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Conserving the endangered Black-throated Finch southern subspecies: what do we need to know?

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ABSTRACT

Successful conservation of threatened species requires judicious allocation of limited resources. The threatened Black-throated Finch southern subspecies (*Poephila cincta cincta*), endemic to north-eastern Australia, has suffered an 80% contraction in its historical range. Stemming ongoing habitat loss is the main priority in its conservation, but remaining areas where habitat has been degraded require active management. However, the scarce information about the subspecies' ecology has inhibited effective conservation planning. In this paper, we gather and review current knowledge on the Black-throated Finch southern subspecies' ecology and threats and propose a list of research priorities aimed to support conservation management. We highlight how available knowledge could lead to false assumptions due to the limited temporal scope of most studies and their focus on a substantially modified area within its current range. There is a shortage of information on the present population size and distribution of the subspecies, which creates uncertainty about its conservation status. Our top three priority actions are focused on monitoring the remaining populations and evaluating the effects of management practices in pastoral land. We expect this paper to serve as a first step to create a cohesive framework for researchers and stakeholders when deciding to invest in the conservation of this iconic finch.

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Introduction

Ongoing declines and extinctions of species worldwide require effective conservation action (Barnosky *et al.* 2011). Australia is recognised as a globally significant region for conservation (Rodrigues *et al.* 2014), but it presents an unusual case in that it has high extinction rates, yet many declines and extinctions have occurred in remote areas, often regarded as relatively unmodified (Woinarski *et al.* 2015). Strong support for hypotheses behind these declines has surfaced only in the last decade, pointing at the expansion of pastoralism and introduced predators after European settlement as the leading threats (Kutt and Woinarski 2007; Frank *et al.* 2014; Woinarski *et al.* 2015).

Endemic granivorous birds are one of the most prominent groups affected by changes in Australian savannahs. One species, the Paradise Parrot (*Psephotus pulcherrimus*), was declared extinct in the 20th century, and many taxa show long-standing trends of decline (Franklin 1999; Franklin *et al.* 2005). Among them, estrildid finches have drawn particular attention, with four species currently listed as threatened at some taxonomic level under Australia's *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Habitat loss is recognised as the top threat for Australian declining finches, caused primarily by clearing and other widespread processes transforming the landscape, such as stock grazing, altered fire regimes, and the spread of exotic plants (Tidemann 1996; Garnett *et al.* 2005; O'Malley 2006; Black-throated Finch Recovery Team (BTFRT) 2007; Legge *et al.* 2015). These changes involve intricate ecological interactions, which are poorly understood and generate much uncertainty for conservation management.

Targeted research on the Gouldian Finch (*Erythrura gouldiae*), one of the most iconic species in the group, has proven useful to understand its responses to complex

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dynamics such as fire (Legge *et al.* 2015). However, information for other species is scarce, and often context dependent. More conservation-oriented research is needed, but acquiring knowledge is costly and time consuming, and, given the limited resources available for conservation, it is important to weigh up the benefits of investing in species research against implementing management actions (Maxwell *et al.* 2015).

Another species of estrildid finch, the Black-throated Finch (*Poephila cincta*), offers a particularly dramatic example of the shortcomings of a lack of ecological information that can be applied to conservation. Its southern subspecies (*Poephila cincta cincta*), one of the two genetically distinct subspecies (Tang 2017), suffered an 80% reduction of its extent of occurrence over the last two decades of the 20th century (Threatened Species Scientific Committee 2005; BTFRT 2007; NRA 2007). As a result of this contraction it is currently considered as 'Presumed Extinct' in New South Wales under the *Biodiversity Conservation Act 2016*, and 'Endangered' both in Queensland and nationally under the *Nature Conservation Act 1992* and the EPBC Act.

Despite the early identification of this decline (Franklin 1999), the conservation of the Black-throated Finch southern subspecies (hereafter BTF) has been hampered by a lack of knowledge around the subspecies' ecology. As a response, a dedicated Recovery Plan was completed in 2007 (BTFRT 2007). Recovery Plans aim to identify research and management actions to conserve threatened species and ecological communities listed under Australia's EPBC Act. However, regardless of recent research efforts (Isles 2007; NRA 2007, 2009, 2011; Whatmough 2010; Maute 2011; Rechetelo 2016; Vanderduys *et al.* 2016; Melton 2017; Tang 2017), few conservation gains have been achieved 11 years after the initial plan (Reside *et al.* 2019), and there is still much uncertainty around the state of knowledge of the BTF or best management guidelines.

A list of clear research questions aimed to inform the management of the BTF is the first step to improve the effectivity of conservation efforts. In this paper, we review the case of the BTF, one of the most alarming examples of the decline of Australian granivores. We present a critical examination of all available information on the BTF's ecology and threats (Appendix A, B), highlighting the main gaps and areas of possible bias that generate uncertainty for conservation planning. Our final aim is to outline research priorities that can be used as guidelines for future studies, optimising conservation investment.

Ecology of the Black-throated Finch southern subspecies

Distribution and abundance

Historically the BTF occurred in an area up to 500 km inland from north-eastern New South Wales to a broad hybridisation zone with the northern subspecies (*Poephila cincta atropygialis*) between the headwaters of the Burdekin and Lynd Rivers in north-eastern Queensland (Morris *et al.* 1981; Ford 1986; Ley and Cook 2001) (Figure 1).

Post-2000 sightings indicate a significant contraction towards the northern edge of their distribution, and most records concentrate within two stronghold areas (Figure 1). These roughly correspond to the Townsville Coastal Plain subregion on the northern border of the Brigalow Belt Bioregion, and the eastern half of the Desert Uplands Bioregion (as described by the Department of the Environment, Interim Biogeographic Regionalisation for Australia version 7, 2012).

Recent bird surveys in the Desert Uplands eastern edge record the highest abundance of BTFs per unit effort (GHD Pty Ltd 2012, 2013), which suggests that the area supports the largest remaining BTF population. However, there is no reliable estimate of the total number of remaining BTFs in the wild, and the lack of systematic long-term monitoring creates uncertainty about ongoing population trends. The longest running monitoring program for the BTF is an annual count conducted at waterholes in the area surrounding the city of Townsville since 2003. However, results are likely to be biased by water availability at waterholes depending on patterns of preceding rainfall.

