors River a distance of >15 km was walked for one site). Overall, 19 surveys were undertaken between July 2006 and September 2008.

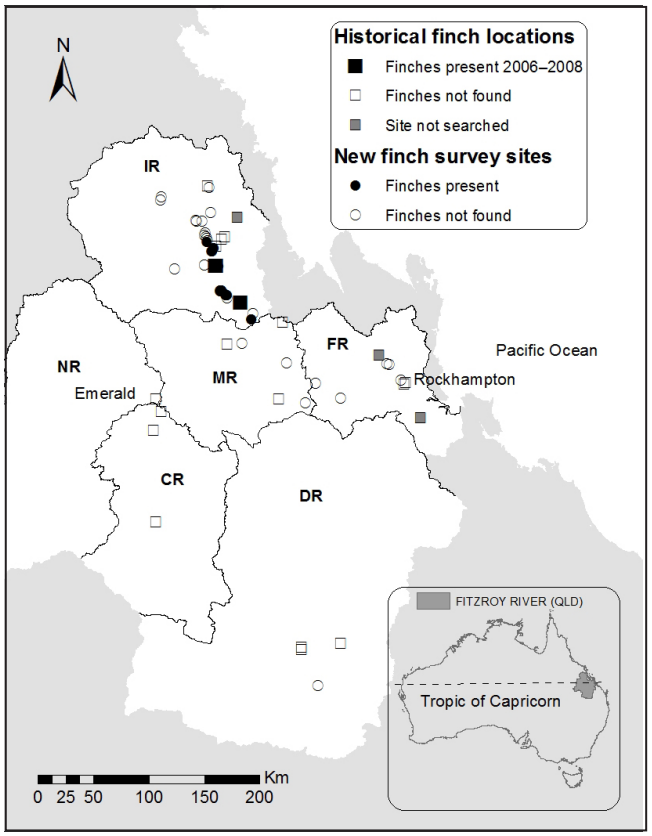

Figure 1. Location of historical (pre-2005) sightings of Crimson Finches in the Fitzroy River Basin, Queensland, and result of surveys there in the present study (squares) and at new survey sites (circles). River subcatchments: CR = Comet, DR = Dawson, FR = Fitzroy, IR = Isaac–Connors, MR = Mackenzie, and NR = Nogoa.

Consistent search effort (~2–4 km of bank at each site) by two observers along the lower and upper stream banks of the riparian zone and bordering vegetation of the alluvial plain was used at all sites where Crimson Finches were found. These data allowed estimates of relative abundance to be made. All sightings were recorded with a GPS and mapped using ArcView to show known extent, and this was then overlaid on the existing Queensland Government Regional Ecosystem mapping (Department of Environment and Heritage Protection 2013).

Habitat attributes of occupied sites

General features of sites where Crimson Finches occurred were noted in order to broadly characterise the vegetation and landscape of occupied habitat. This included a detailed assessment of habitat at three sites that supported breeding subpopulations of Finches (May Downs Crossing, the Isaac–Connors confluence and Twin Bridges). A 200-m transect was established at each site to describe vegetation structure and floristic attributes at 0, 100 and 200 m points. Canopy attributes included species, strata height (average of three trees), crown cover (a visual estimate of percentage of sky covered by leaves and branches), basal area (cross sectional area of trees, m^2 per ha using a 1× basal area wedge) and stem density (stems per ha) of trees (>10 cm diameter at breast height, dbh), saplings (≤10 cm dbh), and shrubs within a 25-m radius of each of the three points. Ground-layer attributes assessed were average height and percentage of cover of grass within a 10-m radius of each of the three points. Disturbances such as fire, logging, clearing, weeds and roads were noted, as was soil type (colour and texture—sand or clay).

Results

Historical distribution and evaluation of regional decline of Crimson Finches

Examination of historical sightings shows that Crimson Finches once had a much wider distribution (Figure 1), with sightings from all six of the main subcatchments of the Fitzroy Basin: the Isaac–Connors, Mackenzie, Fitzroy, Dawson, Comet and Nogoa Rivers. However, there have been no confirmed records along the Fitzroy River (i.e. Rockhampton district) since 1910 (Longmore 1978), and the species has not been recorded from the Dawson, Nogoa or Comet Rivers since the 1940s (Table 1). Resurveys of historical locations in these four subcatchments did not locate any Finches nor did surveys of potential habitat (Figure 1, Appendix 1), suggesting that the species is no longer extant in the southern part of its historical range.

