Threatened Species Recovery Hub

National **Environmental Science** Programme



Background paper: Reintroduction of captive birds to the northern population of the eastern bristlebird

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Cover note to this report

This report was first authored in 2018, prior to the severe and widespread bushfires of 2019–20 and the discovery of disease in captive bristlebird populations. By collating knowledge about the northern population of the eastern bristlebird as at 2018, this report lays the foundation for any future consideration of the captive breeding program and proposed reintroduction of captive-bred birds to the wild population. Please contact the Eastern Bristlebird National Recovery Team's Northern Working Group for more current information pertaining to the population and its management.

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Cover images: (LEFT): Grassy habitat typical of the northern eastern bristlebird. Image: Zoe Stone; (CENTRE): Northern bristlebird. Image: Grant Fraser; (RIGHT): A controlled burn in grassy forest. Image: Zoe Stone.

Contents

Executive summary

The northern population of the eastern bristlebird (*Dasyornis brachypterus*) meets the IUCN criteria for being 'Critically Endangered'. Habitat loss and inappropriate fire has resulted in an 80% decline in the population since monitoring began in the 1980's, and today the wild population stands at less than 40 individuals. Habitat management is helping to improve conditions; however, additional management responses are required.

This plan outlines an emergency response for the next 10 years (2020-2030) to help restore wild populations through a strategy that combines *in situ* habitat management, captive breeding and reintroduction. Population recovery has three fundamental objectives: 1) Increase the wild population to the estimated carrying capacity of habitat fragments (70-80 territories), 2) Improve captive breeding outcomes and genetic potential and 3) identify the most cost-efficient recovery strategy.

Following IUCN translocation guidelines, alternative actions were assessed to determine the most effective management actions to increase the population and meet these fundamental objectives. A combined approach of site-specific habitat management, captive breeding and reintroduction was the only action that was capable of meeting objectives 1 & 2 within the plan's timeframe. Despite a larger cost, the benefit gained from expanding captive breeding and taking steps to increase genetic potential using birds from southern populations could be considerable for the northern population.

Nine priority sites have been identified that either currently meet, or with additional habitat management could meet, habitat requirements for long-term persistence of bristlebirds across their northern range. These priority sites include four Queensland sites (3 National Park, 1 private tenure) and five New South Wales sites (1 National Park, 4 private or jointly private tenure). Habitat management across these sites should focus on weed control and shrub removal to expand existing grassy understorey areas and restore degraded, shrub encroached areas. Following initial weed control work, prescribed burning will likely be capable of maintaining grassy condition, as has been shown at some previously managed sites for the northern populations.

A reintroduction protocol has been developed to increase the chance of successful reintroduction and establishment. The required combination of habitat management + captive breeding + reintroductions will be costly, and to support the recovery team an outline of expected costs for such a project is estimated. Overall implementation of a 10 year reintroduction strategy, including habitat management and captive breeding costs, is estimated to be $4.1 million. This includes $1.1 million of habitat management to improve condition of priority sites and expand high quality grassy habitat so that it is capable of supporting viable subpopulations. Captive breeding costs for the reintroduction strategy are estimated to be $2.3 million, which covers the expansion of the breeding program to house 12 breeding pairs that are capable of producing a minimum of 12 offspring per year. Such funding, carefully directed, is essential to support the reversal of the bristlebird's decline and help achieve a stable, viable population that is capable of recovering further.

Site specific details of habitat condition and management requirements, and a supplementary genetic management report are given in the supplementary information. In addition, ethics approvals and scientific licenses associated with the project have been appended.

Background

Eastern bristlebird

The eastern bristlebird (*Dasyornis brachypterus*) is a small, endemic, ground dwelling passerine that occupies low, dense heathland and grassy vegetation in a severely fragmented distribution along the south-east coast of Australia (Baker, 2000; Lamb et al., 1993). It is listed as 'Endangered' under the Commonwealth Environment Protection and Biodiversity Conservation Act, Queensland's Nature Conservation Act, and New South Wales' Biodiversity Conservation Act because of a steep decline in its distribution and abundance over the past 30 years. As a result of habitat loss and degradation, the once continuous distribution of the eastern bristlebird from Queensland to South Australia is now fragmented into three separate populations (Fig. 1).

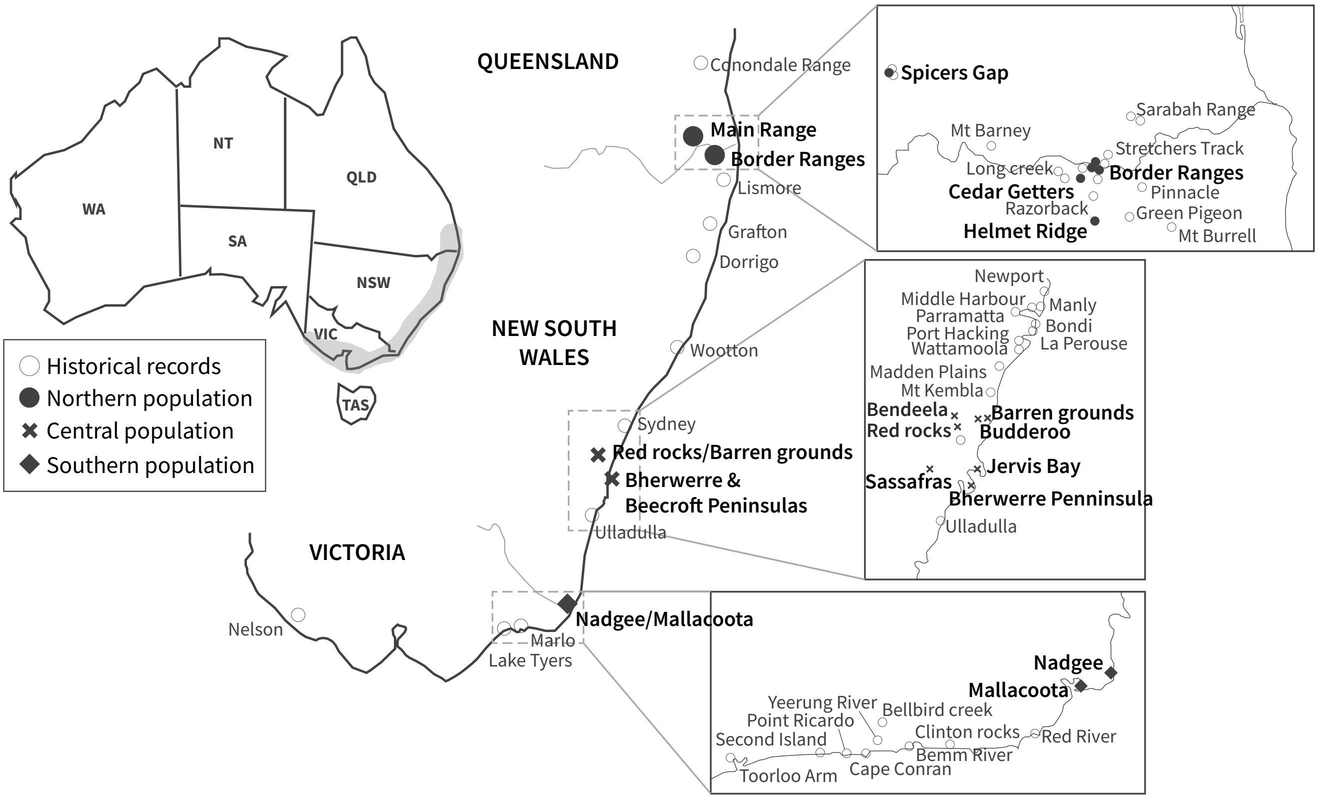

Figure 1. Historical and recent records of eastern bristlebird across south-east Australia. From Stone (2018).