Distribution-wide, opportunistic observations reveal that the number of big flocks has decreased in favour of smaller ones both in the Townsville Coastal Plain and the Desert Uplands (Figure 2). While this could be an artefact of a likely increase in fragmentation due to habitat loss and the non-systematic origin of the data, it raises concerns about an ongoing population decline within both remaining BTF strongholds.

The scarcity and inconspicuousness of the BTF, and its distribution across extensive, rarely surveyed rangelands, poses a significant challenge for the collection of accurate occurrence and abundance data. As a consequence, it is likely that current knowledge of its extent of occurrence and area of occupancy is incomplete. Available habitat suitability models (Vanderduys *et al.* 2016) provide useful information about remaining suitable areas, but these should be treated carefully, as a lack of field data can create a false impression of the true extent of occupied habitat (Cosgrove *et al.* 2017). The shortage of data about BTF abundance and distribution limits the accurate assessment

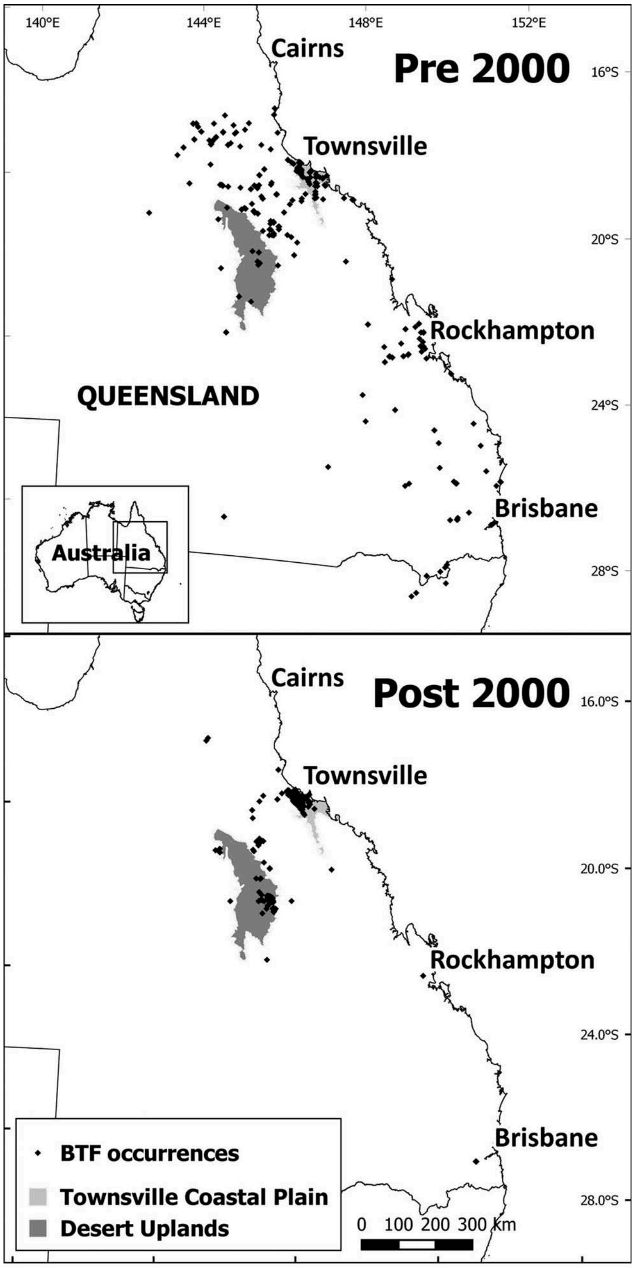

Figure 1. Decline in occurrences of Black-throated Finch southern subspecies (BTF). Data from the BTF Recovery Team Database. Occurrence records pre-2000 (top) and post-2000 (bottom). Greyed areas indicate the two main stronghold bioregions in Queensland, Australia where the BTF occurs: Townsville Coastal Plain in light gray and Desert Uplands in light gray (maps accessed from https://www.environment.gov.au/land/nrs/science/ibra).

of the conservation status of the subspecies, which in turn limits strategic planning.

Habitat

Southern Black-throated Finches inhabit mainly tropical open woodlands dominated by tree species in the genera *Eucalyptus, Corymbia* and *Melaleuca* (Isles 2007; NRA 2007; GHD Pty Ltd 2012, 2013; Rechetelo 2016). These habitats combine areas of sparse woody vegetation, used for nesting, resting, or as vantage points, with a ground layer of grass with patches of bare ground on which to forage (Mitchell 1996; Rechetelo 2016). Their occurrence is associated with areas in the vicinity of permanent sources of drinking water, such as streams or waterholes, which they visit daily (NRA 2005, 2009; Rechetelo 2016). Ephemeral water sources are also used (GHD Pty Ltd 2013), and may be critical to allow dispersion and sustain populations year-round. Black-throated Finches also occur in denser woodland and open forests with riverine vegetation (Baldwin 1976; Morris *et al.* 1981; Immelmann 1982), but the use of riparian areas has been less often reported within their current range.

A significant part of BTF habitat is currently restricted to pastoral lands (NRA 2009, 2011; GHD Pty Ltd 2012). Such areas are often exposed to high grazing pressure and the presence of non-native vegetation, which is likely to result in sub-optimal habitat (BTFRT 2007). Southern Black-throated Finches prefer areas of lightly grazed or ungrazed native grasses (GHD Pty Ltd 2012, 2013; Rechetelo 2016), while heavily grazed sites are avoided (GHD Pty Ltd 2012, 2013). Furthermore, BTFs on pastoral land show significantly higher hormonal indicators of stress compared to individuals of the northern subspecies in protected areas (Maute 2011).

In species conservation, understanding the key habitat features determining suitable habitat is an essential component to guide on-site management practices and identify high-quality areas that need to be protected. This is particularly important in cases such as that of the BTF, where the extent of remaining suitable habitat is already limited. Owing to the lack of quality data from regions other than the highly modified Townsville Coastal Plain (Table A1), it is likely that our knowledge of the optimal habitat requirements of the BTF is biased or incomplete. Information from the Desert Uplands is scarce and relies on broad vegetation classifications and plant inventories (GHD Pty Ltd 2012, 2013). Likewise, the absence of long-term studies (Table A1) limits our understanding of seasonal changes in the habitat, which is critical to design management plans to ensure persistence throughout the year.

