Australian Field Ornithology 2020, **37**, 15–25
http://dx.doi.org/10.20938/afo37015025

Breeding ecology of a marine plain dependent passerine, the Capricorn Yellow Chat *Epthianura crocea macgregori*, in north-eastern Australia

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Abstract. The habitat and timing of breeding of the Critically Endangered Capricorn Yellow Chat *Epthianura crocea macgregori* were studied over 12 years on the central Queensland coast. The labile breeding season, although summer–autumn dominant, corresponded to the wetter months and inundation of breeding habitat, allowing this bird to breed in any season or month following substantial rainfall, and more than once in a year in response to atypical rainfall events in the drier months. Formation of flocks showed a seasonal pattern, with flock size significantly greater during the post-wet period than during the wet or dry season. Breeding birds were in pairs or family groups, and dry-season flocks were small as the birds dispersed widely across the available dry habitat. The relatively large flocks (20–80) at some sites in the post-wet period (typically 4–5 months after breeding commenced) are postulated to coincide with maturation of young birds. Breeding was observed in grass–sedge swamps on marine plains and supratidal saltmarshes with vegetation taller than 40 cm. Nests were placed low (27 cm ± standard error 7 cm above the ground) in clumps of vegetation that averaged 69 ± 8 cm high, and the height of vegetation supporting dependent young averaged 108 ± 7 cm. Nestlings numbered between two and four (average 2.8 ± 0.2). Capricorn Yellow Chats nested in the same habitat and sites from year to year. In the southern part of their range, their requirement for tall (>40 cm) supratidal vegetation and site-faithfulness suggest that conservation prospects could be enhanced by protection of relatively small patches of breeding habitat. In the northern part of their range, co-existence with livestock grazing suggests that appropriate habitat—tall grass and sedge cover—can be maintained providing stocking rates remain conservative. In general, recognition and improved government protection of tall supratidal saltmarsh, as a distinct entity from shorter saltmarsh with regular tidal influence, would enhance conservation outcomes for endangered fauna.

Introduction

The Capricorn Yellow Chat *Epthianura crocea macgregori* (Aves: Meliphagidae) is an insectivorous, wetland-dependent passerine (Higgins *et al.* 2001; Houston *et al.* 2013). It is one of three subspecies of Yellow Chat *Epthianura crocea*: the Inland Yellow Chat *E. c. crocea* occurs patchily throughout inland northern Australia but reaches the coast near Broome, Western Australia; the Alligator Rivers Yellow Chat *E. c. tunneyi* occurs coastally in the Alligator Rivers area of northern Australia; and the Capricorn Yellow Chat occurs in coastal central Queensland near Rockhampton. The latter two subspecies are listed under the *Environment Protection and Biodiversity Act 1999* as Endangered and Critically Endangered, respectively. The Capricorn Yellow Chat occupies <7000 ha of marine plain habitats along a 200-km coastline, with the site furthest inland being <20 km from the coast (Houston *et al.* 2013). Most of its habitat is <5 m above sea level, exposing the subspecies to climate-change risks associated with rise of sea level (Houston *et al.* 2013). Supporting its endangered status, population size was found to be very low, averaging only 250 over the 7-year period from 2004 to 2010 (Houston *et al.* 2018a). Also increasing its vulnerability to extinction, genetic studies have shown limited, if any, dispersal between the two largest groups of Capricorn Yellow Chats in the north and south of their range (Houston *et al.* 2018b).

The Inland Yellow Chat is regarded as a spring–summer breeder by most authors, summarised in Reynolds *et al.* (1982), but it also breeds after good rainfall in dry and arid areas (Beruldsen 1980) and has been observed breeding in most months of the year (Matthew 2007). Preliminary observations suggest a similar pattern for the Capricorn Yellow Chat (Houston *et al.* 2004a,b, 2009; Jaensch *et al.* 2004). Thus, the breeding season appears to be variable and opportunistic and dependent on regional climate, but quantitative data are lacking. The present study provides the first systematic survey to evaluate the breeding season of the Capricorn Yellow Chat.

Improving ecological understanding is key to the development of sound management leading to the survival of endangered species such as the Capricorn Yellow Chat (Male 1995; Pullin *et al.* 2004; Priddel & Carlile 2009). Objectives of our study were to quantify and describe Capricorn Yellow Chat breeding activity, including social behaviour, and to describe the specific types of vegetation used during breeding.

Methods

Study area

The study area is in coastal central Queensland (Figure 1), straddling the Tropic of Capricorn, and comprises the only known sites supporting Capricorn Yellow Chats (Houston *et al.* 2009, 2013). Sites may be characterised as ephemeral to seasonal wetlands of marine plains that are treeless, of slight gradient and low relief, and mostly <5 m above sea level (Houston *et al.* 2013). The marine plains are remnants of previously extensive plains inundated by rising sea levels following the last ice age