All records of Crimson Finches in the present study and in the last 25 years were from either the Mackenzie (three sites) or Isaac–Connors (six sites) subcatchments

Table 1. Sightings of Crimson Finches by time interval in the subcatchments of the Fitzroy River Basin, Queensland.

	Span of years									
	1860–1910	*1911–1939*	*1940–1949*	*1950–1959*	*1960–1969*	*1970–1979*	*1980–1989*	*1990–1999*	*2000–2005*	*2006–2010*
Approx. time interval (y)	50	30	10	10	10	10	10	10	5	5
River subcatchment										
Fitzroy	4	0	0	0	0	0	0	0	0	0
Dawson	2	0	1	0	0	0	0	0	0	0
Comet & Nogoa	1	0	3	0	0	0	0	0	0	0
Mackenzie	0	0	0	0	0	0	2	0	2	0
Isaac–Connors	0	0	0	1	0	0	2	4	7	37
Total sightings per time interval	**7**	**0**	**4**	**1**	**0**	**0**	**4**	**4**	**9**	**37**

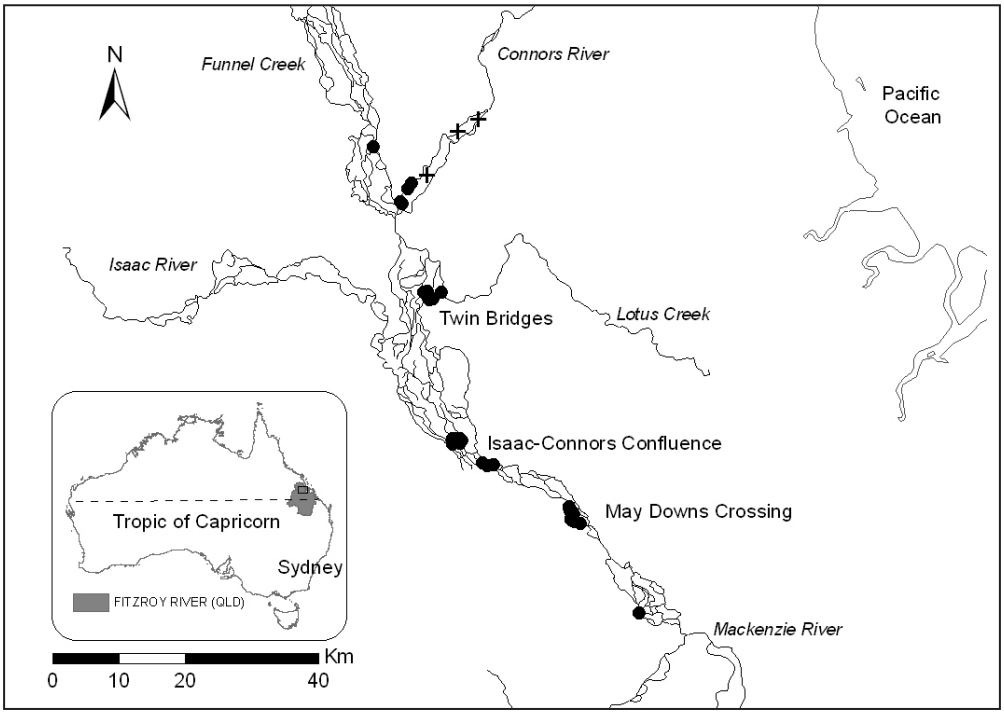

Figure 2. Crimson Finch sightings on the Isaac–Connors Rivers, Queensland, July 2006–September 2008 (black circles) and a reach of the river system where Finches were present in 2005 but absent in 2006–2008 (crosses).

(Table 1, Appendix 1). There were several sightings from the Mackenzie River in the 1980s and in the early-to-mid 2000s. However, although present in early 2005 (Gary Porter pers. comm. July 2006), subsequent surveys during the present study did not find Finches at these sites. Nor were Finches found at four sites along the Isaac–Connors, including three sites along a 15-km section of the Connors River where they were observed to be common between 1993 and 2005 (maximum count of 77: Holmes 1996). These findings indicate a more recent decline and further contraction of the species at the southern edge of its current distribution.