Movement ecology

The BTF is generally described as 'sedentary' or 'resident' (Higgins *et al.* 2006; Garnett *et al.* 2011). Individuals often occupy the same site for 100–600 days (Rechetelo 2016), which suggests that they may inhabit the same areas throughout their life. Genetic population structuring can

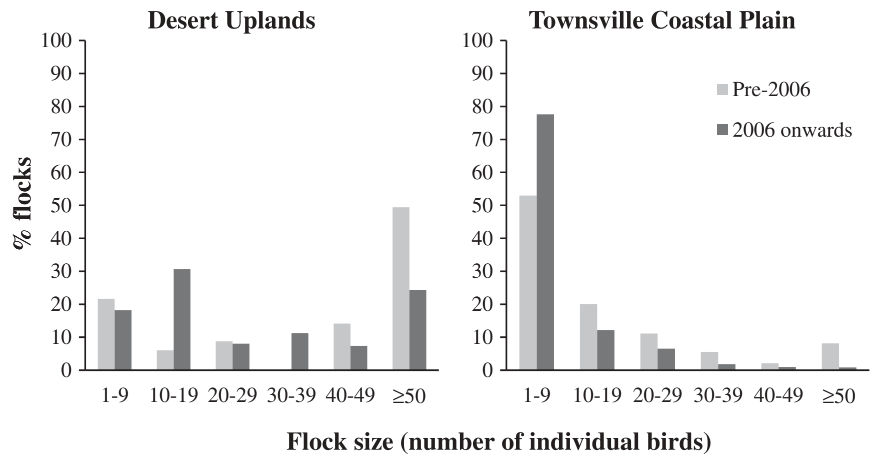

Figure 2. Black-Throated Finch southern subspecies (BTF) flock sizes pre- and post-2006 in two of its remaining stronghold areas in Queensland Australia: the Townsville Coastal Plain and the Desert Uplands. Data from the BTF Recovery Team Database (BTFRT unpub.).

occur over a distance of 10–20 km, seemingly limited by habitat fragmentation and the presence of dispersal barriers, such as large water bodies (Tang 2017).

Locally, BTFs perform daily foraging and drinking movements, which tend to be restricted to less than 350 m from their roost (Isles 2007). Nonetheless, there are records of individuals moving up to 1.5 km in a day (Mitchell 1996). Most daylight hours are spent foraging or perching, moving in small groups early in the morning and aggregating into bigger flocks later (Mitchell 1996; Rechetelo 2016), often mixing with other species (GHD Pty Ltd 2012, 2013; Vanderduys *et al.* 2012).

Home range estimates show that, during the dry season, BTFs use an area of 50.79 ha (min = 25.15; max = 120.88) (Rechetelo 2016). Alternatively, pairs forage in an area of 12 ha during the breeding season (NRA 2005); while shortly after breeding this area may be as small as 2.3 ha (Isles 2007). However, these results remain inconclusive, as they are based on scarce, short-term data, and, as a result of disparities among methods, they are not comparable (Table A2).

Despite their seemingly sedentary habits, BTFs have been recorded moving more than 16 km in a minimum of 49 days (Rechetelo 2016). There is no information on the frequency and drivers of these movements, although it has been suggested that they might be triggered by weather events (Baldwin 1976; McCutcheon 1976; Passmore 1982; Mitchell 1996). This behaviour is common in other estrildid finches, which have developed partially nomadic habits, performing long-range resource-tracking movements as a response to local bottlenecks (Higgins *et al.* 2006).

Given the difficulties in tracking the movements of BTFs and obtaining systematic data, there is still much uncertainty about their movement ecology. The limited information available has been collected exclusively in the Townsville Coastal Plain, where the landscape is highly fragmented; a factor that might bias our interpretation of BTF behaviour in other contexts. Further investigation on the home range and long-distance movements of the BTF is needed to understand its fundamental spatial requirements, which can help inform spatial planning.

Diet and foraging behaviour

Southern Black-throated Finches forage primarily on fallen seeds of grasses, sedges and legumes (Mitchell 1996; NRA 2005; GHD Pty Ltd 2012; Rechetelo 2016). Systematic diet observations are scarce (Table A3), and most information on species consumed originates from opportunistic records and indirect sources such as plant composition at foraging patches (Table B1). There is an apparent preference for native grasses (Rechetelo 2016), but seeds of non-native species are often consumed (Table B1) and could, in particular cases, provide the bulk of their diet (Mitchell 1996).

The high variability in seasonal and inter-annual weather patterns typical within tropical savannahs leads to large fluctuations in plant composition and the condition of foraging habitat (Crowley and Garnett 1999, 2001). Resource bottlenecks might occur at the end of the dry season, when productivity is low, or at the onset of the wet season, when seeds are germinating or inaccessible due to flooding (Mitchell 1996). In response to these bottlenecks, BTFs can shift their dietary habits, widening the diversity of seeds consumed (Mitchell 1996; Isles 2007; Meyer and Agnew 2012), changing their foraging strategies (Mitchell 1996), or preying on termites and other insects (Rechetelo 2016).

Uncertainties about the role of specific grasses common within BTF habitat (Rechetelo 2016) need to be clarified. Habitat management plans should aim to identify and promote local seeding species that can provide suitable seed, while allowing a patchy ground layer where BTFs can forage (BTFRT 2007). A better understanding of the causes and impacts of seed shortages can also prove useful to inform adaptive management that can minimise the risk of seasonal population declines.

Nesting and breeding

Black-throated Finches aggregate in loose colonies to breed, building their nests within the foliage, forks, hollows or mistletoes in the outer branches of trees (North 1901–1914; Roberts 1955; Campbell 1974; Baldwin 1976; NRA 2005; Rechetelo 2016). Preferred nesting trees include species in the genera *Eucalyptus, Corymbia* and *Melaleuca* (GHD Pty Ltd 2013; Rechetelo 2016), rarely found more than 400 m away from a permanent water source (Isles 2007). Nests are made out of woven grass (North 1901–1914; Campbell 1974), and can be used for breeding or roosting, often serving both purposes (NRA 2005). Pairs are socially monogamous and show site fidelity, often using the same nest in consecutive years (NRA 2005; Isles 2007).