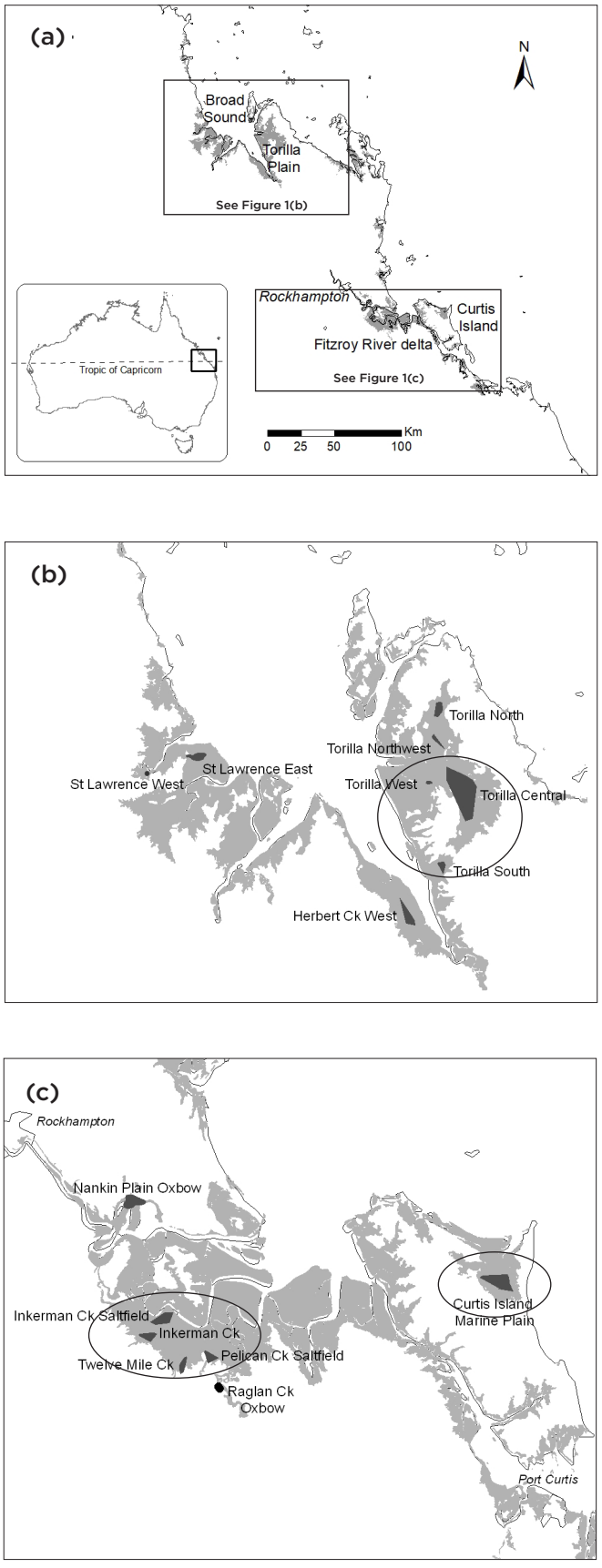

Figure 1. (a) Range of the Capricorn Yellow Chat, with known sites shown by dark-grey polygons superimposed on marine plains indicated by pale-grey shading in (b) Broad Sound and (c) Fitzroy River Delta and Curtis Island. Encircled sites show target sites for regular surveys in this study to determine the breeding season—Broad Sound: Torilla Central, Torilla West and Torilla North; Fitzroy River Delta: Twelve Mile Creek, Inkerman Creek, Inkerman Creek Saltfield and Pelican Creek Saltfield; Curtis Island: Curtis Island Marine Plain. Ck = Creek.

(*c.* 10,000 years ago). Rising seas formed shallow coastal bays, which slowly filled with sediments from tidal (or a combination of tidal and fluvial) deposition (Burgis 1974; Bostock *et al.* 2006). Sites are inundated in the summer wet season by surface run-off but may dry completely during drier winter–spring months, becoming brackish and even hypersaline (Houston *et al.* 2004b, 2013), possibly reflecting the concentration of incipient salts present in soils laid down under marine aggradation (Burgis 1974). Breeding habitats comprise two broad types: grass–sedge depressions (channels, swales and basins) and tall supratidal saltmarshes, the latter with occasional tidal influence on high spring tides (Houston *et al.* 2013).

Climate

The climate of the study area is classified as hot, seasonally wet–dry but with relatively cool winters (Hutchinson *et al.* 2005). Average maximum summer temperatures are just >30°C and winter minima average 11–12°C. The wet season, during which average monthly rainfall is >100 mm, occurs from December to March and accounts for >60% of the annual total (average 815 mm at Rockhampton in 1939–2017). Rainfall is least in June–September. However, the region is typified by highly variable annual rainfall, comparable with semi-arid Australia where rainfall is likely to be irregular from one year to the next—heavy rainfall in some years and much less in others (Bureau of Meteorology 2016).

Commencement of bird surveys in 2004 corresponded with the latter part of an extended period of rainfall that was mostly below average, from 1992 to late 2009 (Figure 2). This was followed by a period of rainfall that was mostly above average from early 2010 to late 2017 before commencement of another below-average rainfall period.

Observations of breeding

Previous studies (Houston *et al.* 2013) have shown that Capricorn Yellow Chats occur in three areas: (i) northern: Broad Sound including Torilla Plain; (ii) southern: Fitzroy River Delta; and (iii) south-eastern: Curtis Island (Figure 1). The northern and southern populations of Capricorn Yellow Chats are separated by ~140 km, the southern and south-eastern by ~40 km. Sites within these three areas were systematically surveyed to evaluate breeding season and behaviour.

At Broad Sound, three Torilla Plain sites representative of two habitat types that grade into each other were sampled: (i) *Cyperus*: upper to mid marine plain dominated by the sedge *Cyperus alopecuroides* and an introduced cattle-pasture species, Para Grass *Urochloa mutica* (Torilla Central), and (ii) *Schoenoplectus*: lower marine plain adjacent to tide-exclusion banks, a mixture of the sedge *Schoenoplectus subulatus* and supratidal saltmarsh (Marine Couch *Sporobolus virginicus* and the samphire *Tecticornia pergranulata*; Torilla West and Torilla South). Between December 2003 and November 2008, these three sites were surveyed at least once in each of three seasons based on rainfall: wet (December–March, comprising the four wettest months: 5 surveys); post-wet (April–July, the