The total population size of the eastern bristlebird is estimated at 2,500 individuals. The central population is the largest and most stable with roughly 2000 individuals (Bain et al., 2008; Baker, 1997; OEH, 2012). There are thought to be approximately 400 birds in the southern population and only 38 wild birds in the northern population. Both the central and southern populations occupy coastal or montane heathy habitats that are now mostly protected in conservation reserves. Habitat varies from dense heathy woodland to sedge or dense heath (Baker, 2000, 2009; Bramwell et al., 1992; Clarke & Bramwell, 1998). Genetic research by Roberts et al. (2011) found that the northern population had insufficient genetic differentiation from southern birds to retain the previously recognised subspecies *D. brachypterus monoides*. Nevertheless, the northern population occupies substantially different habitat to its southern counterparts and has several behavioural differences as well as differences in plumage colouration (Chaffer, 1954; Holmes, 1989; OEH, 2012; Schodde & Mason, 1999). As such, the northern population is considered a separate management unit that requires distinct management actions (OEH, 2012).

Northern population

The northern population of the eastern bristlebird is isolated by more than 700 km from the central and southern populations (Fig. 1). Historically, this population was found from the Conondale Ranges in the north (Holmes, 1989) to Dorrigo (NSW) in the south; a site that is 300 km further south than the southern-most current records. The northern population is highly fragmented across the landscape and territories have become increasingly isolated in patches of grassy sclerophyll forest habitat within a rainforest and pasture matrix (Lamb et al., 1993; Rohweder, 2000).

An early survey of the northern population, Holmes (1982) identified 115 occupied territories (i.e. a discrete location comprising of either a solitary individual or a pair). When surveyed seven years later, 103 territories were recorded, 51 of which were occupied by paired individuals with remainder supporting solitary individuals (Holmes, 1989). By 1992, surveys reported by Lamb et al. (1993), found only 32 territories in Queensland.

Since 1998, New South Wales sites have been continuously monitored by experts, while Queensland sites have been monitored by volunteers[1]. As of July 2016, the northern population was estimated at 38 individuals from at least 11 sites (Wildsearch Environmental Services, 2016b). Of these sites, only six (five in NSW, one in QLD) have confirmed breeding pairs (D. Charley pers. comm.).

The small effective population of birds in the wild spread across disjunct habitat patches reflects the highly isolated nature of bristlebird territories with little to no dispersal and gene flow occurring (Roberts et al., 2011). The population qualifies for 'Critically Endangered' under the IUCN red list criteria based on criterion B2a = severely fragmented or known to exist at only a single location, B2b = continuing decline in (ii) area of occupancy, (iii) area/extent/habitat quality, (iv) number of locations/subpopulations, and (v) number of mature individuals, C2a = continuing decline in mature individuals and (i) subpopulation of < 50 individuals, and D = population size of < 250 mature individuals (Garnett et al., 2011; OEH, 2012). The northern population also likely qualifies for critically endangered status under criterion A2bc = reduction in population size of ≥ 80% over the last 10 years or three generations based on abundance index and area of occupancy (Stone, 2018).

Recovery actions for the northern population

A National Recovery Team, with the objective of curating and helping guide implementation of a National Recovery Plan for the eastern bristlebird, was established in 1997 (Holmes, 1998). In recognition of the very different ecology of the northern population, a Northern Working Group was subsequently established and a draft recovery plan developed in 2001 for the northern population.

This plan was formalised as a *Northern Working Group Business Plan* in 2010 (Charley, 2010). At the same time, the National Recovery Plan was updated to include specific information on management priorities for each bristlebird population (OEH, 2012).

The Northern Working Group includes experts from government agencies, conservation and natural resource management non-government organisations, private consultants, three universities, a wildlife park (Currumbin Wildlife Sanctuary), and private landholders. Because the northern population of the eastern bristlebird is distributed across a state border, there are many partners involved and invested in its management and recovery. Key organisations involved include Queensland Department of Environment & Science, New South Wales Department of Planning Industry and Environment, Queensland and New South Wales National Parks departments, Currumbin Wildlife Sanctuary, BirdLife Southern Queensland, Birds Queensland, and Healthy Land & Water.

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[1] NSW monitoring has been continuous and more consistent (in frequency, extent and the people undertaking surveys, namely David Charley and David Rohweder) and supported financially by the NSW Government. By comparison, in Queensland a consistent monitoring program was undertaken 1999-2006 by birding group volunteers with support from the Queensland Government and coordinated by Sheena Gillman (BirdLife Australia Southern Queensland / Birds Queensland). Following a short break, funding from the Australian Government through the Natural Heritage Trust, supported further volunteer surveys between 2008-10. Since 2010, volunteer monitoring in Queensland has reduced in frequency and extent, though it has been intermittently supported by small grants from BirdLife Australia, Birds Queensland, Scenic Rim Regional Council and Healthy Land and Water; some detector dogs surveys were also able to be supported. Limited support for monitoring has been provided by the Queensland Government since 2008.

Recovery work over the last decade has included on ground habitat management and captive breeding with the goal of reintroducing birds to the wild. Weed control and prescribed burns have contributed to improving habitat condition at occupied sites and potential sites. Key conservation outcomes achieved to date include:

- Biennial and annual population surveys of northern New South Wales populations since 1998;
- Population surveys of Queensland populations since 1998 (not every year – Queensland surveys have relied heavily on volunteer contribution organised by BirdLife Australia and Birds Queensland)
- Pilot captive breeding program at David Fleay Wildlife Park, Currumbin Wildlife Sanctuary and Hidden Vale Wildlife Centre;
- Pilot re-introduction of captive birds into the wild;
- Long-term vegetation and habitat monitoring over 56 permanent transects in NSW and 16 in QLD;
- Detailed weed and habitat mapping at a majority of sites in NSW;
- Extensive habitat restoration across various QLD and at a majority of the NSW sites;
- Protection of habitat through stock fencing and removal of grazing stock
- Development of detailed fire management strategies for all important habitat areas in NSW;
- Ecological burns conducted to manage habitat; and
- Research on vegetation responses to fire, changes in vegetation structure with fire history and invertebrate abundance across key habitat areas.

Despite these achievements, the low density of birds and probable low genetic potential in the wild requires expansion of the captive breeding program and renewed effort to reintroduce birds to the wild. These priorities are consistent with the 2010 *Northern Working Group Business Plan*, where a target was set at a captive stock of 120-300 birds for release over the 10 year timeframe (2010-2020) so that the wild population may attain at least 156 birds (Charley, 2010). In response, the captive breeding program resumed at Currumbin Wildlife Sanctuary in 2014, building upon the pilot program at David Fleay Wildlife Park from 2002-2009[2]. This new program, along with increased efforts to implement more active habitat management including appropriate prescribed burning and control of invasive weeds, has meant that reintroductions of captive-bred individuals into suitable habitat within historic territories may soon be possible. Currently, the captive breeding program (now at Currumbin Wildlife Sanctuary) is experiencing high levels of infertility (Stone, 2019), with only 16 chicks successfully raised from 123 eggs between 2014 and 2018 (13% fledging success).

The need for population management

Much has been learned about habitat management actions that favour recovery of the wild population. However, even with adequate habitat management, the small effective population size of the population intensive population management may be needed for many years to come. Habitat is currently highly fragmented, with little interaction between breeding pairs in different sites. Small populations that have undergone a severe bottleneck often have limited genetic diversity (Frankham et al., 2014; Ingvarsson, 2001; Ralls et al.). Low genetic diversity is likely to be contributing to low breeding success in the captive population, but also likely in the wild population, given that most sites have one or two breeding pairs (with the exception being seven pairs at the largest site). Because of this, population growth may be extremely limited and a high level of inbreeding may occur due to limited connectivity resulting in higher risk of deleterious genetic effects if the population remains unmanaged. This, in combination with small, fragmented, fire dependent habitat could have significant impacts on the long-term health and viability of the northern population. Improving the viability of the northern population will depend on the introduction of new individuals and targeted genetic management to improve breeding success, adaptive potential and long-term persistence. The Northern Working Group has identified captive breeding and reintroduction as a Very High priority for recovery (Wildsearch Environmental Services, 2010), but for these actions to be successful, genetic limitations in the population need to be addressed.

A pilot reintroduction was undertaken in 2008 when eight birds were reintroduced to two locations. Birds were monitored for four weeks until transmitter batteries failed, after which six birds were still alive while two had been predated. At least three birds survived until 2010. No attempted reintroductions have taken place since.