Southern Black-throated Finches can breed at any time of year (Forshaw *et al.* 2012) (Table A4), though peaks in breeding activity seem to coincide with periods of high food availability, which, in the Townsville Coastal Plain, tend to occur 2 months after substantial rainfall (Mitchell 1996). Black-throated Finches lay five to six eggs per clutch (North 1901–1914; Campbell 1974), and juveniles remain with their family group months after becoming fully independent (Forshaw *et al.* 2012). There is a shortage of information on the BTF's life cycle in the wild, but captive individuals reach sexual maturity after 6 months, while life expectancy is 4–6 years (Shephard 1989).

Factors influencing breeding success in the BTF are still largely unknown. In other estrildids, competition over high-quality sites can cause a reduction in reproductive success (Brazill-Boast *et al.* 2010, 2011, 2013). In the case of the BTF, limited access to foraging resources is a more likely cause for breeding failure. Seed shortages can lead to the abandonment of their nesting areas (NRA 2005). Understanding the factors leading to breeding success is essential to manage populations and support their recovery.

Main threats to the Black-throated Finch southern subspecies

Habitat destruction: land clearing

Land clearing is recognised as the leading historical cause for the decline of the BTF (BTFRT 2007; Reside *et al.* 2019). Southern Black-throated Finch habitat loss due to clearing has been more intense in the southern parts of its former range, particularly affecting riparian woodlands (BTFRT 2007; NRA 2007; Reside *et al.* 2017). The Brigalow Belt Bioregion, which encompasses the Townsville Coastal Plain, one of the two BTF strongholds, has one of the highest current and historic rates of clearing in Queensland, with more than 50% of its area already cleared (Accad *et al.* 2017; Reside *et al.* 2017).

Ongoing urban expansion around Townsville further threatens to remove BTF habitat. Since European settlement, the estimated average size of habitat patches available to BTFs in the region has dropped from 168 to 33 ha (Whatmough 2010). In 2010, proposals for development of the Townsville Coastal Plain were predicted to cause the further loss of 3190 ha of BTF habitat (Whatmough 2010), some of which has already occurred.

Globally, more than 36 000 ha of BTF habitat were cleared between 2013 and 2015, and another 120 000 ha have been slated for clearing for agriculture (Department of Science, Information Technology and Innovation of Queensland 2015, 2016). Further habitat loss in areas that might be crucial to the persistence of surrounding populations, either as seasonal resource refuges, or as stepping stones, might lead to a collapse of BTF populations (Saura *et al.* 2014). Habitat suitability models predict that 56.9% of remaining BTF habitat falls within resource extraction or exploration tenures (Figure 3; Vanderduys *et al.* 2016). Within these, currently approved plans for extensive areas of open-cut and underground mining within the Desert Uplands (Hancock Prospecting Pty Ltd 2010; AMCI Pty Ltd, Alpha Coal Pty Ltd 2012; Macmines Australia Pty Ltd 2012) would remove almost 50% of BTF habitat within the region (Vanderduys *et al.* 2016).

Most described projects propose to individually mitigate their impacts through offsetting (Eco Logical Australia 2012; EHP 2013). However, the limited area of suitable BTF habitat remaining, the poor condition of selected offsets, and the lack of a BTF-specific cumulative impact assessment, or a coordinated plan for development, makes offsets unlikely to compensate for the losses caused by clearing (Vanderduys *et al.* 2016; Melton 2017).