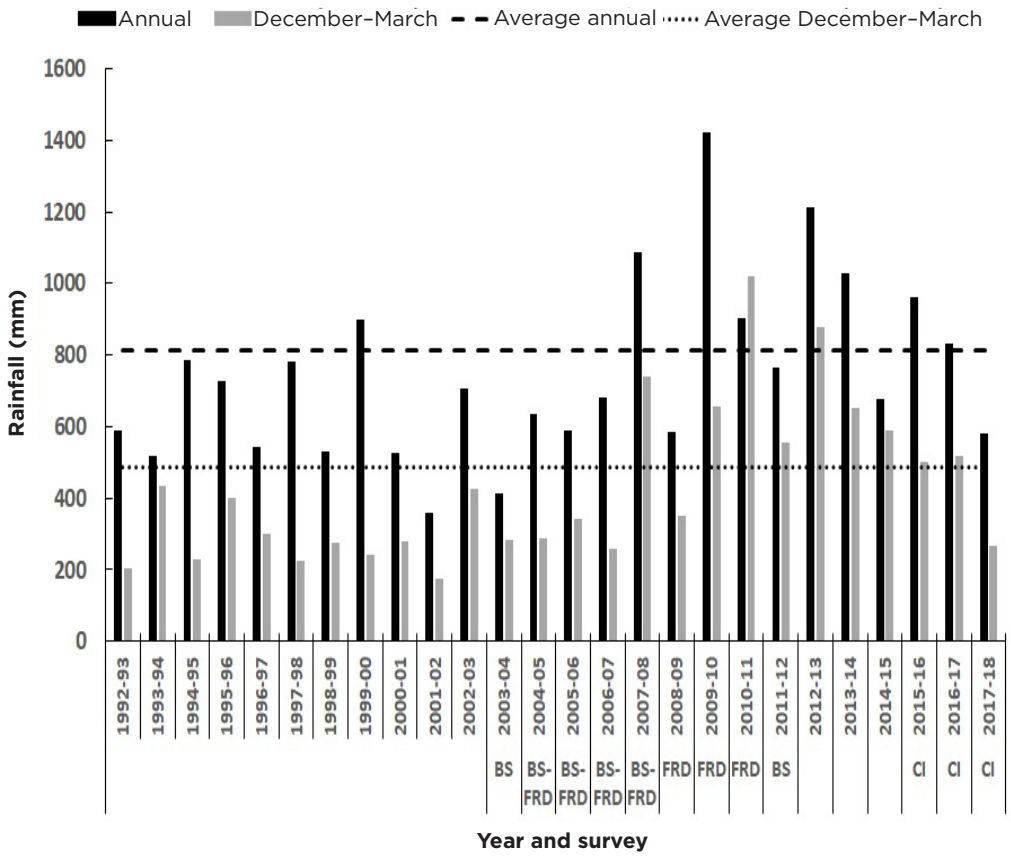

Figure 2. Rainfall (mm) at Rockhampton (23°23′S, 150°29′E): annual and cumulative for the four wettest months (December–March) in relation to the long-term averages (78 years of data: Bureau of Meteorology, Station 039083). Location of Capricorn Yellow Chat surveys in these years: BS = Broad Sound, FRD = Fitzroy River Delta and CI = Curtis Island.

4 months immediately following the wet season: 6 surveys) and dry (August–November, coinciding with relatively low rainfall and high evaporation rates: 9 surveys). In all, there were 20 surveys, each of 2–4 days' duration.

In the Fitzroy River Delta, four sites representative of two habitat types were sampled: (i) supratidal saltmarshes with occasional tidal influence on high spring tides, dominated by *T. pergranulata* and Marine Couch (Twelve Mile Creek and Inkerman Creek) and (ii) saltfield sites comprising modified saltflats with several rectangular pools of ~75 ha bordered by levee banks, supporting narrow bands (~1 m wide) of terrestrial grasses and salt-tolerant vegetation (Inkerman Creek Saltfield and Pelican Creek Saltfield). These sites are separated to some extent by extensive saltflats with almost no vegetation. There are patches of embedded remnant saltmarsh habitat at both the saltfield sites. These four sites were sampled at monthly intervals, Twelve Mile Creek commencing in February 2004, Inkerman Creek in January 2005, and Inkerman Creek Saltfield and Pelican Creek Saltfield in September 2008 following discovery of the Capricorn Yellow Chat there in June and July 2008, respectively (Houston *et al.* 2009). In all, 73 monthly surveys (of 1-day duration) were undertaken at Twelve Mile Creek until June 2010, except for June and August 2005 and July 2006. In addition, a further 10 surveys were undertaken of these four sites at approximately 2-monthly intervals between July 2010 and December 2011.

At the Curtis Island Marine Plain site, systematic surveys of 1 day's duration were undertaken at intervals of ~6 weeks between September 2015 and January 2018.

In all three areas of the surveys, the marine plain was searched using standard search effort (the same person-hours and search area) on each occasion. When Chats were sighted, or nests found, the following general information was recorded: geolocation plus number, gender and age—males, females, dependent young and immatures, feeding of young and other breeding behaviour (such as display flights, male–male interactions, nest building, begging behaviour). When possible, standard measurements of each nest were made: internal diameter, distance above the substrate and height of the surrounding vegetation. Visual estimates of percentage cover (within radii of 1 and 5 m) and maximum height (within 5-m radius) of vegetation for each sighting were also recorded.

A combined approach using both observations at nests and of dependent young was used to determine the breeding season following Cox *et al.* (2013). Numbers of nests, nestlings, pairs with fledglings or dependent young (i.e. birds that were out of the nest but were still being fed by adults) were recorded during each survey to quantify breeding activity. Only confirmed sightings of fledglings being fed, or birds with confirmed juvenile plumage (e.g. short tail-feathers, the presence of dark irides and a yellow gape or ventral surface with yellow confined to the vent or lower belly) were used to define dependent young. Because the length of time that fledglings persist in attempting to elicit food following rejection by the adults is not yet known, begging behaviour was noted but not used to define dependency. These observations were then used to define breeding sites and habitat, and to determine the month of

breeding based on standard development estimates for Yellow Chats and other species of chats. This was possible as development times are consistent for all species of chats (Major 1991a; Higgins *et al.* 2001). To estimate the date of commencement of a breeding event, observations of nesting were back-dated by 2 weeks for eggs, 4 weeks for nestlings and 6 weeks for dependent young. In all, 53 observations of nesting or dependent young were obtained from systematic surveys of the three study areas. Although few in number, these observations were sufficient to allow the data to be analysed, and were within the sample range used by others to evaluate breeding season (Cox *et al.* 2013).

Nesting data were supplemented by *ad hoc* surveys of other Broad Sound sites between 2004 and 2008, population surveys of all Broad Sound sites in October 2009 and Torilla Plain sites in 2012. Supplementary data were also obtained from other sites in the Fitzroy River Delta and the Curtis Island Marine Plain site outside the systematic survey period.

The term 'immature' was used to define young birds that were no longer dependent on parental care but were not yet sexually mature. Frequently, such birds were in family groups but appeared to be feeding independently. Because of considerable overlap in plumage between immatures and non-breeding adults, particularly females (Higgins *et al.* 2001), only birds with little indication of adult plumage were classified as immature. Thus, immature Capricorn Yellow Chats were distinguished from adults on the basis of having >40% non-yellow plumage (white, brown or a mixture of brown and white) on the ventral surface.

Vegetation used by breeding birds (for nesting, feeding dependent young or foraging for dependent young) was described at each site and the following information was recorded: (i) dominant plant species; (ii) formation class: visual estimates of vegetation cover by total and by dominant species (isolated = <1% ground-cover, very sparse = 1–10%, sparse or open = 11–30%, mid-dense = 31–70% and closed or dense = >70%); and (iii) height of the tallest stratum (for grass and sedges: low = ≤0.25 m, mid-tall = 0.26–0.5 m, tall = 0.51–1.0 m and very tall = 1.1–3.0 m). Conventionally, the tallest stratum that contributes at least 10% of the vegetation cover is used to define the dominant species (Walker & Hopkins 1990). These measures and growth forms (e.g. tussock grass, sedge, rush, chenopod shrub, shrub and forb) were then combined to define vegetation of the breeding habitat. Habitat type was also classified according to geomorphology (Speight 1990).