[2] Captive breeding commenced in 2004 with a pilot program at David Fleay Wildlife Park. This program established husbandry methods and captive breeding potential using two wild nestlings (siblings). Over the five years of the pilot program, 38 eggs were produced from 22 clutches. From these, 14 chicks successfully fledged (36% of total eggs laid).

This Reintroduction Strategy for the Northern Population of the Eastern Bristlebird (Strategy) outlines a 10-year plan focussing on captive breeding and reintroduction and aims to complement existing management plans, such as the *Northern Working Group Business Plan* and individual site management strategies, and key State Government programs such as New South Wales' Saving our Species Program. This strategy has been developed following the IUCN reintroduction guidelines, and therefore complies with best practice suggested by the Conservation Translocation Specialist Group (previously 'Reintroduction Specialist Group'). Their guidelines follow a structured decision making process to ensure reintroductions goals and objectives are clear and actions have been well considered prior to implementation (Fig. 2).

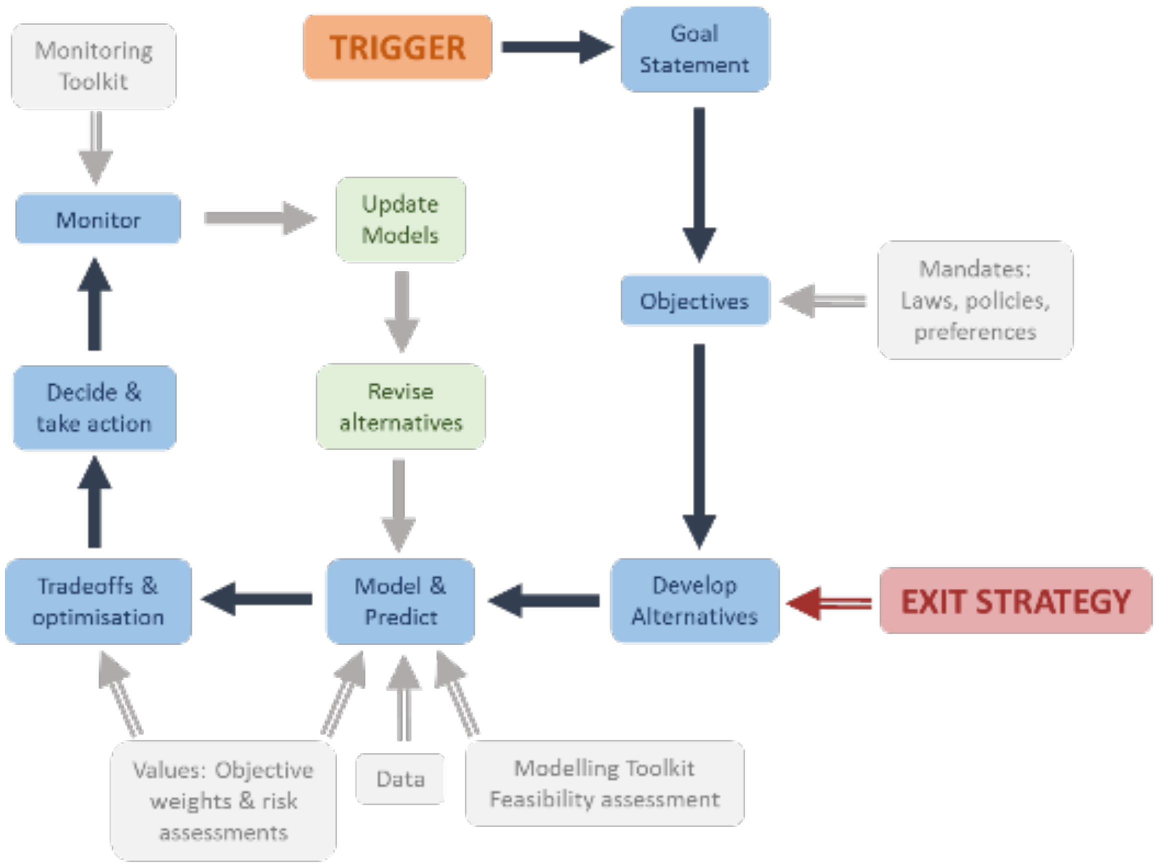


Figure 2. Conservation translocation cycle used by IUCN Conservation Translocation Specialist Group for translocation planning. Modified from IUCN RSG 2018 training course.

For reintroductions to be successful, it is important that the captive breeding program is developed to achieve specific targets and goals to support a reintroduction program. In addition, reintroduction locations need to be carefully considered for their suitability for not only immediate establishment but also long-term persistence of the species. Long-term persistence of bristlebirds will be highly dependent on the ability of reintroduction sites to meet key habitat requirements. Previous attempts at reintroduction were successful in the short term, and some of the protocol used for these will be maintained. However, there have been advancements in reintroduction science since the pilot reintroduction was conducted. This plan will provide up-to-date protocols for release and monitoring of bristlebirds based on global research, best practice and improved ecological understanding of the requirements of the northern population of the species.

This plan will cover

1. Project goal statement
2. Fundamental objectives and assessment of management actions
3. Summary of current captive breeding facilities
4. Captive breeding management requirements
5. Reintroduction protocol
6. Estimated management costs
7. Project timeframe
8. Remaining research questions and uncertainties
9. Priority site condition and management requirements (Supplementary information – not for public release due to sensitivity of information)

This plan is not intended to act as a standalone management plan for the northern population. Site-specific management plans will remain an important planning tool to guide on-ground management. This plan will focus on the reintroduction potential of sites and provide a summary of current habitat condition at priority sites considered suitable for reintroduction. If additional habitat management not already outlined by individual site management plans is needed, this plan will provide guiding principles for preparing sites to receive, promote successful establishment and sustain long-term persistence of birds.

Goal statement

The long-term goal is to increase the number of eastern bristlebirds in the wild within the northern population to a self-sustaining, viable population that is capable of long-term persistence with minimal management intervention. The immediate goal is to increase the size of the wild population and improve genetic diversity of both wild and captive populations, while minimising recovery costs.

Objectives

1. Increase wild population to (an estimated 70-80 territories)

This fundamental objective aims to recover the wild population to 70-80 territories. Based on research by Stone et al. (2018), eastern bristlebirds from the northern population are more likely to persist within grassy forest patches over 40 ha in in size. Patches of grassy forest understorey with suitable canopy gaps of this size could be capable of including up to 10 breeding territories (D. Charley pers. comms.).

Roughly 200 ha of high-quality grassy habitat has been identified within the distribution of the northern population, and many sites are smaller than 40 ha. Therefore, habitat management will be critical. An appropriate target is to increase high quality grassy habitat in patches at least 40 ha in area to 300 ha, mainly in patches larger than 40 ha, enabling the northern population to increase to the target 70-80 territories. Increasing the wild population to 70-80 territories corresponds to roughly 150 birds, which would meet the population target identified in the Northern Working Group Business Plan.

2. Improve breeding and genetic potential of the northern population through a captive breeding program

Even with successful habitat management, long-term persistence and sustainability of the wild population is likely to be limited due to the small and fragmented population. The success of reintroductions is currently hindered by low reproductive success of the captive population. Careful genetic management of both the captive, and reintroduced populations will therefore be crucial if the full benefits of habitat management are to be realised.

3. Ensure sustainability of the reintroduction program through cost effectiveness

The Strategy maps out has a 10 year plan, however achieving the overall goal of recovering a self-sustaining, viable population is likely to require a considerably longer period of sustained investment and management. This Strategy therefore provides approximate cost estimates for alternative management actions that could achieve objectives 1 & 2, and will provide an assessment of which action is the most cost-effective for recovery. A total estimate of costs for the best management action will then be provided across a ten-year timeframe to guide funding decisions and priority setting.

Assessment of alternative actions

Reintroduction programs can be a high risk, costly management action. They require long-term, secure investment and a good understanding of the species' ecology and threats in the wild. Prior to initiating a reintroduction program, the IUCN translocation guidelines advocate that all alternative management actions should be assessed against the fundamental objectives of a given conservation program (IUCN/SSC, 2013). To adhere to IUCN translocation specialist group protocols for reintroductions, a consequence table is included in this Strategy to assess five alternative actions against the reintroduction objectives for the population (Table 1).