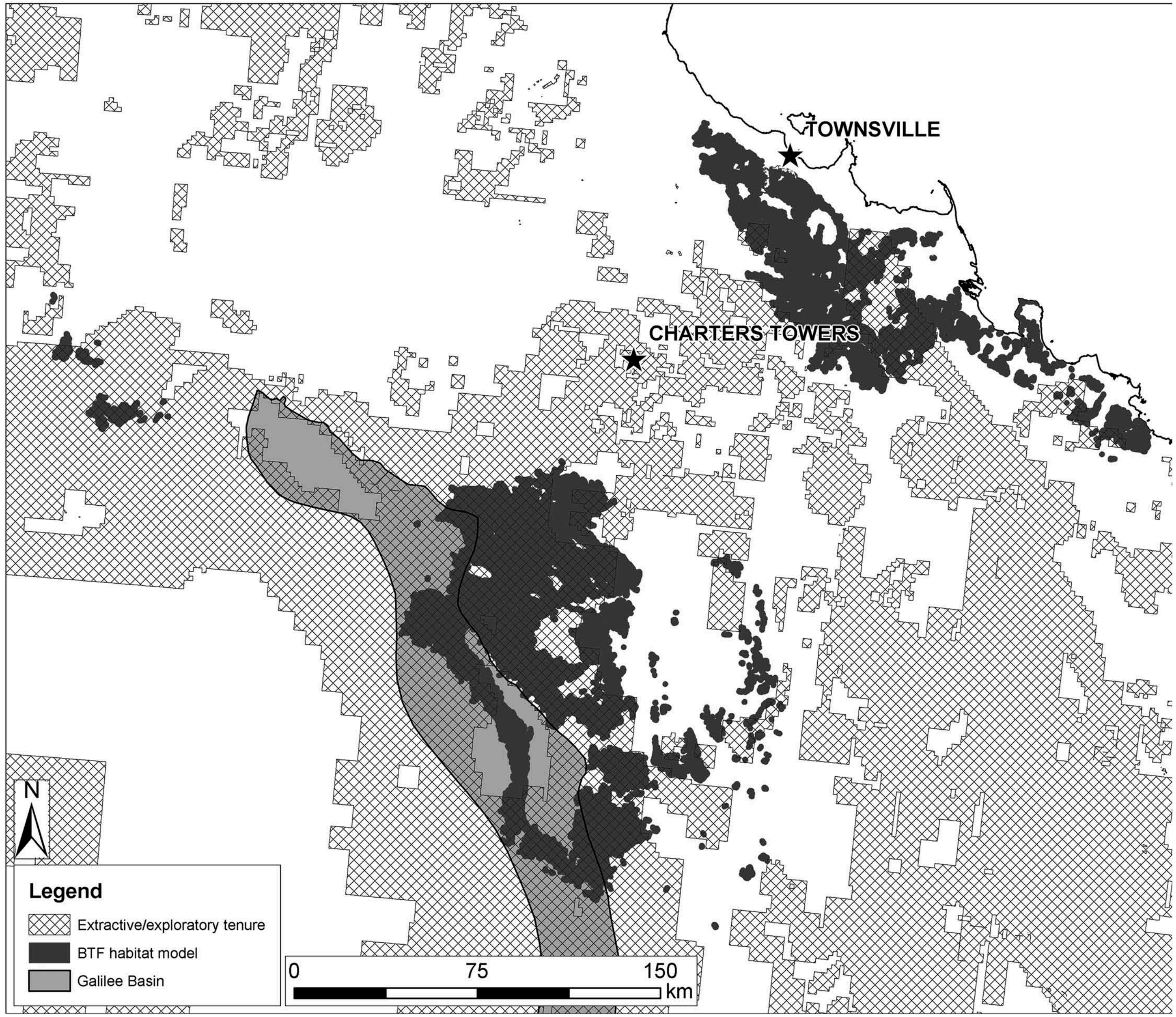

Figure 3. Predictive model showing remaining suitable habitat for the Black-throated Finch southern subspecies (BTF) (dark grey). The hashed area represents tenures with granted extractive or exploratory permits and susceptible to clearing. The light grey area marks the Galilee Basin, which encompasses properties with approved plans for open-cut coal mining. Source: Vanderduys *et al.* (2016). Used under a CC BY licence, with permission from Eric Vanderduys, original copyright 2015.

Habitat modification: changes in grazing and fire regimes

Widespread livestock farming has led to significant changes in habitat condition within BTF range, often resulting in a degradation of available habitat (BTFRT 2007). Increased grazing pressure and trampling removes biomass from the grass layer, decreasing seed production and altering the composition of the community (Woinarski and Ash 2002; Read and Cunningham 2010). The severity of these threats has been greater in the southern parts of the BTF's historical range, coinciding with a predominance of sheep grazing rather than cattle, and larger rabbit populations (Garnett 1993; Franklin 1999), which might help explain past patterns of disappearance.

Changes in fire regimes are known to affect Australian bird communities (Woinarski 1990; Woinarski and Legge 2013). Intensive grazing regimes often result in a reduction in natural fuel loads (Roques *et al.* 2001). Additionally, fire management practices in small pastoral properties of northern Australia typically involve exclusion (Fensham 1997). As a result, there is likely to have been an overall reduction in fire frequency and intensity within BTF habitat, favouring the predominance of shrubs and low stratum woody vegetation (Moreira 2000), which compete with grasses (Scholes and Archer 1997).

Habitat modification: introduced plant species

Pastoralism has contributed to the spread of non-native plant species in Australia (Grice *et al.* 2013). Invasive shrubs such as Chinee Apple (*Ziziphus mauritiana*) and Lantana (*Lantana camara*) often form thickets, dominating the landscape (Smith 2002). The proliferation of both species in areas inhabited by the BTF coincides with a decrease in BTF abundance (Rechetelo 2016), suggesting that they are impacted negatively by invasive shrub species.

The impacts of introduced grasses are less well understood. Some species may be less suitable food sources when compared to native grasses (NRA 2007; Grice *et al.* 2013), and BTFs tend to avoid foraging patches where introduced species, such as Grader Grass (*Themeda quadrivalvis*), are abundant (Rechetelo 2016). However, other non-native species such as Sabi Grass (*Urochloa mosambicensis*) and Southern Crabgrass (*Digitaria ciliaris*) can be dietary resources (Mitchell 1996).

Other threats

Other threats might have contributed to local extinctions, aggravating the impacts of habitat loss. Introduced predators such as Cats (*Felis catus*) are known to prey on estrildid finches (Barratt 1997; Paltridge 2002), including BTFs (Woinarski *et al.* 2017). However, specific records on predated BTFs are anecdotal, leading to uncertainty about the magnitude of this threat.

Droughts and other catastrophic phenomena, such as tropical cyclones or storms typical of north-eastern Queensland, can lead to abandonment of nests and deterioration of suitable habitat (NRA 2005). These phenomena might become a severe threat in areas where fragmentation is greater, as access to alternative suitable habitat is limited, and may result in mortality events.

Aviculture might also negatively affect BTF populations (BTFRT 2007). Trapping is likely to have led to local extinctions in the past, although it is unlikely to be a substantial threat in the present (Roberts 1979; Garnett *et al.* 2011). Likewise, hybridisation with escapees can be detrimental for the genetic stock of small populations (BTFRT 2007), but little is known about hybridisation rates in the wild.

Future research aims

There is still much uncertainty around the status and ecological requirements of the BTF. While its decline was identified decades ago, available data on the abundance and distribution of the BTF are scarce. Establishing adequate monitoring programs is a top priority to assess the true status of the BTF, identify the impact of ongoing threats and the outcomes of management actions.

Further ecological studies should target information necessary to implement effective management actions. The current partial understanding of many aspects of the BTF's ecology could lead to inefficient allocation of resources, or even result in perverse conservation outcomes (e.g. Game *et al.* 2013). Many of the gaps in BTF knowledge are a result of the difficulties associated with collecting data on a rare and inconspicuous species, as well as the limited spatial and temporal scope of past studies.

With these priorities in mind, we propose the following list of research actions:

(i) Monitor BTF population trends by implementing adequate long-term count schemes, prioritising the two known strongholds. A combination of techniques, such as waterhole surveys, active searches and camera trapping, has been shown to improve accuracy (GHD Pty Ltd 2012, 2013).

(ii) Map the current area of occupancy of the BTF and monitor possible contractions. Surveying for presence throughout its potential extent of occurrence using methods as described in research action (i) can improve detection, but passive techniques such as bioacoustic monitoring should be tested, as they might provide an inexpensive alternative.

(iii) Conduct field experiments to identify the best grazing and fire management regimes to provide management recommendations that can ensure BTF persistence in pastoral lands.

(iv) (iv) Improve our understanding of the main habitat features determining suitability. Comparative habitat studies between the two strongholds can prove particularly informative, especially focusing on the role of vegetation structure.

(v) Evaluate the effects of fragmentation on population size and viability. Similar to action (iv), a study should focus on possible differences between the highly fragmented Townsville Coastal Plain and the less modified Desert Uplands Bioregion.