Analysis of data

Changes in flock size of Capricorn Yellow Chats by season (wet, post-wet and dry) were assessed using a non-parametric equivalent of an Analysis of Variance, the Kruskal–Wallis test. Paired *t*-tests were used to compare vegetation cover within 1 m and 5 m of the nest location (Quinn & Keough 2002). These tests used 0.05 as the level of significance.

To evaluate the relationship between earlier rainfall and timing of recruitment of young birds into the population at Broad Sound and the Fitzroy River Delta, monthly rainfall 4–8 months before each count of Chats was cross-correlated with the bird abundance data. As the data were highly skewed, Spearman's non-parametric rank correlation was used. Only sites that regularly supported Capricorn Yellow Chats in the dry season were included in the analysis—Torilla Central at Broad Sound and both saltfield sites in the Fitzroy River Delta (Houston *et al.* 2013, 2018a). To allow for multiple testing, a probability level of $P = 0.01$ was used (Quinn & Keough 2002).

Results

Breeding season

Overall, there were 53 breeding events (i.e. nests with eggs or nestlings, dependent young or juveniles) of Capricorn Yellow Chats, 15 from Broad Sound, 23 from the Fitzroy River Delta and 15 from Curtis Island. Extrapolating observations of nesting and dependent young to estimate the commencement of breeding showed that breeding occurred predominantly in the wet season (53%), with 21% in the post-wet and 26% in the dry season (Figure 3).

To allow comparison with existing literature, seasons for commencement of breeding were examined: 38% of breeding events commenced in summer, 34% in autumn, 11% in winter and 17% in spring. Thus, breeding has been confirmed for all seasons and months except one winter month (July), with most in summer–autumn (72%). In general, breeding coincided with the wetter months and was least during the low-rainfall months of winter.

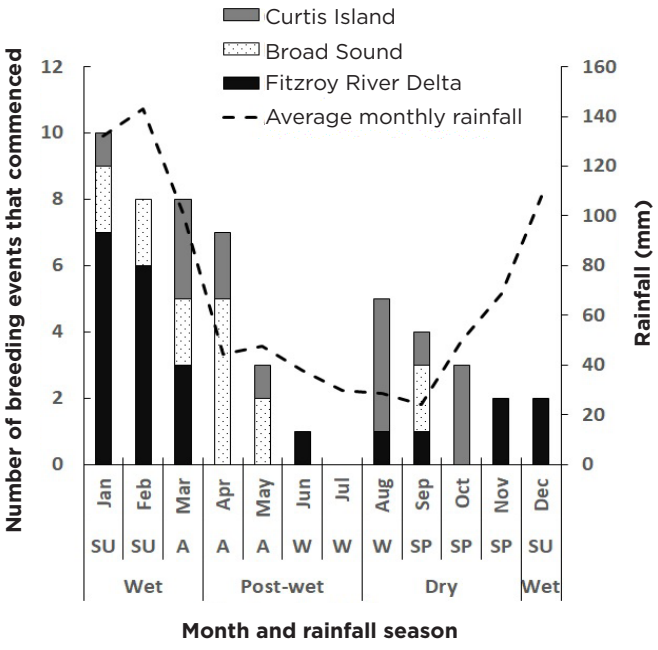

Figure 3. Commencement of breeding of Capricorn Yellow Chats calculated from observations of nests and dependent young at Torilla Plain, Broad Sound (regular surveys 2004–2008); the Fitzroy River Delta (monthly observations February 2004–June 2010 followed by 2-monthly observations until December 2011); and Curtis Island (6-weekly surveys between September 2015 and January 2018) plotted against average monthly rainfall at Rockhampton. SU = summer, A = autumn, W = winter and SP = spring.

Figure 4. Capricorn Yellow Chat nest with two nestlings, Pelican Creek Saltfield, October 2012. Note the structure of the nest. Photo: Robert L. Black

Nesting

Capricorn Yellow Chat nests were found in the following plants: the sedge *Schoenoplectus subulatus* (2 nests), Marine Couch (2), a samphire *Tecticornia pergranulata* (2), Water Couch *Paspalum distichum* (1), Para Grass (1), and mixtures of Marine Couch with *T. pergranulata* (2), *S. subulatus* (1) or Para Grass (1).

Nests were of an irregular bowl shape (Figure 4) and the internal diameter averaged 5.3 cm ± standard error 0.33 cm at their narrowest and 5.8 ± 0.31 cm at their widest (n = 6). Nest materials were mainly grass (Marine Couch) but also included stalks of sedges and the samphire *T. pergranulata*, and flower-stalks of another samphire *T. indica*. Nests were usually lined with fine grass.

For 12 nests, percentage cover of vegetation within a 1-m radius averaged 80% (range 60–90%) and was significantly greater than that within a 5-m radius (45%, range 20–80%) (Paired t-test: df = 7, P <0.001) (Table 1). Height of vegetation with nests averaged 69 ± 8 cm (range 35–120 cm). Nests were typically close to the ground or water surface, averaging only 27 ± 7 cm (range 6–50 cm) above the surface.

Six of the nests were located in small discrete patches of vegetation situated in low-lying basins that flooded ephemerally (Figure 5).

Adult Chats were typically seen in pairs before nesting. Only one nest-construction episode was observed: a female was seen carrying a 10-cm length of grass to a nest; the male was not seen directly assisting in nest construction

Table 1. Characteristics of Capricorn Yellow Chat nest locations: percentage cover and height of vegetation and height of nest above the ground or water surface, mean ± standard error (n = 12) (range in parentheses).

Vegetation cover (%)		*Vegetation height (cm)*	*Nest height (cm)**
Within 1 m	*Within 5 m*		
80.0 ± 3.9 (60–90)	45.4 ± 6.6 (20–65)	69 ± 8 (35–120)	27 ± 7 (6–50)