Current distribution and relative abundance

Several new Crimson Finch sites were found on the lower Isaac River, including the property where the Isaac joins the Mackenzie River, the confluence of the Isaac and Connors Rivers, and on properties farther upstream along the Connors River and Funnel Creek (Figure 2). Overall, Finches occupied discontinuous patches of suitable habitat within the river channels over a distance of ~75 km.

Crimson Finches were mostly found in small flocks of <15 individuals, comprising one or two pairs of adults and their offspring. The site with the most consistent survey effort, May Downs Crossing, had a maximum site count of 44 in March 2008 and averaged 17.6 ± standard deviation 9.7 from 15 targeted surveys. Combining counts from the five more intensively surveyed sites (May Downs, Twin Bridges, Langley, Lotus Park and Manly), a maximum monthly total count of 66 Crimson Finches was obtained in May 2008. However, numbers of Finches observed at sites were significantly correlated with an index of search effort (length of river bank; Pearson Correlation Coefficient r = 0.93, P <0.01), and the size of the known population would be increased with greater search effort.

Habitat attributes of occupied sites

Vegetation supporting Crimson Finches mostly matched the description for Regional Ecosystem (RE) 11.3.25: "*Eucalyptus tereticornis* [Forest Red Gum] open-forest to woodland, fringing major and minor stream channels on Cainozoic alluvial plains" (Department of Environment and Heritage Protection 2013). Riparian forests where Finches occurred had tall trees that were widely spaced, abundant shrubs and a well-grassed understorey (Table 2). Forest Red Gum was the dominant canopy species, but Weeping Paperbark *Melaleuca fluviatilis* was also common and provided nesting habitat. Crimson Finch sites were also typified by a midstorey of Flax-leaf Paperbark *M. trichostachya,* Sandpaper Fig *Ficus opposita* and a shrub Snowball Bush *Flueggea virosa* on the terraces that provided roosting habitat, used particularly when the birds were disturbed. These structural attributes may assist in identifying potential Crimson Finch habitat.

Important sites (i.e. those where moderate numbers of Crimson Finches were recorded and with evidence of breeding) included: (1) May Downs Crossing Reserve and adjoining properties on the Isaac River; (2) the Isaac–Connors confluence, upstream of the May Downs Crossing; (3) Twin Bridges Reserve and the surrounding property on the confluence of the Connors River and Lotus Creek; and (4) lower Funnel Creek, comprising two properties on the Connors River–Funnel Creek confluence. These sites had relatively intact riparian habitat with permanent waterholes and extensive mid-level flood channels, typically with clay substrates that supported extensive tall, dense patches of Chionachne grass. Chionachne at these sites was mostly >1.5 m tall (often >2 m), with contiguous patches extending from the low to the high river bank. Tall Chionachne occurred only where grazing pressure was relatively low.

Table 2. Vegetation structural attributes at each of three core sites for Crimson Finches in the Fitzroy River Basin, Queensland. See text for further detail.

	May Downs Crossing	*Isaac–Connors confluence*	*Twin Bridges*
Basal area (m^2ha^{-1})	8.0	8.0	3.0
Canopy height (m)	28.6	28.8	30.3
Canopy cover (%)	15.7	17.5	10.0
Tree stem density (m^2ha^{-1})	57.7	163.0	40.7
Sapling density (m^2ha^{-1})	8.5	5.1	5.1
Shrub density (m^2ha^{-1})	97.1	35.7	297.1
Grass cover (%)	70.0	50.0	50.0
Grass height (cm)	133.3	145.0	85.0
Soil type (colour, texture)	Brown clay	Brown clay	Brown clay

Grazing management and decline of Crimson Finches

In the present study, Crimson Finches were not found in the 15-km section along the Connors River where they had been recorded before 2006 (Figure 2). This property had changed to continuous grazing management of the riparian zone before 2006 (Figure 3a). In contrast, Finches were present at properties farther downstream that had retained the wet-season spelling management style (Figure 3b). In all three surveys of the continuously grazed site, Chionachne had been heavily grazed, averaged <0.5 m in height, and flowering was never observed. In contrast, the height of Chionachne under the wet-season spelling management style was always >1 m, and often >2 m.

Discussion

Distribution of the Crimson Finch

The present study confirms an early decline between first European settlement in the 1860s to 1940s, with a more rapid decline in the more settled part of the Fitzroy Basin nearest to Rockhampton. The Fitzroy Basin population of the Black-bellied Crimson Finch appears to be an isolated remnant from a former distribution ~300 km south to the upper Dawson River and 200 km to the south-west to the Comet River (Higgins *et al.* 2006). All confirmed records of regular occupation since the mid 2000s are from the Isaac–Connors catchment plus its junction with the Mackenzie River, confirming a contraction of this species at the southern edge of its range in central Queensland. This decline is consistent with reductions in range reported for other estrildid finches, making it imperative that understanding of the ecology of this species in its refugia be gained.