The five alternative actions identified were:

1. Do nothing – no action taken
2. Habitat management only – habitat managed across all sites, consisting of weed control (300 ha restored/managed, 45 ha actively maintained annually) and fire management (prescribed burns every 2-4 years) to improve habitat condition
3. Wild translocations – habitat management (see 2) + translocation of adult birds from central population; estimates based on five translocations of 15-20 individuals (every 2nd year)
4. Captive breeding, birds from the northern population only – habitat management (see 2) + captive breeding (and reintroduction of offspring) under current scenario, 3-4 breeding pairs producing 2.25 chicks per year
5. Captive breeding + genetic supplementation – habitat management (see 2) + captive breeding with a target population of 12 breeding pairs, from collection of extra northern wild eggs (2 additions) and addition of southern individuals for improving breeding.

Indicator responses were calculated based on data provided by the Northern Working Group (refer to S2 & S3 for calculations and cost data). Population responses were calculated based on recent rate of decline (action 1 only) – 27% decline per decade (Stone, 2018) – current breeding success from the captive population (0.75 chick per pair per year), post release survival rate (75%) and number of wild breeding territories (5). The population size estimates do not take in to account negative impacts of ongoing genetic depression in the population and are based on vital rates from captive breeding as wild estimates are unknown. Consequently, population estimates may be optimistic given the uncertainty around wild breeding success and genetic depression. Costs were calculated using the cost information from the Northern Working Group, which includes weed control, prescribed ecological burning, captive breeding and translocation costs. A detailed summary of the estimated costs for management is provided from page 31.

Table 1. Consequence table following IUCN protocol of the effectiveness of alternative management actions on recovery across a ten-year timeframe.

			Alternative actions				
Objective	**Direction**	**Indicator**	**Do nothing**	**Habitat management only**	**Habitat management + Wild translocations**	**Habitat management + Captive breeding**	**Habitat management + Captive breeding + Genetic supplementation**
Genetic potential	Maximise	Scale	Very low	Low	Very low	Low-Medium	Medium-High
Wild population size	Maximise	Number of Territories	0-10	30-50	30-80	40-60	70-90
Costs	Minimise	$AUD	0	1,334,000	1,382,000	3,688,00	4,011,000
Action rank			5	2	4	3	1

1. **Do nothing** – Doing nothing, including ceasing habitat management, means the population will remain at very high risk of extinction from stochastic events and continued decline in population size driven by further loss of suitable habitat.
2. **Habitat management** – Habitat management alone may increase the population to 30-50 territories by 2029, based on successful raising of an average 0.75 chicks per year from each of the five known wild breeding pairs. This assumes no loss or impact on the breeding territories and that current breeding rates are not affected by future inbreeding depression. In analysing this alternative, habitat management was presumed to occur only across the 11 occupied sites, as habitat management on unoccupied sites would be unlikely to affect population growth. This action would consist of weed control and fire management across 600 ha of habitat to maintain high quality habitat (200 ha), improve high quality breeding habitat, and restore degraded habitat (shrub encroached) at occupied sites (400 ha). This action has the lowest cost of any alternative actions, but does not deal with the high risk of deleterious genetic effects in the population. Under a habitat management only scenario, occupied patches are likely to remain highly vulnerable to stochastic events, with little ability to adapt to changing environmental conditions. It also assumes that offspring at the largest breeding site (which is nearing capacity) can establish new breeding territories at other patches to grow the overall population, which is unlikely given the small size and fragmented nature of patches. There is some chance that offspring from this site may disperse to nearby grassy forest patches, but information on dispersal ability through rainforest is limited.
3. **Wild translocations + habitat restoration** – Direct translocation of birds from other populations would remove any ability to control the introgression of southern genetics into the northern population. The upper population estimate for this action is based on existing data from the southern EBB population of a 75% survival rate post release. However, there is high uncertainty in the ability of birds from southern or central populations to survive under northern environmental conditions. In addition, behavioural differences between populations may limit breeding between northern birds and those introduced from other populations. Because of the high risk to the genetics of the northern population and uncertainty regarding survival, this alternative is not favoured.
4. **Captive breeding (northern population birds only) + habitat restoration** – A captive breeding program currently operates with three breeding pairs and achieves low breeding success. As such, the current approach to captive breeding may have only a marginal benefit above habitat management. On average, the captive population produces 2.25 chicks per year (0.75 rate of successful fledgling per pair), which will result in an additional 10-20 territories in the wild, compared to habitat management, depending on success of breeding impact of inbreeding and deleterious genes. This is an expensive action, expecting to cost over three times that of habitat management over a ten-year timeframe ($3.2 million). This cost includes additional attempts to supplement the captive population with wild northern birds, however given the difficulty in finding nests, and reliance on small number of breeding territories, genetic benefit is still likely to be low. Given the high cost and low return for wild population size, captive breeding of only northern individuals in the existing breeding program is unlikely to meet Strategy objectives within the desired timeframe. Even though this action could potentially increase the wild population over a longer timeframe, costs will increase substantially, and is unlikely to address genetic issues that may influence long-term viability.
5. **Captive breeding + genetic supplementation + habitat restoration** – Incorporating genetics from the central population into the northern captive breeding population has the greatest potential to recover the bristlebird population. Under this action, the introgression of the new genetic material can be maintained at a low rate to minimise genetic swamping (Harrisson et al., 2016; Sunnucks, 2013). As an isolated population that occupies different environmental conditions to the central and southern populations, maintaining genetic integrity of the northern population is important for overall eastern bristlebird persistence and adaptive potential (de Villemereuil et al., 2019; Weeks et al., 2015). Wild egg collection at northern breeding sites and genetic rescue using minimal southern individuals is likely to greatly improve breeding success and resilience of the bristlebird population. Through this action, the northern population is predicted to reach an estimated 80-90 territories by 2029, with $400,000 additional cost to continuing the current captive breeding program (action 4). In this case, cost is high, however there is likely to be a considerable increase in the population size. As increasing the wild population size is the overall goal, captive breeding + genetic management may improve the conservation status of the bristlebird.

Given the overarching goal and objectives of the Strategy, the recommended management action for recovery of the northern population of the EBB is to expand the **captive breeding program with genetic management and habitat management**. The remainder of this report provides details for its implementation.

Recommended management action: habitat management + captive breeding + genetic management

A captive breeding program with genetic supplementation in conjunction with ongoing habitat management, is recommended. This action includes four core components: 1) captive breeding, 2) genetic supplementation, 3) habitat management, and 4) reintroduction of captive bred birds into the wild. The remainder of this report will provide detailed information on each of these core components required for successful implementation.

1. Captive breeding program

The overall objective of the captive breeding program is to have a sustainable captive population that is capable of supporting multiple reintroductions of bristlebirds into the wild to supplement the wild population to reach carrying capacity within high quality habitat patches. The bristlebird has been shown to be sensitive to stochastic disturbance events (Lamb et al., 1993). It is therefore essential to grow the population across multiple habitat patches. In addition, because of low connectivity between patches (at present) priority release sites should be able to support a minimum of 10 territories. Restoring connectivity of habitat patches will be a long-term management action, therefore supplementing each occupied patch to reach a minimum of 10 territories will aid genetic diversity within each habitat patch.

To meet the recovery objective over a 10-year time frame, a key target for **captive breeding a minimum of 12 chicks suitable for release need to be achieved each year**. A founding population of at least 12 breeding pairs may be capable of producing this level, but only if genetic barriers currently present in the captive population are resolved. Consequently, a key means to achieving this target will be to improve reproductive output of the captive population that results in successful fledging of 12 chicks/year for release.

The captive breeding programme for the northern population of eastern bristlebird is currently managed by Currumbin Wildlife Sanctuary on behalf of New South Wales DPIE. The breeding programme is predominantly based at Currumbin Wildlife Sanctuary, with additional aviaries being utilised at David Fleay Wildlife Park and Hidden Vale Wildlife Centre. Currumbin Wildlife Sanctuary is responsible for managing the captive breeding programme. As of March 2019 – prior to the capture of central birds under a pilot genetic supplementation – the northern captive population consisted of 16 birds, with three established breeding pairs and five juvenile pairs. In April 2019, four central birds were captured and transported to the northern captive breeding program. Of the four central birds, two have survived and are currently housed separately from northern birds. Breeding pairs are housed in purpose built breeding aviaries, while young pairs are housed in temporary cages that are not suitable for breeding. Space is a considerable barrier to the current captive breeding programme.