*Recorded from 6 nests only

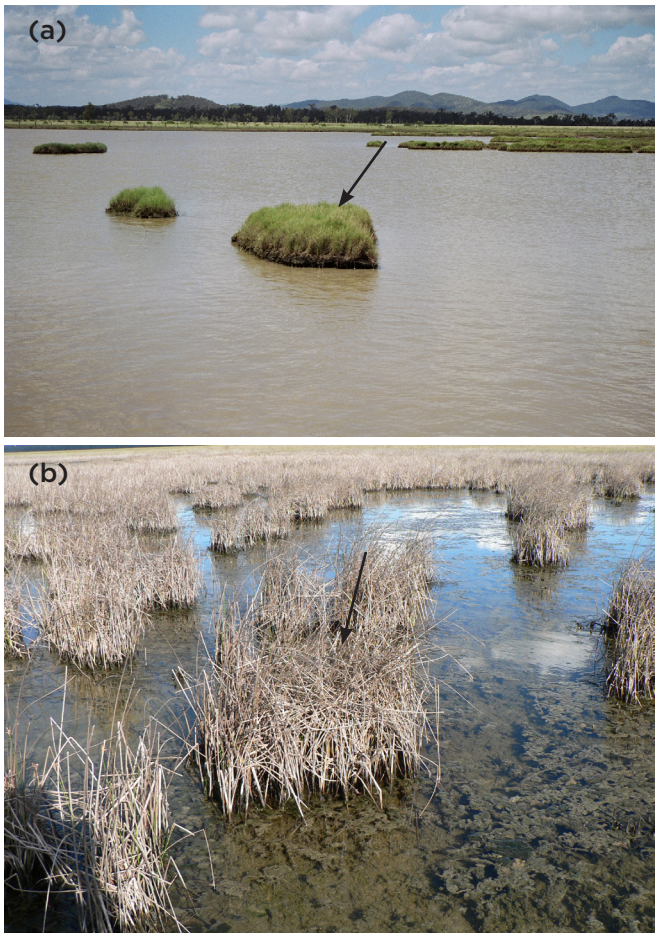

Figure 5. Examples of Capricorn Yellow Chat nest locations surrounded by water: (a) Marine Couch, Twelve Mile Creek, February 2004 and (b) sedge *Schoenoplectus subulatus*, Torilla South, May 2006. Approximate nest locations are shown by the arrows. Photos: (a) Wayne A. Houston and (b) Robert L. Black

although he remained in close proximity. When breeding, males frequently engaged in chases with other males, often involving bill-clapping, and undertook steep display flights. At three sites, a total of about 30 nesting pairs were regularly spaced at intervals of ~50–100 m but nesting was clustered (5 pairs <10 m apart) at another site.

Two nests contained three eggs, one had four nestlings, four had three, and three had two nestlings (average 2.8 ± 0.2 nestlings/nesting event, assuming that all eggs hatched, n = 10). On one occasion, coinciding with a very cool autumn day following a late breeding event, a male was observed incubating. However, it is likely that mostly females incubate because, during nesting, males were commonly seen but females only rarely, suggesting that females incubate for longer periods.

Observations of nest failure

Coinciding with an extreme king tide of 5.7 m at Port Alma, the bottom of a Capricorn Yellow Chat nest at Inkerman Creek was immersed in ~1 cm of water for an unknown length of time. Before this, the adults had been observed incubating. They remained in the area during the period in which the nest was inundated but subsequently abandoned the nest. This suggests that an extreme tidal event was the cause of nest abandonment in this case.

Observations on feeding

Both male and female Capricorn Yellow Chats fed nestlings and fledglings. During 2 hours of observation of a nest at Curtis Island, the nestlings were fed 15 times per hour, mostly by the male. On one occasion, following drying out of most of the surface water, Chats were observed flying several hundred metres to the nearest water to gather food for nestlings. Following fledging, families foraged widely and were not restricted to the nest area.

When breeding, Capricorn Yellow Chats were observed foraging mainly on mud substrates around the margins of shallow channels and pools, targeting semi-aquatic prey such as flies (Diptera) associated with the mud surface. This type of foraging behaviour often occurred at the base of sedges and samphire vegetation, although Chats were sometimes seen foraging some distance from vegetation on broad muddy substrates of drying edges of pools. The lush growth of wetland vegetation following inundation provided another focus for foraging activity. Capricorn Yellow Chats were frequently observed feeding on sedge and grass seed-heads, particularly sedges (*Schoenoplectus subulatus* and *Cyperus alopecuroides*) as well as new growth associated with samphire vegetation (mainly *Tecticornia pergranulata*) and occasionally low shrubs such as Yellow Pea Bush *Sesbania cannabina*.

Adults with dependent young were observed capturing caterpillars and moths (Lepidoptera) and other invertebrates, particularly web-building spiders (Araneae). On occasions, when wetland inundation was extensive, leaving no shallow water or mud, Chats were observed perching on sedge-stems over deeper water, feeding on damselflies (Zygoptera) emerging from nymphal cases. They also preyed upon other insects, such as grasshoppers (Orthoptera), cockroaches (Blattodea) and beetles (Coleoptera).

Social behaviour

Flock sizes of Capricorn Yellow Chats at Torilla Plain were mostly <20 individuals (95% of all observations there), and at the Fitzroy River Delta mostly <10 (96% of all observations there). They varied significantly with rainfall season for each area (Kruskal–Wallis test: $H_2 = 14.7$, $P < 0.001$ for Torilla Plain and $H_2 = 20.2$, $P < 0.001$ for the Fitzroy River Delta, based on pooled data for all years; $n = 526$ and 443, respectively) (Figure 6). Post-wet-season flocks were the largest

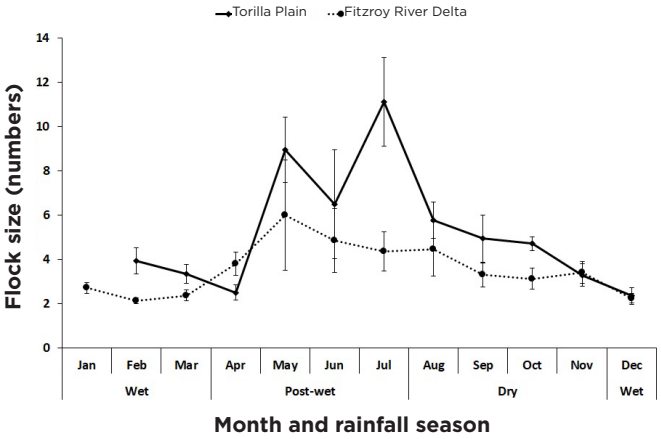

Figure 6. Mean flock size (number of individuals) of Capricorn Yellow Chats at Torilla Plain (all years) and the Fitzroy River Delta (2009 only, the first year for which a complete dataset was available), pooled by month. There were no observations from January at Torilla Plain and the March sample excludes a 70+ flock aggregated at a waterhole on Torilla Plain during a heatwave. Error bars show the standard errors.

(9.0 ± 1.1 individuals) and significantly bigger than those in the wet (4.4 ± 1.1) and dry (4.5 ± 0.3) seasons at Torilla Plain (*post-hoc* Multiple Comparison test). A similar pattern was observed at the Fitzroy River Delta (4.5 ± 0.5 post-wet, compared with 2.3 ± 0.1 for the wet and 3.4 ± 0.3 for the dry season). Thus, although variable, flock size at both Torilla Plain and the Fitzroy River Delta was higher during the months immediately following peak breeding (April–July, Figure 6), and corresponded to the time when young birds became independent.