Reasons for local decline

Of the six properties in the Connors and lower Isaac River catchments known to have Crimson Finches present before the current study in 2006–2008, only two (May Downs and Twin Bridges) had Finches present in this study. Both of these sites had retained wet-season spelling (i.e. removal of grazing during the wet season) and used riparian fencing to exclude cattle when required. This style of management was also used in the four newly discovered sites on the Isaac–Connors Rivers. In contrast, three of

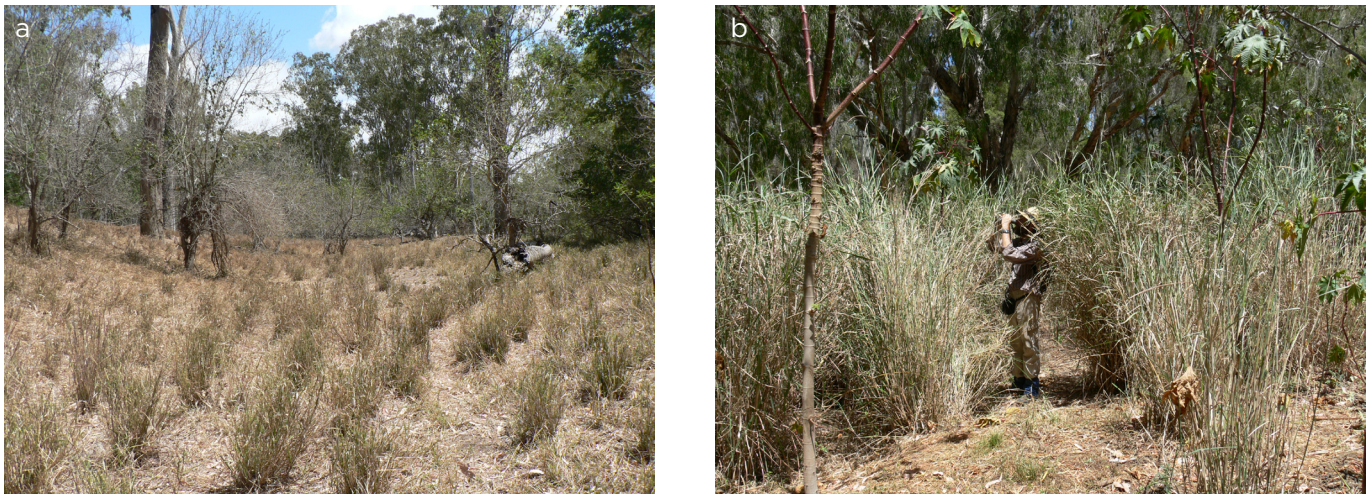

Figure 3. A comparison of the appearance of Chionachne grass (a) at a property with continuous grazing management where Crimson Finches were present before 2006 but not subsequently, and (b) at a property with grazing management typical of wet-season spelling. Photos: Robert Black (a), Wayne Houston (b)

the four sites where Finches were not found had changed grazing management style in late 2005 from wet-season spelling to continuous grazing. Land managers of these properties used riparian fencing to concentrate grazing in the river channels, the strategy being to use persistent heavy grazing to keep the Chionachne in a younger and more palatable form for cattle. However, the heavier grazing pressure also greatly reduced Chionachne height and cover. Evidence of the heavy cattle grazing pressure at these sites included: (1) all grass tussocks, including Chionachne clumps, were <30 cm tall, with no flowering or seeding observed, and (2) the Castor-oil Bush *Ricinus communis*, a species known to be unpalatable to cattle (Anderson 2003), was heavily browsed. In contrast, the grass height of Chionachne under the wet-season spelling management style was usually >1 m (often >2 m) and Castor-oil Bush was never browsed. Consistent with these observations, the Mackenzie River site where Finches were recorded in 2004 and 2005, but were absent in 2006 and 2008, also showed evidence of heavy grazing when surveyed for this study.