Currumbin Wildlife Sanctuary – Currumbin

Decision maker: Anthony Molyneux & Allison Beutel (in conjunction with NSW DPIE)

Currumbin Wildlife Sanctuary (as of March 2019) houses 14 birds in 9 aviaries (plus one central bird added in April 2019). This site is highly limited by aviary space and only supports three suitable breeding aviaries. The breeding aviaries were purpose built for bristlebirds, as standalone aviaries roughly 5 m apart to reduce visual interaction and potential conflict between pairs (Fig. 3). Birds have successfully bred at Currumbin Wildlife Sanctuary but infertility has been high and breeding success therefore limited.

To meet our fundamental objectives, Currumbin Wildlife Sanctuary needs to be capable of supporting four breeding pairs and holding offspring (at least four per breeding season) for a minimum of six months. Currumbin has the potential to house additional breeding aviaries, and as of July 2019, another three breeding aviaries are scheduled to be constructed during July – September 2019 (A. Molyneux, pers. comms). This activity will disrupt the 2019 captive breeding season, however as space is the most pressing constraint to this plans implementation it is a necessary step towards increasing breeding capacity of the programme. Increasing Currumbin's capacity to 6 breeding aviaries will help reduce requirements of other breeding facilities, which need additional operating costs.

Figure 3. Purpose built bristlebird breeding aviaries (top) and holding aviaries (bottom) at Currumbin Wildlife Sanctuary.

Hidden Vale Wildlife Centre – Grandchester

Decision maker: Andrew Tribe & Dalene Adam (under supervision of Anthony Molyneux, Currumbin Wildlife Sanctuary)

Hidden Vale Wildlife Centre is a newly built centre by the Turner Foundation, managed jointly by The Turner Family Foundation and The University of Queensland. Two aviaries have been specifically modified to house two breeding pairs of bristlebirds (Fig. 4). The aviaries were created from a single large holding pen so therefore share a central wall. This central wall was constructed of a solid material to reduce visual interactions between the adjacent pairs. As of March 2019, it houses two birds who have not yet bred successfully (newly paired). Hidden Vale Wildlife Centre has the potential to house four breeding aviaries (eight birds), but does not have suitable aviaries to hold offspring or non-breeding individuals (as at early 2019). An additional holding pen (same size) may be available to be converted into another two breeding aviaries. This pen is roughly 10 m away from the first pen, allowing some separation of breeding pairs.

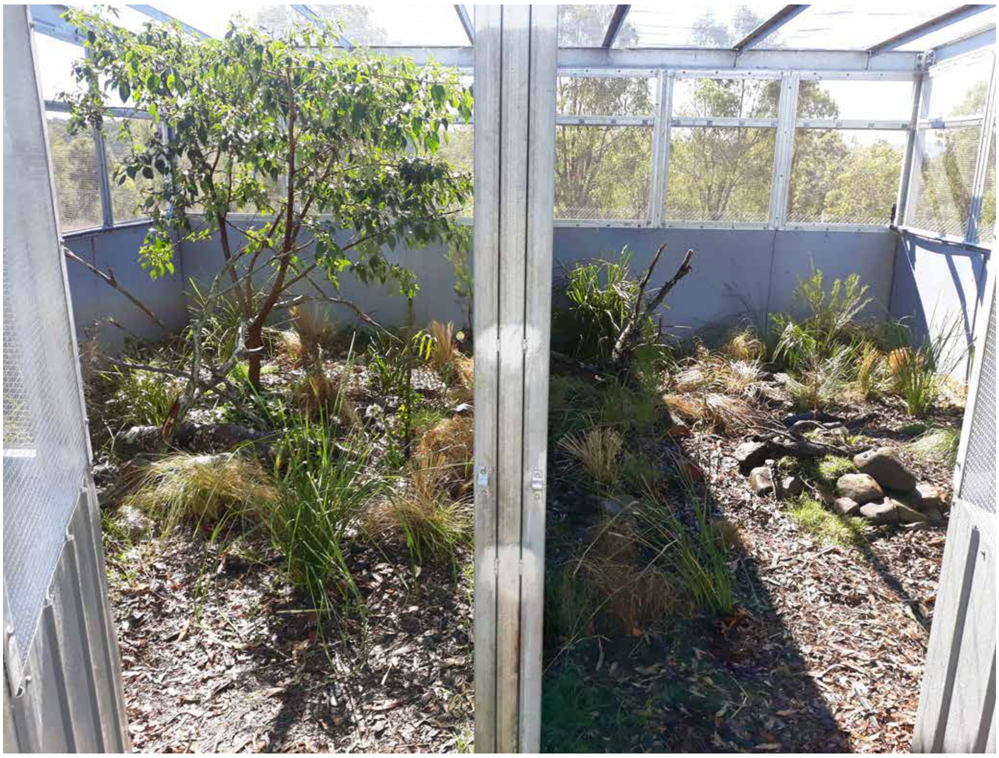


Figure 4. Modified bristlebird aviaries after planting at Hidden Vale Wildlife Centre. Photos provided by Sheena Gillman

David Fleay Wildlife Park – Burleigh Heads

Decision maker - (under supervision of Anthony Molyneux, Currumbin Wildlife Sanctuary)

The captive breeding programme was originally housed at David Fleay Wildlife Park, where three purpose built bristlebird aviaries were constructed. The standalone aviaries are roughly 10 m apart and are positioned in straight line to reduce visual interaction between breeding pairs (Fig. 6). David Fleay Wildlife Park is a government run operation and is managed by Queensland Parks and Wildlife Department. These aviaries have been out of commission for 10 years. In September 2018, permission and funding was secured for the recovery team to refurbish these aviaries and utilise them for the captive breeding programme. There are currently three suitable breeding aviaries present at David Fleay Wildlife Park and in March 2019, two bristlebird breeding pairs were relocated from Currumbin Wildlife Sanctuary to David Fleay Wildlife Park. In April 2019 a central bristlebird pair was transported to David Fleay Wildlife Park, of which one individual has survived. There may be the potential to build additional aviaries (both breeding and non-breeding temporary aviaries) at the site, with considerable space available.

Figure 6. Purpose built bristlebird breeding aviaries at David Fleay Wildlife Park (top) and potential holding aviaries (bottom).

2. Genetic management

The current captive breeding program has suffered from low egg fertility and chick fledgling (Stone, 2018). To increase the breeding success of the captive breeding program, systematic genetic management is essential and the inclusion of additional genetic material from southern or central birds, or wild northern birds is needed. Genetic considerations are being addressed through ongoing founder collection (eggs and adults) and there is further genetic profiling planned for all wild populations. Birds from the central population (Jervis Bay, NSW) are being added into the northern breeding program from 2019. It is hoped that with these new individuals breeding success may improve through genetic rescue.

Table 2. Number of breeding pairs, holding aviaries and chicks produced per captive breeding facility with targets needed to achieve to meet fundamental objective 2 (improve genetic diversity and breeding success) for the reintroduction of bristlebirds.

Breeding facility	March 2019	Recovery target
Currumbin Wildlife Sanctuary	3 breeding pairs*	4 breeding pairs
	6 holding aviaries	8 holding aviaries
	2.25 chicks per year	4 chicks per year
David Fleay Wildlife Park	2 breeding pairs*	4-5 breeding pairs
	4 holding aviaries	8 holding aviaries
	0 chicks per year	4-5 chicks per year
Hidden Vale Wildlife Centre	1 pair (not breeding)	4 breeding pairs
	0 holding aviaries	8 holding aviaries
	0 chicks per year	4 chicks per year

*Plus single central bristlebird individual (April 2019) – housed in separate aviary

To date the captive breeding program has experienced 74% failure for all eggs laid, with 41% of those failures from confirmed infertility (Stone, 2018). The three successfully breeding pairs housed at Currumbin Wildlife Sanctuary have produced 123 eggs over four years (201-2018), averaging 30 eggs per year (not including summer 2018/19 breeding season). By increasing the captive population to 12 breeding pairs, the captive program may be capable of producing over 100 eggs per year.