Timing of recruitment of young birds

At Torilla Plain, mixed flocks of adults, immatures and indeterminate-aged Capricorn Yellow Chats (the last probably younger birds although they could not be positively distinguished from non-breeding adults) were observed in all years during the 4–5-month period following the wet season (May–August), although the extent of flocking behaviour (i.e. the number and size of flocks) varied considerably (Table 2).

Cross-correlations of Chat abundance by site with previous monthly rainfall showed that abundance at Torilla Central (the only Torilla Plain site where Chats persist all

Table 2. Timing of the formation of large flocks (>20 individuals) of Capricorn Yellow Chats at Torilla Plain between 2004 and 2008, and the interval since the last month of substantial wet-season rainfall.

Year	*Month*	*No. of flocks (& maximum flock size)*	*Month of last substantial rainfall (& amount, mm)*	*No. of months between substantial rainfall & flocking*
2004	July	4 (30)	Feb. (185)	5
2005	May	10 (80)	Jan. (125)	4
2006	August	1 (30)	Apr. (105)	4
2007	July	1 (36)	Feb. (119)*	5
2008	July	2 (75)	Feb. (416)	5

*There was also a rainfall event of 154 mm in June in 2007, the month before flocking behaviour in this year

year) had a significant positive correlation with rainfall 7 months earlier (r_s = 0.63, P <0.01). There was a similar pattern at the two saltfields with dry-season habitat for the Fitzroy River Delta population, with peaks in abundance at Pelican Creek Saltfield correlating with rainfall 6 (r_s = 0.59, P <0.01) and 7 (r_s = 0.62, P <0.01) months earlier, and a trend was observed for rainfall 6 months earlier at Inkerman Creek Saltfield (r_s = 0.47, P <0.03).

Breeding habitat

In general, breeding habitat of Capricorn Yellow Chats was confined to wetlands associated with depressions or flats of marine plains dominated by sedges, semi-aquatic grasses or samphire, some of which were saltmarshes with occasional tidal influence (Table 3). The most important habitat types supporting breeding were sedgelands dominated by either *Schoenoplectus subulatus*, *Cyperus alopecuroides* or Chinese Water Chestnut *Eleocharis dulcis*, mid-tall dense tussock grasslands of Marine Couch, and samphire shrublands of *Tecticornia pergranulata*. Para Grass bordering sedge-lined channels or pools also provided valuable breeding habitat.

Additional vegetation types used by adults with dependent young were tidal flats of closed samphire shrubland and occasional Grey Mangrove *Avicennia marina* shrubs, and terrestrial grasslands and shrublands of the adjoining terraces, but in both cases only where these immediately abutted supratidal breeding habitat. Adults gathering food for dependent young were observed in all the vegetation units in Table 3 plus low swards of Marine Couch or grass-dominated depressions of Couch Grass *Cynodon dactylon* and/or Water Couch. They were also observed foraging in shrubs such as Yellow Mangrove *Ceriops tagal* and Yellow Pea Bush, the latter occurring sporadically in depressions and adjoining alluvial terraces.

Habitats supporting family groups with dependent young, like nesting habitats, had relatively tall vegetation (average height 108 ± 7 cm, range 40–200 cm, n = 44).

Attachment to breeding site

The continuous record of monthly observations at Twelve Mile Creek was used to examine attachment to breeding site. Based on sightings in the months for which breeding was calculated as commencing, nesting occurred within the supratidal portion of the habitat occupied and this was consistent with observations of nest locations. The extent of occurrence was similar in the two wetter years (2007–2008 and 2008–2009: 24 and 30 ha, respectively), but substantially smaller in the two drier years (2004–2005 and 2005–2006: <10 ha; Figure 7). Importantly, the area occupied during the two drier years was within that for the two wetter years, showing that the birds are faithful to this habitat and site, although the exact location of nesting may vary from year to year. Other breeding sites had a similar pattern of consistent use of the same habitat from year to year.

Table 3. Vegetation used by Capricorn Yellow Chats during nesting and by families with dependent young: landform, vegetation type and description of vegetation (dominant species, height and cover).

Landform	*Vegetation*	
	Type	*Dominant species, height and cover*
Habitat used during nesting		
Depressions of marine plains	Sedgelands	*Schoenoplectus subulatus* tall to very tall and sparse to mid-dense sedgeland, sometimes in clumps with bare soil between
	Grasslands	Water Couch mid-tall, mid-dense to closed tussock grassland; Chinese Water Chestnut also present
	Grasslands	Tall, mid-dense to closed Para Grass
Marine plain and supratidal flats	Grasslands	Marine Couch mid-tall, mid-dense to closed tussock grassland; sometimes mixed with *S. subulatus*
	Samphire shrublands	*Tecticornia pergranulata* mid-tall to tall and sparse to mid-dense samphire shrubland
Additional habitat used by adults with dependent young		
Depressions of marine plains	Sedgelands	Tall to very tall and sparse to closed *Cyperus alopecuroides* or Chinese Water Chestnut or Marsh Club-rush *Bolboschoenus caldwellii*
Tidal flats	Samphire shrublands	Mid-tall, closed samphire (*Tecticornia pergranulata, T. indica*) shrubland and occasional Grey Mangrove or Yellow Mangrove shrubs but only where bordering marine-plain sites occupied by Chats
Terraces and banks	Grasslands and shrublands	Mid-tall to tall and sparse to closed Guinea Grass *Megathyrsus maximus* var. *maximus*, terrestrial grasslands (e.g. *Chloris* spp.) and Yellow Pea Bush shrublands but only where bordering marine-plain sites occupied by Chats

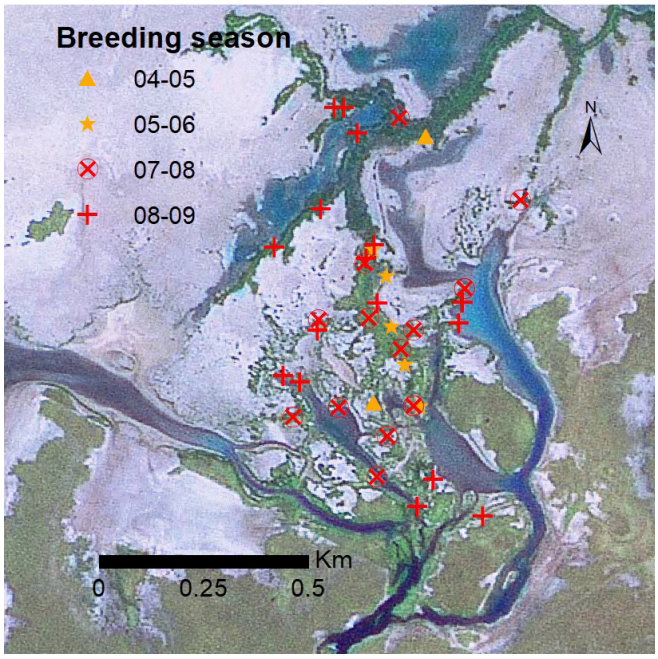

Figure 7. Location (23°40′S, 150°45′E) of Capricorn Yellow Chats breeding at Twelve Mile Creek in the Fitzroy River Delta between 2004 and 2009. Orange symbols are used for the drier years and red symbols for the wetter years.