Although there are no quantitative data on flowering and seed set, flowering and seeds of Chionachne were never observed in the three surveys of the three continuously grazed sites along the lower Connors River where Crimson Finches had been present until 2005. This contrasted with the sites where Finches were relatively abundant, which typically had the wet-season spelling style of management, and both May Downs and Twin Bridges had abundant Chionachne seeds available throughout the year (Houston & Black 2014). At these sites, mature, coarse Chionachne was used as a dry-season fodder reserve, and grazing followed flowering and seed set, apparently allowing substantial seed set and a reliable source of seeds into the dry season (Houston & Black 2014). Because Chionachne normally flowers when >1 m tall, continuous grazing reduces the amount and reliability of the seed supply upon which Crimson Finch survival may depend. In addition to food resources, it is likely that tall Chionachne provides cover for protection from predation. However, other factors may be involved, and more research is needed to evaluate habitat preferences and to confirm that continuous grazing does reduce seeding in Chionachne.

Along with grazing management, fire is suspected to be a contributing factor in the decline of granivorous species in northern Australia (Franklin 1999; Franklin *et al.* 2005; Woinarski & Legge 2013) and has been credited with fragmenting the populations of the White-bellied Crimson Finch on Cape York Peninsula (Garnett *et al.* 2011). However, discussions with landholders indicated that fire is not typically used in the riparian zone in this region. Hence, there was no difference in fire regime between properties at which Crimson Finches persisted or were newly found and those where they had declined.

Reasons for general decline

This recent decline of Crimson Finches on heavily grazed properties may help to explain the historical decline of this species across the Fitzroy River Basin. Even within largely uncleared riparian zones, heavy cattle grazing, particularly in long dry cycles, would prevent the formation of viable quantities of grass seeds, and be likely to affect breeding and possibly survival of adult birds. Franklin *et al.* (2005) noted that the impact of grazing on riparian grasses is much more severe during droughts. The eminent pioneer ornithologist Charles Barnard chronicled changes on his grazing property, 'Coomooboolaroo' in the Dawson River catchment, between 1873 and 1933 (Barnard 1925, 1934). He recorded the loss of waterholes and riparian vegetation in the early pastoral period, and described the effects of the severe 'Federation Drought' of 1897–1901. Once Crimson Finches were lost from a large reach of the rivers, their sedentary nature would make natural re-establishment in former areas very unlikely to occur. The decline of the Star Finch (which inhabits wetlands) in the early pastoral period may have had similar causes (Garnett *et al.* 2011).

Grazing management systems favouring persistence of the Crimson Finch may have resulted from the type of landscape in the lower Isaac–Connors system. Complex channelling tends to favour reduced stocking pressure, as graziers usually remove cattle from the riparian and bordering alluvial plain grasslands to avoid cattle losses during the wet season when flooding is likely. This may have unintentionally reduced pressure on grazing sensitive plants such as Chionachne, allowing it to persist in a more vigorous condition than elsewhere in the Fitzroy River catchment. Such landscape drivers of habitat were also noted in the marine plain habitat of coastal central Queensland where the Critically Endangered Capricorn Yellow Chat *Epthianura crocea macgregori* occurs (Houston *et al.* 2013), and a similar mechanism may also protect critical habitat of the Star Finch on Cape York Peninsula (Garnett *et al.* 2005). Franklin *et al.* (2005) noted that impacts of grazing and fire on granivorous species were ameliorated in topographically varied landscapes. Here we provide a possible mechanism by which this may occur, in which the landscape has led to graziers altering management practices to protect stock during floods. However, other factors associated with topographic complexity such as availability of permanent water and provision of favourable habitat for important vegetation such as Chionachne may also contribute to persistence of Crimson Finches in this landscape by enhancing key resources for survival. Consistent with this, the periodic pattern of grazing and consequent healthy condition of the ground layer observed in this study have been identified as landscape attributes relevant to the conservation of endangered ground-foraging woodland birds in other parts of Australia (Ford 2011; Watson 2011).

Conservation and management issues

Stream confluences appeared to be particularly important for Crimson Finches: three of the four most important Finch sites identified in this study were at stream confluences. In addition to extensive swards of Chionachne on clay soils, these junctions have the greatest fine-scale landscape complexity, and possibly a greater likelihood of holding permanent water, all of which appear to be important factors in defining favourable Finch habitat. This suggests that stream junctions should be targeted as highest priority for future searches for Crimson Finches.