(vi) Determine dietary preferences by conducting seed-choice experiments, as well as investigate the local role of specific grass species to inform vegetation management. This information might prove difficult to obtain in the field, but captive individuals can help to clarify current uncertainties.

(vii) Investigate the spatial requirements of the BTF by acquiring long-term systematic movement data that can help refine current home-range estimates and reveal the drivers for longer distance movements.

(viii) Identify the main drivers of reproductive success, targeting the effects of the most likely limiting factors, such as food resource bottlenecks.

The proposed list of research actions is ranked according to our qualitative assessment of pressing knowledge needs. However, given the limited resources available for conservation, it is important to evaluate the costs and benefits of investing in ecological research against threat abatement (Maxwell *et al.* 2015). Any research should be conducted while obvious threats are halted or minimised, the most prominent being habitat clearing.

We recommend further quantitative evaluation of research priorities to determine the value of obtaining new information. For this purpose, we suggest performing a value-of-information analysis, a decision-making tool used to quantify the expected management gains of investing in reducing uncertainty (Runge *et al.* 2011). The results of such study can help set up an objective framework for resource allocation that can be implemented in structured decision making and adaptive management plans (Moore and Runge 2012; Saura *et al.* 2014)

We expect that this review and our recommendations will add valuable information to previous and ongoing conservation efforts such as the upcoming update of the Black-throated Finch Recovery Plan, leading towards more cohesive planning and the successful conservation of the BTF. Much of the knowledge gained by our recommendation is likely to be relevant to other declining granivorous birds, and also for other components of declining woodland bird communities (Fraser *et al.* 2019). Further understanding the effect of different management regimes, particularly for grazing and fire, are still research priorities for woodland birds across Australia (Ford 2011).

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Appendix A

The following tables list the main sources of information for each of the four main aspects of the BTF's biology and ecology.

Table A1. Major original sources and key findings describing Black-throated Finch southern subspecies (BTF) habitat.

Source	Area	Methods	Key findings
Morris *et al.* (1981)	New South Wales	Compilation of records	• Recorded in dense shrubbery bordering watercourses in savannah woodlands
Immelmann (1982)	Distribution-wide	Personal observations and literature review	• Habitat described as woodland with a dense understorey of grass and scrub
Baldwin (1976)	New South Wales	Compilation of records	• Recorded in dense riparian vegetation
NRA (2005)	TCP	Two observational studies at nesting sites. First study: Site 1 visited on 32 occasions, March 2004–May 2005. Site 2 visited on 10 occasions, April 2003–May 2005. Second study: both sites visited monthly, October 2004–May 2005	• Observed foraging in eucalypt woodlands, exotic and native grasslands and exotic shrublands. Apparent preference for foraging in disturbed areas next to areas of intact habitat • Nests found primarily in areas of *Eucalyptus platyphylla* and *Corymbia clarksoniana* woodland on alluvial plains. Also recorded in non-remnant vegetation
Isles (2007)	TCP	Habitat surveys and systematic observations conducted at two sites. Sites visited every second week, March–August 2006	• Recorded breeding in areas of *Eucalyptus platyphylla* and *Corymbia clarksoniana* woodland on alluvial plains
Maute (2011)	TCP and Cape York	Blood sampling at two sites visited November and December of 2007 and 2008 as well as June of 2008 and 2009; 228 BTFs sampled	• BTFs in grazed areas showed higher variation in health indices than *P. cincta atropygialis* in protected areas
NRA (2009)	TCP	Desk-based analysis using nest locations and environmental layers. Nest data obtained from previous surveys, 2003–2009	• Nests found predominantly in woodlands and open woodlands in alluvial plains, pediplains or rises dominated by *Eucalyptus platyphylla*, *E. drepanophylla*, *Corymbia clarksoniana*, *C. dallachiana*, *C. erythtrophloia* and *Casuarina cunninghamiana* • During the dry season, predicted nesting habitat contracts by 44% in the Brigalow Belt North Bioregion and 17% in the Wet Tropics Bioregion • Average distance of nests to water was 167 m
GHD Pty Ltd (2012)	DEU	Study comprising four survey methods (water source watches, 2 ha bird searches, remote fauna cameras and habitat assessment) conducted 21–26 May 2012	• Mostly recorded in *Eucalyptus melanophloia* open woodland, with a mosaic of *Eucalyptus brownii* open woodland to woodland and *Eucalyptus melanophloia* woodland, with occasional *Corymbia dallachiana*, on sandy alluvial plains. Also recorded in non-remnant vegetation • Grass species *Digitaria divaricatissima*, *Paspalidium rarum*, *Schizachyrium fragile* and *Themeda triandra* significantly more abundant at sites where BTFs were present
GHD Pty Ltd (2013)	DEU	Study comprising four survey methods (water source watches, 2 ha bird searches, remote fauna cameras and habitat assessment) conducted 23–31 May 2013.	• Most abundant in areas dominated by *Eucalyptus melanophloia* woodlands and the associated *Eucalyptus similis* and *Eucalyptus populnea/brownii* woodlands • Presence associated with higher percentages of hummock grass cover and particular species such as *Triodia pungens*, *Cymbopogon obtectus*, *Panicum effusum* and *Tripogon loliformis* • Recorded using smaller and ephemeral water sources (troughs, scrapes, puddles in drainage lines)
Rechetelo (2016)	TCP	Multiple studies: bird surveys conducted weekly or monthly, November 2011–January 2014 at 10 sites. Habitat surveys conducted July to December 2013 at the same sites. Vegetation and ground cover surveys conducted June 2013–January 2014 at 33 foraging patches. Tree characteristics measured for 50 nesting trees. Habitat surveys carried out around a subset of 20 nests	• General BTF habitat characterised by a prevalence of native grass species, low shrub cover and abundance, high density of dead standing trees and presence of grasses *Eragrostis* spp. and *Setaria surgens* • Foraging habitat characterised by medium cover of woody vegetation, maintaining a low abundance of shrubs and dead standing trees used as a medium stratum • Foraging patches (as small as 2 m^2) characterised by lower habitat complexity, ground cover and diversity than adjoining areas. Most of them <400 m away from water • Nesting habitat characterised by lower tree density and shrub density than surrounding areas, ground cover parameters did not play an important role in nesting site selection

TCP = Townsville Coastal Plain; DEU = Desert Uplands.