Discussion

Capricorn Yellow Chats have been shown to breed in most months of the year, indicative of a labile breeding season responsive to rainfall and to inundation of the wetlands used for breeding. Nests were generally regularly spaced and always associated with relatively tall cover (>40 cm high) provided by grass–sedge wetlands or supratidal saltmarshes, particularly the sedges *Schoenoplectus subulatus* and *Cyperus alopecuroides* and saltmarsh species Marine Couch and *Tecticornia pergranulata*. Although mostly in pairs or small family groups for much of the year, larger flocks were observed 4–5 months post-breeding, coinciding with maturation of young birds. The Chats were found to be site-faithful and had the capacity to breed more than once in a year, as evidenced by pairs of Chats with two ages of offspring, both begging young and older immatures.

Breeding season

Breeding by Capricorn Yellow Chats occurred predominantly in the summer–autumn (72% of 53 observations), corresponding to the wet and early post-wet season period. This differs from the typical spring–summer pattern of insectivorous passerines in northern Australian (Nix 1976), but it matches the summer–autumn pattern of northern Australian waterbird species and inland northern Australian insectivores (Ford 1989; Morton & Brennan 1991; Noske & Franklin 1999). Both these foraging guilds are dependent on rainfall events (and inundation in the case of waterbirds), as are Capricorn Yellow Chats (Houston 2013). Availability of invertebrate food also peaks in the late wet season, coinciding with the time when most dependent young Capricorn Yellow Chats were present (Houston 2013). Consistent with this were observations that breeding activity of marine plain insectivores such as the Brown Songlark *Cincloramphus cruralis* (Black & Houston 2013) and Horsfield's Bushlark *Mirafra javanica*, Zitting *Cisticola juncidis* and Golden-headed Cisticolas *C. exilis*, Little Grassbird *Poodytes gramineus* and Australasian Pipit *Anthus novaeseelandiae* peaked in the late wet season (Robert Black pers. obs.). Appearance of the wetland-dependent Australian Painted Snipe *Rostratula australis* in the marine plain wetlands of coastal northern Australia also coincided with this period (Black *et al.* 2010).

The breeding season of Capricorn Yellow Chats showed slight differences between the three study areas, with breeding activity in the Fitzroy River Delta more rapidly attenuating in autumn than in the other two areas (Figure 3). The inundation in this area is not as persistent compared with Torilla Plain, which is much greater in extent and also has deeper channels than the Fitzroy River Delta. The lack of records for Torilla Plain during summer is most likely an artefact, reflecting the difficulties in accessing this area by vehicle when fully inundated. Curtis Island had relatively more spring breeding than the other two areas but this might have reflected the unusual rainfall pattern at Curtis Island in 2016, when an average wet season was followed by a very wet winter (rainfall was 84 mm in June and 142 mm in July compared with long-term averages of 38 and 41 mm, respectively). The last rainfall event led to substantial breeding in August 2016 and subsequent months. To what extent slight differences in breeding season from north to south reflect slight differences in intensity and amount of rainfall are not known. However, both intensity and amount of rainfall are more pronounced in the north (Broad Sound), where average annual rainfall (1019 mm) is greater than at Rockhampton (815 mm), and December–March rainfall accounts for 65% compared with 60% of the annual rainfall.

Some aspects of the breeding ecology of Capricorn Yellow Chats are typical of arid-adapted birds where rainfall is highly variable, thereby providing supporting circumstantial evidence that the epthianurine chats are an arid-evolved group (Schodde 1982). Findings from the present study supporting this hypothesis include (i) the ability of Capricorn Yellow Chats to breed in any season and in most months of the year and (ii) their capacity to achieve breeding readiness more than once in a year in response to out-of-season rainfall events. This was observed at Torilla Plain in 2008, with dependent young present in April and October; those present in April represent the result of normal wet-season breeding, but the presence of young birds in October followed a substantial rainfall event (105 mm) in July. There were also two confirmed breeding events in 2007 at Inkerman Creek, with nesting observed in February and dependent young in October and November, the latter following out-of-season rainfall in June (160 mm). Similarly, there were two breeding events at Curtis Island in 2016: typical wet-season breeding in April–May and late-winter and spring breeding following substantial rainfall in July. Rapid and labile breeding responses to unseasonal rainfall events are typical of arid-adapted birds (Davies 1977; Schodde 1982; Zann *et al.* 1995).

Social behaviour

Many species of birds form large mixed flocks of immatures and adults in the post-breeding period (Newton 1998), and Capricorn Yellow Chats are no exception, with flock sizes in the post-wet season (up to 80 birds) significantly greater than in both the dry and wet seasons in our study. A seasonal pattern in flock size was observed at both Torilla Plain and the Fitzroy River Delta. Associated with breeding, Chats were in pairs or small family groups during the wetter months (December–March) and larger groups during the post-wet season (April–July), but group size rapidly declined during the dry season (Figure 6). This is broadly consistent with the pattern for other chat species described by Williams (1979). It is not known whether formation of larger flocks of mixed adult and immature birds relates to an anti-predator strategy or is an adaptation to maximising resource utilisation of local food-rich patches (Major 1991b).

Based on a previous study, breeding of Capricorn Yellow Chats at the Torilla Plain sites (Broad Sound area) commenced 1–2 months after a rainfall event, but at Twelve Mile Creek (Fitzroy River Delta) in the same month as a rainfall event (Houston 2013). In the present study, Chats in both these areas showed peaks in abundance that were correlated with rainfall 6–7 months earlier. Combining these findings, and assuming that peaks in estimates of population abundance correspond to the time of recruitment of young birds (Newton 1998), suggests a time to independence of 4–5 months after hatching. The data on plumage maturation are also consistent with these observations. For the 3 years with unequivocal data at Torilla Plain (2004, 2006, 2008), immatures took at least 4–5 months to develop plumage indistinguishable from the range shown by adults.