The riparian habitat suitable for Crimson Finches in the Fitzroy Basin is mostly in a fragmented condition, with considerable intervening areas of unsuitable habitat. Because this species has poor dispersal ability (Doricott & Garnett 2006), even relatively narrow gaps could present

major barriers to natural re-establishment. However, there was evidence of subpopulations extending along contiguous suitable riparian habitat in wetter periods to exploit new sites, although some of these did not persist in subsequent dry periods. Favourable rainfall leads to growth of more suitable habitat, and pressure on the riparian grasses from stock is lower. Conversely, in drought conditions when semi-permanent waterholes dry out and grazing pressure on the riparian zone is at a maximum, populations of Finches may shrink back to core areas. Thus, survival of birds at the core sites (e.g. May Downs Crossing, Isaac–Connors confluence, Twin Bridges and the Connors–Funnel Creek confluence) during dry years may be essential to the persistence of the Crimson Finch population in this region. Preservation of relatively small areas of habitat in good condition near permanent waterholes, as little as 1–2 km of river bank, may ensure local survival in drought periods. However, larger-scale preservation of the riparian corridors in good condition has many wildlife benefits, and should be the overall goal of conservation managers.

Reliance of breeding Crimson Finches on grass growth during the wet season, and extended breeding of the species observed following a low-flow flood event in June 2007, and the major floods of early 2008, suggest that environmental flows could be significant to Crimson Finch breeding and, therefore, persistence in this region (Houston & Black 2014). The tolerance of Chionachne to flooding, and its expansion after the 2008 floods, indicate that floods may be important in maintaining the dominance of this grass over the introduced Green Panic *Megathyrsus maximus* var. *pubiglumis* (Houston & Black 2014). Chionachne appears to be the key food plant for the Finch, and the potential impact on Finch habitat of reduced flood flows following dam construction needs to be considered in any development of this nature.

Dams may also impact on Finches in other ways. Core populations of Crimson Finches identified in this study are all near permanent waterholes, and water is essential for Finches during the dry part of the year for digestion of dry seeds (Evans *et al.* 1989). It is likely that diminished river flows in the dry season, as a result of new upstream dams, could also reduce the permanence of pools and thus pose a serious threat to the survival of Crimson Finches in the region.

The major aim of management plans for Crimson Finches should be to maintain a continuous, natural riparian system with a dense cover of Chionachne. It seems likely that restricting grazing along riparian channels until after a large proportion of Chionachne seed has matured in the dry season enhances the habitat for this species. Grazing should also not be heavy enough to remove the cover of Chionachne. These considerations are especially important in drought periods, when the impact of grazing on riparian grasses is much more severe.

Conclusions

Most properties supporting Crimson Finches have riparian fencing and are grazed at low-to-moderate levels. However, riparian fencing does not guarantee habitat for the species. In some cases, it was used to concentrate cattle grazing on the Chionachne zone. There is evidence indicating that a change in management regime, resulting in increased stocking densities where Finches previously existed, has caused loss of Finches from these areas. This suggests that this species is highly sensitive to grazing regime and vulnerable to local extinctions, particularly in low-rainfall periods. It also demonstrates that changes in grazing management alone can cause local extinction irrespective of fire regime or clearing practices. This is contrary to prevailing wisdom, in which these factors are thought to act in concert to cause habitat decline for granivorous species (Franklin 1999).

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Appendix 1. Crimson Finches in the Fitzroy River Basin, Queensland. Summary of data from historical, resurveyed and new sites, showing 1) presence (p) or number of Crimson Finches and number of surveys (in parentheses) for the historical period (until 2005) and 2) the maximum count of Finches and (in parentheses) number of surveys in which Finches were present out of the total surveys at that site during this study (2006–2008). * = Finches were not found at that site. Sources: 1 = WildNet database; 2 = Wilson (1988); 3 = Wilson (1990); 4 = Holmes (1996); 5 = McAllan (2000); 6 = Mackay and Whitsunday Branch, Bird Observers Club of Australia Newsletter *The Wren*; 7 = Gary Porter (pers. comm. July 2006); 8 = Boisen *et al.* (2010); and 9 = WH unpubl. data 2012; all other data are from the present study. Ck = Creek, R = River, Rd = Road, St = Street; Grazing = grazing management: G = heavily grazed, N = no wet-season spelling, W = wet-season spelling. B indicates that breeding of Crimson Finches was observed.