Table A2. Major original sources and key findings describing the movement ecology of the Black-throated Finch southern subspecies (BTF).

Source	Area	Methods	Key findings
Baldwin (1976)	New South Wales	Compilation of records	• BTFs not found in their regular areas of occurrence after a drought period in 1976
McCutcheon (1976)	New South Wales	Compilation of records	• BTFs recorded in 1968 in an area where they were not observed before, as a severe drought took place in surrounding areas
Longmore (1978)	Rockhampton area (Queensland)	Field observations from February 1973 to October 1974	• BTFs reported to move locally • Mostly recorded in pairs and flocks of up to 20 individuals
Passmore (1982)	South Queensland	Compilation of records	• Recorded in 1979 but reported to have left after a drought in 1980. Later recorded in close areas but not same site as it was mined
Mitchell (1996)	TCP	Observational study around five general areas visited monthly, January–December 1995	• Dispersion to breeding sites occurred early in the year • Pairs returned to non-breeding sites late in the year, after the onset of the wet season • Daily foraging movements of up to 1.5 km, depending on foraging habitat availability
NRA (2005)	TCP	Two observational studies at nesting sites. First study: Site 1 visited on 32 occasions, March 2004–May 2005. Site 2 visited on 10 occasions, April 2003–May 2005. Second study: both sites visited monthly, October 2004–May 2005	• Predominantly seen in pairs, foraging in small groups (two to eight individuals), although less often in larger groups of >20 • Early in the breeding season pairs used the same small area (12 ha) intensively to forage, breed and roost • Distance from nest sites to foraging sites increased as conditions became drier • In the dry season, BTFs found infrequently during the day around nests, although they would return to roost overnight
Isles (2007)	TCP	Habitat surveys and systematic observations conducted at two sites. Sites visited every second week, March–August 2006	• Main portion of the day spent foraging close to the nest in short bouts, rarely travelling more than 350 m • Foraging occurred more often at particular locations that were visited repeatedly
GHD Pty Ltd (2012)	DEU	Study comprising four survey methods (water source watches, 2 ha bird searches, remote fauna cameras and habitat assessment) conducted 21–26 May 2012	• BTFs moving or foraging in mixed flocks on 33% of occasions they were recorded. Most predominantly with *Artamus cinereus, Tanaetopygia bichenovii, Oreoica gutturalis, Myiagra inquieta* and *Microeca fascinans*
Vanderduys *et al.* (2012)	Northern Queensland	Multiple bird surveys between 2004 and 2010	• BTFs commonly found in mixed flocks with other species such as *Artamus cinereus*
GHD Pty Ltd (2013)	DEU	Study comprising four survey methods (water source watches, 2 ha bird searches, remote fauna cameras and habitat assessment) conducted 23–31 May 2013	• Found foraging in mixed flocks, especially with *Artamus cinereus* and *Rhipidura leucophrys*
Rechetelo (2016)	TCP	Studies conducted at eight sites, 2012–2014. Banding study: 102 BTFs banded in a total of 1088.5 mist-netting hours. Radio-tracking study: 15 BTFs radio-tracked individually at different times in the dry season. Average tracking time for each individual was 11.6 days, with active tracking 5–12 h a day. Number of fixes varied from 1 to 11 per day and a total of 2–111 per individual	• >50% of re-sightings within first 100 days and 200 m of banding site • Five re-sightings at the same site 400 days after banding, and 1 > 600 days • Three re-sightings >15 km from banding site (49 and 132 days after last sighting) • Home ranges from 25.15 to 120.88 ha (95% KDE) and increased later in the dry season • Seen in small flocks (two to three individuals) early in the morning and aggregating at foraging areas into bigger flocks (20–40 individuals) by mid-morning
Tang (2017)	TCP	Sampled blood from 86 BTFs at seven sites between 2011 and 2013. Forty-eight additional samples obtained in 2009 from a previous study (Maute 2011)	• Distinct spatial population structuring occurs at a scale of 10–20 km • Large bodies of water are a barrier reducing gene flow, while other landscape structural variables are potential drivers limiting dispersal

TCP = Townsville Coastal Plain; DEU = Desert Uplands.

Table A3. Major original sources and key findings describing the diet and foraging ecology of the Black-throated Finch southern subspecies (BTF).

Source	Area	Methods	Key findings
Mitchell (1996)	TCP	Systematic observations around five general areas visited monthly, January–December 1995	• Thirteen seed types explicitly recorded as consumed out of 21 seed types potentially used, six from non-native grasses and most of them perennial • Introduced grass *Urochloa mosambicensis* dominated diet in January and early February. After that, birds moved to breeding areas and actively selected for patches of native *Digitaria ciliaris* • Diet breadth largely increased after September until the end of the year • Foraged predominantly from the ground, although the diversity of foraging techniques increased in September and remained high until November
NRA (2005)	TCP	Opportunistic observations between 2003 and 2005	• Twelve seed types recorded as consumed, three from non-native grasses
Isles (2007)	TCP	Habitat surveys and systematic observations conducted at two sites. Sites visited every second week, March–August 2006	• Nine grass species identified as significantly more abundant within foraging areas compared to habitat matrix, predominantly natives • Five other grass species were found to be significantly less abundant
GHD Pty Ltd (2012)	DEU	Opportunistic observations in May 2012	• Recorded foraging on five seed types, all native
Meyer and Agnew (2012)	DEU	Opportunistic observation	• Recorded likely foraging on eucalypt seeds
Rechetelo (2016)	TCP	Opportunistic observations between 2011 and 2014	• Foraging on seeds of *Melinis repens, Gomphrena celosioides* and flying termites

TCP = Townsville Coastal Plain; DEU = Desert Uplands.

Table A4. Major original sources and key findings describing the nesting and breeding ecology of the Black-throated Finch southern subspecies (BTF).