Large flocks of Chats were rarely observed outside the 4–5-month post-wet-season period. One large flock coincided with a hot day (~40°C) in March 2007, when ~70 adults aggregated at a small dam on the marine plain of Torilla Central. Another large flock (40 birds, including 10 males) was observed in the November 2004 survey (late dry period), i.e. when extended periods of above-average temperatures are frequent. Constant hot weather (temperatures >40°C) is a problem for small passerines such as chats, which may increase evaporative cooling by bathing (Schodde 1982). Concurrently with extended hot dry periods (March 2007 and October 2009), Capricorn Yellow Chats were observed perching in elevated positions (e.g. fences), gaping and lifting their wings to permit airflow to the flanks and back (pers. obs.). Although gaping is typical of passerines (Schodde 1982), lifting of wings has not been reported previously for chats but may be part of the behavioural repertoire to increase evaporative cooling.

Location of nests

Nests of Capricorn Yellow Chats were constructed close to the ground in dense cover (>70%), in sedge, grass or samphire but were never found in vegetation <35 cm tall. This also corresponds to descriptions of nest-sites of the Inland Yellow Chat (Higgins *et al.* 2001).

The average vegetation cover within a 5-m radius of a nest was much less than that of the immediate (within 1-m radius) nest-site. The olive-brown back of a Capricorn Yellow Chat may provide camouflage from aerial predators but the bright-yellow chest and belly are very visible from the ground. It is possible that nest-sites are selected to provide cover for the immediate nest-site and to reduce detection by predators, but the more-open vegetation surrounding the area would assist in the observation of approaching predators such as snakes. These hypotheses require further testing.

Predation by ground-predators of nesting Capricorn Yellow Chats may be a strong selective pressure because when nesting first occurred, some of the nest-sites were effectively on islands (i.e. small patches of vegetation surrounded by shallow water: Figure 5). Banded Stilts *Cladorhynchus leucocephalus* nest in similar circumstances in arid wetlands (Schodde 1982), and it has been hypothesised that species that build nests overhanging streams or inundated areas are better protected from predation (Noske 2001). It is possible that nesting on vegetated islands might have evolved for a similar function. Again, this hypothesis requires testing.

Life history strategy

Capricorn Yellow Chats appear to occupy a niche not exploited by other passerines inhabiting coastal plain wetlands. They have the capacity to feed from and on low vegetation, the mud around and below this vegetation, and bare ground. No other bird species in this habitat have this particular combination of foraging strategies. During the breeding season, they appear to be dependent on abundant invertebrate food resources, such as caterpillars and spiders (Houston 2013) associated with lush new growth of sedges and shrubs, and semiaquatic fauna of muddy substrates such as chironomid flies (Diptera: Chironomidae). Capricorn Yellow Chats were also occasionally seen to peck at the surface of shallow water at the margins of pools and thus may also possibly feed on aquatic species such as mosquito larvae (Diptera: Cuculidae).

Conservation issues

An important issue for conservation of the Capricorn Yellow Chat in the southern part of its range is the status of areas of saltmarsh, particularly those dominated by samphire *Tecticornia pergranulata* and Marine Couch in the Fitzroy River Delta. The substantial loss of saltmarshes and saltflats in the last 60 years (Duke *et al.* 2003) and relatively small area of equivalent vegetation type defined under government legislation (regional ecosystem 11.1.2b) suggest that the conservation status of this vegetation may need review. It is currently listed as ‘Least Concern’ (Queensland Herbarium 2016).

Another issue relates to the importance of tall (>40 cm) vegetation, rather than the more typical tidal-saltmarsh vegetation (<35 cm tall), of some supratidal saltmarshes as breeding habitat. Adding to its conservation value, this type of vegetation was previously found to provide nesting habitat for non-migratory shorebirds such as the Pied

Stilt *Himantopus leucocephalus* and Red-capped Plover *Charadrius ruficapillus*, and foraging habitat for migratory waders such as the Sharp-tailed Sandpiper *Calidris acuminata*, Red-necked Stint *C. ruficollis* and Common Greenshank *Tringa nebularia*, which are locally abundant at times (Houston *et al.* 2006). The importance of taller vegetated supratidal saltmarshes needs to be recognised in conservation plans. Ideally, this would include official recognition, mapping and application of conservation status to taller supratidal saltmarsh vegetation.

Repeated nesting by Capricorn Yellow Chats in the same location and habitat each year suggests that these birds are site-faithful. Under these circumstances, protection of known breeding habitat from development would further enhance the conservation prospects of this endangered subspecies, particularly in the southern part of its range.

Other key land-management issues relate to cattle grazing, as the site supporting the largest numbers of Capricorn Yellow Chats (Torilla Central) comprises three pastoral properties (Houston *et al.* 2013). The co-existence of cattle grazing and conservation of an endangered bird demonstrates that marine plains can support both activities. Conservative stocking rates allow the retention of tall grass cover (>40 cm) and key wetland species for breeding Chats such as the sedges *Schoenoplectus subulatus* and *Cyperus alopecuroides*.

Acknowledgements

We thank the many landholders/managers who willingly allowed their properties to be surveyed, including Ralph and Lorraine Bartlem, Craig and Latisha Mace, Lachlan and Trudi Mace, Lawson and Linda Geddes, Peter Naylor and his manager Gary Hall, Simon and Garry Nolan, Graham McCamley, the Christiansen family (Ian, Margaret and Adrian), Ray Smith, Frank Titmus, Cheetham Salt (Richard Segal in particular) and George and Joy Wilson. We wish to acknowledge the great support we have received from our colleagues and volunteers; they have always been enthusiastic with fieldwork, even in the face of adversity, and we would particularly like to thank Leif Black and Roger Jaensch for their efforts. Funding was provided by several sources (Birds Queensland, BirdLife Australia, Fitzroy Basin Authority, Central Queensland University and Queensland Parks and Wildlife Service) and we are most grateful for the support of these organisations. This study formed part of WAH's Master of Applied Science at Central Queensland University, which was supervised by Steve McKillup and Bob Newby; their advice and support were much appreciated. Chats were surveyed under Central Queensland University ethics permits A06/07-201 and A12/02-279 and the Queensland Government Scientific Purposes Permits WISP03967706, WITK03666406, WISP06388809, WITK06388609 and WISP08039210. Finally, we wish to thank the reviewers and editor for their valuable comments and suggestions to improve the quality of the paper.

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Received 5 November 2018, accepted 25 September 2019

published online 26 March 2020