Subcatchment	*Stream*	*Site*	*Source*	*Grazing*	*Years*				
					1859–1956	*1987–1989*	*1991–1993*	*2002–2005*	*2006–2008*
Historical sites not resurveyed									
Fitzroy	Tributary	Rockhampton district, Port Curtis	1		p (1)				
Fitzroy	Fitzroy R	Upper Fitzroy R beyond Yaamba	1		p (1)				
Connors	Connors R	Connors R 150 km S of Mackay	1				p (1)		
Historical sites resurveyed, Crimson Finches not found									
Fitzroy	Fitzroy R	Rockhampton 'A'	1		p (1)				*(0/1)
Fitzroy	Fitzroy R	Rockhampton 'B'	1		p (1)				*(0/1)
Dawson	Dawson R	Upper Dawson R	1		p (1)				*(0/1)
Dawson	Robinson Ck	Verbena Park	1		p (1)				*(0/1)
Dawson	Robinson Ck	"near Verbena Park"	1		p (1)				*(0/1)
Comet	Comet R	"Comet River-mid"	1		p (1)				*(0/1)
Comet	Comet R	"Comet River-lower"	1		p (1)				*(0/1)
Comet	Comet R	"Comet-Nogoa junction"	1		p (1)				*(0/1)
Nogoa	Nogoa R	"Nogoa"	1		p (1)				*(0/1)
Mackenzie	Springton Ck	"Mackenzie south"	1			p (1)			*(0/1)
Mackenzie	Apis Ck	Apis Ck	1, 3			1 (1)			*(0/1)
Mackenzie	Mackenzie R	Beef Rd	7, 8	G				8 (2)	*(0/1)
Connors	Funnel Ck	Old Highway Crossing	6	G				p (1)	*(0/1)
Connors	Connors R	Old Highway Crossing	1, 6	N	p (1)			p (1)	*(0/3)
Connors	Connors R	Top Island (8 km upstream from Isaac–Connors confluence)	4, 7	N			2 (1)	p (1)	*(0/3)
Connors	Connors R	Connors R (10 km upstream from Isaac–Connors confluence)	4, 7	N			77 (1)	p (1)	*(0/3)
Historical sites resurveyed, Crimson Finches found									
Connors	Connors–Lotus confluence	Twin Bridges[B]	1–3, 6	W		7 (2)	p (1)	p (1)	16 (12/15)
Isaac	Isaac R	May Downs Crossing[B]	5, 6	W				p (2)	44 (15/15)

Appendix 1 continued

Subcatchment	*Stream*	*Site*	*Source*	*Grazing*	*Years*				
					1859–1956	*1987–1989*	*1991–1993*	*2002–2005*	*2006–2008*
New surveys, Crimson Finches found									
Connors	Funnel Ck	Overflow		W					2 (1/2)
Connors	Connors–Funnel confluence	Lotus Park Stn		W					22 (2/2)
Isaac	Isaac–Connors confluence	Langley[B]		W					24 (5/5)
Isaac	Isaac R	Manly Stn		W					2 (1/3)
New surveys, Crimson Finches not found									
Fitzroy	Fitzroy R	Belmont Research Stn	9						*(0/1)
Fitzroy	Belmont Ck	Belmont Research Stn	9						*(0/1)
Fitzroy	Fitzroy R	Rockhampton–Farm Stn							*(0/1)
Fitzroy	Fitzroy R	Moora							*(0/1)
Fitzroy	Meleleuca Ck	Rookwood							*(0/1)
Dawson	Dawson R	Anabranch							*(0/1)
Mackenzie	Mackenzie R	Duaringa–Apis Ck Rd Crossing							*(0/1)
Mackenzie	Mackenzie R	Honeycombe							*(0/1)
Mackenzie	Mackenzie R	Leura Ck Stn							*(0/1)
Connors	Bee Ck								*(0/1)
Connors	Harrybrandt Ck								*(0/1)
Connors	Boothill Ck								*(0/1)
Connors	Funnel Ck	Joe Lodges							*(0/1)
Connors	Funnel Ck	Saltbush Park							*(0/1)
Connors	Funnel Ck	Brenalie Stn							*(0/1)
Isaac	Isaac R	Jimarndi/Tawarri							*(0/1)
Isaac	Isaac R	Crossing on Beef Rd							*(0/1)
Isaac	Isaac R	Crossing on Dysart–Lotus Ck Rd							*(0/1)
Isaac	Isaac R	Clive/Clements Ck							*(0/1)
Peak monthly count									**66 (15/15)**