To improve genetic diversity and breeding success, the captive breeding program must reduce rates of egg failure, infertility and chick mortality to a level that allows a minimum of 12 successfully fledged chicks to be produced per year. The current rate of fledging success (7.32%) would not meet the desired 12 chicks per year for a captive program with 12 breeding pairs. Therefore, genetic management of the captive population needs to **increase fledging success to a minimum of 12%, however a target of 15 – 20% fledging success would allow for an increased supply of birds for reintroduction, and would provide insurance against unexpected mortality**. This could be reached through a) reducing infertility and egg failure rates through supplementation of breeding pairs with additional wild founders (implementation underway); and/or b) improving nesting success of young, inexperienced females through pair matching (already implemented by captive breeding rangers, although space limited). Both these actions have the potential to improve breeding success. Based on the results of the 2018 and 2019 breeding seasons, these actions may be adequate to improve genetic diversity and breeding success but are highly dependent on aviary space at the present.

For more information on the genetic state of the bristlebird captive breeding program & genetic management, recommendations see attached genetic assessment document (Stone, 2018).

3. Habitat management

The northern population of the EBB relies on a dense grassy understorey for persistence (Hartley & Kikkawa, 1992, 1994; Holmes, 1989; Lamb et al., 1993; Rohweder, 2006; Sandpiper Ecological Surveys, 2000; Stone, 2018; Stone et al., 2018). Previous research has clearly demonstrated the strong relationship between grass structure and presence, suggesting tall grasses; dense grass cover and tussock (*Sarga leiocladum* or *Poa*) are key habitat characteristics. More recently, Stone et al. (2018) showed that the long-term persistence of territories is highly dependent on a tall (average grass height of >40 cm), dense (>100% grass cover) grassy layer with canopy gaps and that larger habitat patches are more likely to contain bristlebird territories.

Bristlebirds are highly territorial, and likely require large habitat patches to support sustainable population sizes. Current occupied patches consist of only a few territories, with the biggest site having an estimated seven territories present (D. Charley pers. comms.). For long term persistence, these sites need to be capable of supporting larger populations to avoid genetic issues such as inbreeding depression and that populations are large enough to survive stochastic disturbance events. To support persistence, habitat patches must be capable of supporting a minimum of ten territories, connectivity between grassy forest fragments must be restored and appropriate grassy understorey conditions must be present.

Reduced fire is a key contributor to the decline in bristlebirds within the northern population. Stone (2018) and Rennison (2016) showed that grassy forest habitat has declined by over 50% in the last 30 years across the historical distribution of the northern population. To increase high quality habitat, restoring appropriate fire regimes is crucial.

To encourage recovery of wild populations, and support reintroductions, habitat management to control weeds and shrub growth, and restore appropriate fire regimes into the landscape is essential.

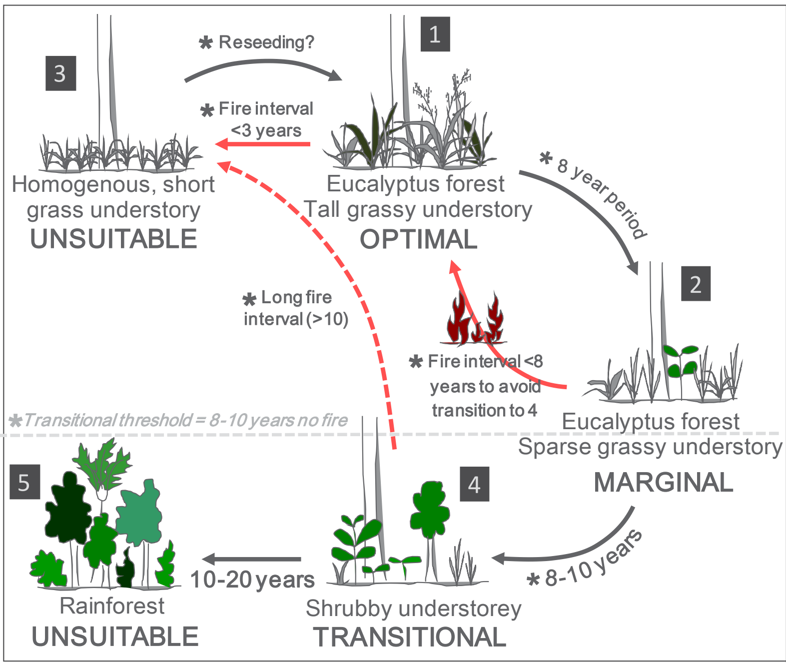
For this reintroduction strategy to have the greatest chance of success, reintroduction sites need to meet essential habitat requirements for short term survival of individuals and long term persistence of the population. Habitat management across all sites should follow these general guidelines:

1. Sites need to have at least 40 ha of high quality, grassy understorey present within each forest patch (Stone et al., 2018). High quality, grassy habitat refers to dense, thick, tall grassy understorey dominated by tussock grass species with minimal mid-storey vegetation. Modelling of habitat extent in relation to bristlebird presence suggested sites smaller than 40 ha were unable to support long-term persistence. Based on bristlebird territory sizes, a site of 40 ha is likely to only be able to support up to 20 territories.
2. Priority sites, therefore, should aim to have enough habitat to support multiple pairs, and be at least 40 ha to maximise the change of population persistence. However, the larger the site the higher the change of long-term persistence. Smaller sites can be valuable if they are part of a connected network of grassy forest fragments. It is imperative that management actions to improve connectivity and expand habitat patches are implemented.
3. Ensure areas of thick dense tussock dominated grass cover are present. The northern population of EBB depends on tussock grass species (*Sorghum, Foxtail Grass* and *Poa* spp) to provide appropriate structural resources for refuge and nest building (Hartley & Kikkawa, 1992, 1994; Lamb et al., 1993). Rohweder (2006) suggested that grass cover >75% and the presence of at least 1 good clump of tussock grasses (*Sarga, Poa* or *Themeda* and occasional *Lomandra*) within a territory were a key habitat requirement for bristlebirds. Specific evidence for *Sarga leiocladum* as a critical habitat requirement has been inconsistent across previous research (Lamb et al., 1993; Rohweder, 2006; Sandpiper Ecological Surveys, 2000), however it is clear that the structure of the grassy understorey is important. Stone et al. (2018) demonstrated that bristlebirds had a higher chance of persisting at sites with an average grass height of 44cm, which roughly corresponds to the height nests are constructed (captive nests are always 10-45cm off the ground). Tall tussock grasses, allow nests to be built off the ground while providing adequate cover for protection. In many cases, long-unburnt sites have reduced grassy understorey, and many of the large tussocks disappear. Prior to releasing birds, habitat management may be needed to create areas of open tree canopy of which tussocks species are dominant in the grass layer (>75% tussock).
4. Habitat is highly fragmented, and a key management action needs to be restoring connectivity between sites to facilitate breeding and dispersal between subpopulations. Habitat management should include restoring marginal habitat between habitat patches to improve their condition, and provide grassy habitat that bristlebirds can use for movement between grassy forest patches. Many bristlebird sites are found on ridgelines, and have the potential to expand along them to connect patches. Habitat management in degraded habitat will focus on intensive weed control and follow up burns to reduce shrub encroachment and reduce mid-storey vegetation to encourage grassy understorey regrowth.