Source	Area	Methods	Key findings
North (1901–1914)	Queensland and New South Wales	Compilation of records	• Multiple records of breeding behaviour as early as March and as late as December • Nests recorded in tree branches, hollows, under raptor nests or sugar-cane leaves • Number of eggs recorded ranged from one to seven, with five or six being the most common clutch size recorded
Roberts (1955)	Queensland	Compilation of records since 1954	• BTFs recorded using old nests of babblers
Campbell (1974)	Australia	Compilation of records	• Bottle-shaped nests constructed out of grass in hollows or the foliage of tree branches • Clutch size average is five to six eggs
Morris *et al*. (1981)	New South Wales	Compilation of records	• Eggs found mainly during August–December
Shephard (1989)	Captivity	Compilation of records	• Captive BTFs reach sexual maturity after 6 months • Life expectancy is 4–6 years
Mitchell (1996)	TCP	Observational study around five general areas visited monthly, January–December 1995	• Breeding activity began in March, 2 months after substantial rain, when seed was most abundant
NRA (2005)	TCP	Two observational studies at nesting sites. First study: Site 1 visited on 32 occasions, March 2004–May 2005. Site 2 visited on 10 occasions, April 2003–May 2005. Second study: both sites visited monthly, October 2004–May 2005	• BTFs form communal nesting sites, including both breeding and non-breeding dormitory nests • Most nests recorded in *Eucalyptus platyphylla* and *Melaleuca viridiflora*. Other hosts included *Corymbia tesselaris, C. dallachiana* and *Ziziphus mauritiana* • Most nests constructed >4 m above the ground in branches and less often tree hollows, mistletoes or the base of raptor nests • Average distance of nests to water was 280 m. Up to 400 m for permanent water • Nests often used >200 days • First breeding evidence recorded late January and last in mid-July • Apparent return to same breeding area in consecutive years

(*Continued*)

Table A4. (Continued).

Source	Area	Methods	Key findings
NRA (2009)	TCP	Desk-based analysis using nest locations and environmental layers. Nest data obtained from previous surveys, 2003–2009	• Average distance of nests to water was 167 m
GHD Pty Ltd (2013)	DEU	Study comprising four survey methods (water source watches, 2 ha bird searches, remote fauna cameras and habitat assessment) conducted 23–31 May 2013	• Nests found in *Eucalyptus melanophloia* and *Acacia coriacea*
Rechetelo (2016)	TCP	Surveys conducted during 2011–2014. Tree characteristics were measured for 50 nesting trees. Habitat surveys carried out around a subset of 20 nests	• Preferred nesting tree species were *Eucalyptus platyphylla* and *Melaleuca viridiflora* • Nests most often built within foliage in the top quarter of trees • Nests predominantly located within 400 m of a water source

TCP = Townsville Coastal Plain; DEU = Desert Uplands.

Appendix B

Table B1. List of identified species used as seed sources by the Black-throated Finch southern subspecies (BTF). 'Record' column categories include: O = observed. Individuals observed consuming the seed of the species in the wild; P = potential. Species found to be significantly more present in foraging patches used by BTF (results based only on quantitative studies).

Species	Phenology	Origin	Region	Record	Reference
Alloteropsis cimicina	Annual	Native	TCP	P	Isles (2007)
Alloteropsis semialata	Perennial	Native	TCP	O, P	Mitchell (1996); NRA (2005)
Bothriochloa decipiens	Perennial	Native	TCP	O, P	Mitchell (1996); Isles (2007)
Chloris inflata	Annual/perennial	Introduced	TCP	O, P	Mitchell (1996); NRA (2005)
Chloris spp.	–	–	TCP	P	Isles (2007)
Dactyloctenium spp.	–	–	TCP	O, P	Mitchell (1996)
Dicanthium sericeum	Annual/perennial	Native	TCP	O	NRA (2005)
Digitaria brownii	Perennial	Native	DEU	O	GHD Pty Ltd (2012)
Digitaria ciliaris	Annual	Introduced	TCP	O, P	Mitchell (1996)
Digitaria divaricatissima	Perennial	Native	TCP	P	Mitchell (1996)
Echinochloa colona	Annual	Introduced	TCP	O, P	Mitchell (1996)
Echinopogon spp.	–	–	TCP	O, P	Mitchell (1996)
Eleusine indica	Annual/perennial	Introduced	TCP	O, P	Mitchell (1996)
Enteropogon acicularis	Perennial	Native	TCP	O, P	Mitchell (1996)
Enteropogon ramosus	Perennial	Native	DEU	O	GHD Pty Ltd (2012)
Eragrostis basedowii	Annual	Native	TCP	O	NRA (2005)
Eragrostis sororia	Perennial	Native	TCP	O	NRA (2005)
Eragrostis spp.	–	–	TCP	O, P	Mitchell (1996); Isles (2007)
Eriachne mucronata	Perennial	Native	TCP	O	NRA (2005)
Eulalia aurea	Perennial	Native	TCP	P	Mitchell (1996)
Gomphrena celosioides	Other	Introduced	TCP	O	Rechetelo (2016)
Heteropogon contortus	Perennial	Native	TCP	P	Mitchell (1996)
Melinis repens	Annual/perennial	Introduced	TCP	O, P	Mitchell (1996); NRA (2005); Rechetelo (2016)
Oxychloris scariosa	Annual/perennial	Native	TCP	P	Mitchell (1996)
Panicum decompositum	Perennial	Native	TCP	O	NRA (2005)
Panicum effusum	Perennial	Native	TCP	O	NRA (2005)
Panicum spp.	–	–	TCP	P	Mitchell (1996); Isles (2007)
Paspalidium rarum	Annual	Native	DEU	O	GHD Pty Ltd (2012)
Paspalum spp.	–	–	TCP	O, P	Mitchell (1996)
Schizachyrium fragile	Annual	Native	DEU	O	GHD Pty Ltd (2012)
Setaria apiculata	Annual	Native	TCP	P	Isles (2007)
Setaria surgens	Annual	Native	TCP	O	NRA (2005)
Sorghum spp.	–	–	TCP	O	Mitchell (1996)
Sporobolus caroli	Annual/perennial/ephemeral		TCP	P	Isles (2007)
Sporobolus diander (type)	–	–	TCP	P	Mitchell (1996)
Sporobolus indicus (type)	–	–	TCP	P	Mitchell (1996)
Stylosanthes spp.	–	–	TCP	P	Isles (2007)
Themeda triandria	Perennial	Native	TCP	O, P	Mitchell (1996); NRA (2005)
Urochloa mosambicensis	Perennial	Introduced	TCP	O, P	Mitchell (1996); NRA (2005); Isles (2007)

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