5. Where possible, attempts should be made to restore patches of grassy habitat, particularly where rainforest encroachment has not completely converted habitat. Some landowners have been involved in manual manipulation of habitat through shrub removal to help improve grass structure at their sites. Such experimental trials show that with intensive weed effort, grassy forest patches can be restored, however this is highly dependent on some grass structure still being present to provide a seed bank.
6. Fire management will be an integral part of maintaining and restoring bristlebird habitat. Fire has a strong influence on the structure and condition of the grassy understorey (Rohweder, 2006). It is vital that fire intervals not exceeding 5-10 years occur within sites, as research has suggested that sites that have had long periods of no fire (≥10 years) are likely to be difficult to return to optimal grassy habitat. Stone (2018) showed that the period of longest fire absences was a stronger predictor for habitat loss than the mean fire interval, supporting the idea that such periods may accelerate rainforest encroachment into these grassy forest patches. This has been observed at some sites where recent prescribed burns have resulted in a higher abundance of shrubs germinating following the burn (Watson & Tasker unpublished data). It is highly likely that fire intervals of 3-5 years are needed to maintain grass structure (Watson & Tasker unpublished data) and avoid shrub encroachment that develops with >8 years intervals. Fire at intervals of less than three years may be detrimental to maintaining grassy structure that benefits bristlebirds (Rohweder, 2006). Sites that have had a more frequent fire regime, with fire interval of < 3 years show reduced complexity of the grass community, and increased dominance of rhizomatous ground covers (e.g. bracken fern, blady grass) (Rohweder, 2006; Stone, 2018). Stone (2018) found that bristlebird sites at Stretcher Track and Conondale Ranges have been subject to more frequent fire intervals (mean fire interval of 1.93 and 2.3 years respectively) which was correlated with reduced tussock cover and grass diversity, and an increase in dominance by *T. triandra*. Reduction in the diversity and structural characteristics of the grassy understorey may negatively impact protection provided for bristlebird, nest building and foraging ability and invertebrate resource availability. Stone et al. (2019) demonstrated that invertebrate resources are greater in taller, thick grasses closer to the rainforest margin where higher moister is present. Maintenance of a diverse grassy understorey near rainforest margins needs to be an important consideration in habitat management of bristlebird sites.

Figure 7 demonstrates overall habitat dynamics occurring within bristlebird sites (Stone, 2018). For habitat that has been too frequently burnt (stage 3), reduction in burning practises may help improve grass understorey condition, however additional action to restore tussock species that are needed for breeding may be required. Transitional habitat (stage 4) is likely to be common on the margins of bristlebird sites, and will require a more intensive strategy of weed control, manual shrub clearance and prescribed burning to help restore it to appropriate grassy forest. Management strategies to restore marginal and transitional habitat are critical to the goal of increasing the extent of current habitat. For transitional habitat, evidence suggests that pre-burn weed control, followed by a series of prescribed burn in closer succession can be successful in reducing shrubs and restoring grassy understorey. Additional actions to manually remove larger shrubs and trees that escape fire or regeneration specific tussock species may also be needed in areas where shrubs have escaped fire and have contributed to canopy thickening.

This reintroduction strategy focusses on nine priority sites that are most likely be maintained or increased to meet necessary habitat requirements and support the target population by 2029. It will be important for site-specific habitat management plans to be guided by on ground land managers who have excellent knowledge of their sites. A summary of habitat condition within each of the priority sites along with current management and management needs listed us provided in the supplementary information (*S1- Habitat condition and management requirements for bristlebird priority sites*). More detail on specific work areas for weed control, and areas were habitat expansion through more intensive restoration and manual shrub/tree removal will need to be identified in conjunction with land managers to ensure up-to-date information on habitat condition and requirements that may not be provided in this plan. Property management plans developed for private properties should be referred to for more detail of these sites. It will be important for land managers and rangers of national park sites to meet to discuss their role in the implementation of appropriate habitat management, and the information provided in this plan should be used to guide their management to ensure park management aligns with grassy forest restoration and bristlebird recovery.



1	• Large grassy habitat patches • Grass height > 40 cm • Ground cover 100 % or more (accumulative total for 0-1 m strata) • Higher abundance and nutritional value of invertebrates
2	• Transition from stage 1 → 2 occurs within approximately 8 years • Grasses < 40 cm in height • Sparse homogenous grass layer (Blady grass)
3	• Biennial fires reduce tussocks and increase dominance of *Themada triandra* • Reduced grass diversity and potentially invertebrate community
4	• Transition between 2 → 4 occurs between 8-10 years without fire • Evident changes in vegetation structure towards closed forest • Fewer, larger invertebrates • Loss of tussocks if fire reintroduced (4 → 3)
5	• Irreversible transition to closed forest 10-20 years without fire

Figure 7. Suggested habitat dynamics of bristlebird habitat (Stone, 2018 page 122). For bristlebird persistence, land managers should focus on ensuring habitat remains within stages 1 and 2 using prescribed burns. Suggested fire intervals are displayed based on research, however an adaptive management approach should be taken at individual sites to adjust fire intervals based on real time condition of vegetation structure.

Reintroduction

Reintroduction protocol

Selection of release sites

The IUCN reintroduction guidelines (IUCN/SSC, 2013) state that release sites should meet two main criteria, a) reintroduction implementation and logistics that reduce stress and allow ease of monitoring and b) habitat suitability for individual survival and population persistence. Previous research has demonstrated a strong association of bristlebird territories with grass height and cover (Lamb et al., 1993; Rohweder, 2000, 2006) and fire (Hartley & Kikkawa, 1994; Sandpiper Ecological Surveys, 2000). More recently, Stone (2018) found that bristlebird persistence was highly dependent on 1) habitat patch size, 2) grass structure, 3) proximity to other occupied sites, and 4) fire history. Bristlebird territories are always found close to the rainforest margin (Holmes, 1989), and Stone (in press) found increased invertebrate resources in tall grasses and on the rainforest margin. Hartley and Kikkawa (1994) suggested that invertebrate declined during droughts may impact breeding success of birds, therefore the microhabitat along the rainforest margin may be an important for providing invertebrate resources for breeding. Priority release sites should therefore have (or be close to achieving) these critical habitat elements that are known to promote bristlebird persistence. In addition, criteria relating to management of known or potential threats and stability of tenure and management, which will be important for the successful implementation and monitoring of each reintroduction attempt should be considered. Ultimately, the release site prioritisation process must be undertaken as part of the translocation planning to ensure that recent impacts from wildfire are appropriately considered.

Release site habitat criteria for bristlebirds:

1. At least 40 ha of contiguous, good quality grassy habitat (Stone et al., 2018)
2. Average grass height must be greater than 40 cm (Stone et al., 2018), tussock of > 90cm present (Lamb et al., 1993)
3. Thick understorey cover (>75% cover within the 0-1m vegetation strata), with dense *Sarga* and/or *Poa* tussocks areas present (Lamb et al., 1993; Rohweder, 2000, 2006; Stone et al., 2018)
4. Suitable open shrub layer and canopy gaps for nesting sites (Rohweder, 2000; Stone, 2018; Stone et al., 2018; Young, 2003)
5. Within 1 km of occupied bristlebird habitat (Stone, 2018)
6. Easily accessible for release and monitoring (preferably < 1hr access time from road)
7. Land owner support and long-term stability for management

Husbandry

Prior to release of any birds from the captive breeding facility, they will undergo a thorough veterinary check. Any recommended medication and / or isolation prior to release will be strictly followed. Further investigations of disease management will be undertaken as part of ongoing husbandry for the captive breeding program, which will also inform reintroduction planning.

Transport

Birds will be transported in individual transport boxes that are modified versions of the standard passerine design (Fig 8). Transport boxes have padded interior roof, adequate ventilation, non-slip flooring, filtered lighting and vessels for food and water. Transport box size will be 300mm (H) x 160mm (W) x 210mm (D). A thermometer will be attached to each box, with probe inside to monitor box temperature. A small amount of vegetation (e.g. grass) will be placed within the box to provide shelter and refuge. Currumbin Wildlife Sanctuary currently has boxes (newly built, unused) specifically for Eastern Bristlebirds, which will be utilised during reintroductions and southern bird collection. During travel, birds will be provided with food items such as crickets and mealworms, which provide the best chance of feeding and maintaining energy intake during transport. Water will be provided using a small container glued to the floor of the transport box with a small piece of sponge in it to prevent water spilling. Extreme care will be taken handling transport boxes to minimise motion to birds and prevent food, water and vegetation from dislodging and causing harm.

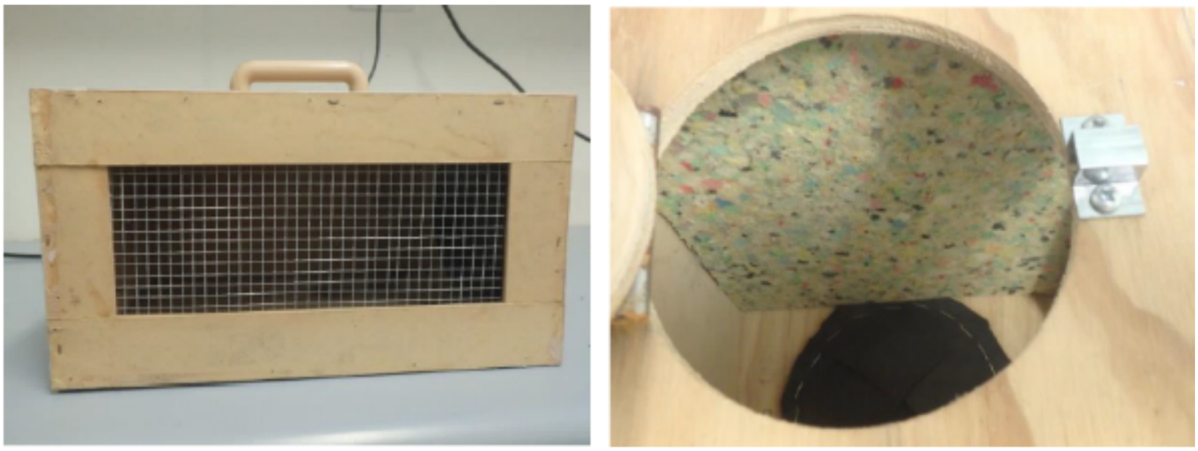


Figure 8. Transport boxes showing padded interior roof. Photos provided by Allison Beutel

Prior to birds arriving temporary aviaries should be set up to ensure minimal time birds are kept waiting in the transport boxes. Once at release sites, birds be checked by the accompanying vet and then transferred to the temporary aviaries. Once released inside, birds should be monitored for 30 minutes from a distance of 10 m to observe behaviour and possible stress responses. If birds are deemed healthy and fit for reintroduction to proceed the delayed release strategy and post-release monitoring (detailed below) will be followed.

Release method

A pilot reintroduction was undertaken in 2008 when eight birds were reintroduced to two locations. Birds were monitored for four weeks until transmitter batteries failed, after which six birds were still alive while two had been predated. Surveys have indicated that at least three birds survived until 2010. Despite the predation, the methodology used for this pilot release was deemed successful, with the remaining six birds persisting over the monitoring period. As such, a similar release method will be employed for future reintroductions; however, a dynamic decision approach will be taken depending on breeding scenario and site conditions.

Release group size

From studies of translocations of both the southern population of the eastern bristlebird and western bristlebirds, reintroduction success is more likely from group releases that involve more than 10 birds (e.g. (Bain, 2006; Bain et al., 2012). Bain et al (2006) undertook multiple translocations of wild birds from the southern population, where groups of 15 birds were released in three consecutive years. These translocations were all deemed successful, indicating that these small release group sizes are suitable for Eastern Bristlebird translocations. Translocations of a similar passerine species, the noisy scrub bird (*Atrichornis clamosus*) has also indicated that successful reintroductions are possible from repeated small releases (Comer et al., 2010).

For the bristlebird, reintroductions and supplementation will be highly dependent on breeding success of captive breeding program each year. As such, a dynamic decisions process will have to be implemented for reintroductions based on breeding output and availability of space for holding juvenile birds. To increase the chance of establishment of captive individuals, especially at sites that do not have an established subpopulation present releases should be done with as many individuals as possible. For bristlebird releases, it is suggested that birds should not be released in groups of < 10 individuals.

Birds do not remain at the point of release but break into compatible pairs and disperse up to 2km into suitable habitat (Allan Burbidge pers. com.). Because of this, some individuals should be released with radio transmitters to follow their progress (refer to monitoring section).

Delayed release

The pilot release in 2008 employed a delayed release strategy where birds were released into temporary enclosures at release sites for a 2 week process. Temporary enclosures were constructed using modified tents either that had the base removed (Fig 9) or from modified trailers (Fig 10).

Figure 9. Temporary tent aviaries used for delayed release of captive bristlebirds during pilot release into Border Ranges National Park in 2008. a) Set up of tent interior with supplied food and water to match captive breeding presentation, b) closed tent during acclimatisation period with bristlebird inside, c) tent door left open after day 3 of release for birds to freely enter and leave, feed bowls and water still supplied and d) disturbed area around tent. Photos provided by Stephen King.

Figure 10. Temporary trailer aviaries up used for delayed release of captive bristlebirds during pilot release into Main Range National Park in 2008. Photos provided by Stephen King.

The trailer enclosures were furnished with mulch substrate, grass tussocks and hollow logs to provide shelter. Birds were left inside enclosures for 3 days to acclimatise to the wild surroundings, after which they were opened and birds were allowed to move freely between the enclosure and habitat for 2 weeks while resources were provided both within the enclosure and at 4 feed stations within the vicinity of the enclosure. During the pilot release, birds overall responded well to the delayed release strategy, with most individuals foraging easily in the wild for food following release.

Feeding regime used during 2008 pilot reintroduction (Stewart et al., 2009):

Day (post release)	Location	Frequency
1-3	Feed in soft release cages	Morning & afternoon
4-9	Feed in cages & scatter feed outside	Morning & afternoon
10-11	Feed in cages & scatter feed outside	Afternoon
12-15	Scatter feed outside	Afternoon

Captive released animals are often naive to wild conditions (ref), and delayed releases have been shown to be beneficial in acclimatising individuals to wild conditions. Birds released using temporary enclosures showed little sign of distress. Because this method was successful, a similar delayed release strategy is suggested for future releases.

For future releases, it is suggested that only the modified tent temporary enclosures should be used. Release locations should be away from main walking tracks to reduce disturbance. Bristlebirds are known to be sensitive to disturbance (A. Beutel pers. comms.), with mortality in captive birds higher in areas with higher nearby human disturbance (e.g. construction work). Given these releases will be using captive individuals, it is important to provide as natural, sheltered environment as possible to help birds become used to their surroundings. Using a modified tent enclosure will allow birds to be released further form the main track at sites where grass structure is more suitable, disturbance is minimal and enclosures are less exposed.

Release group composition

In some reintroductions, familiarity between release individuals, particularly for social animals, can influence reintroduction success (Letty et al., 2007). Bristlebirds are territorial, and have relatively simple social structures. To maximise chance of individuals establishing, it is suggested that individuals from the captive breeding programme be familiarised with one another before being released together. This may help reduce post-release aggression and dispersal and encourage mating at release sites (Batson et al., 2015). An even ratio of male to female birds should be released. If this is not possible based on captive breeding success prior to reintroduction, at least 4 pairs should be released together. If there is an excess of males or females, consideration should be made to supplement existing subpopulations where single territories are known to occur.

Monitoring

The goal of immediate post-release monitoring is to establish survival rates of released birds post-release and identify their post-release movements to identify whether they remain in the release area. Based on the methodology developed from the pilot release of EBB in 2008, birds should be monitored for a minimum of 4 weeks, ideally 6-8 weeks (or as long as transmitters allow), following reintroduction. This will be supplemented by annual population surveys which should be carried out to determine long term success of the reintroductions.

GPS transmitters can provide detailed information on animal movements, however they rely on being recaptured to download the data. Satellite or Argos transmitters that do not require the recapture of devices are unable to be used for bristlebirds due to weight restrictions. Given the habitat conditions and weight restrictions of the bristlebird, small VHF transmitters which do not require recapture are suggested for use. Following advice from Sirtrack Wildlife Tracking Solutions, Pip Ag376 or PicoPip Ag376 VHF transmitters would be the best option for monitoring birds, lasting between 5-8 weeks depending on the frequency set for signal output. Both transmitters can last 8 weeks for 20ms/ppm. These transmitters weigh 0.73g (Pip Ag376,) and 0.6g (PicoPip Ag376) which are consistent with the < 2% body weight suggested rules for avian tail mounted transmitters. These transmitters are compatible with standard Telonics TR4 receivers used commonly used for monitoring. Transmitters cost $210-260 each (details outlined in S2- Bristlebird strategy costs).

Success indicators

Monitoring is an important part of reintroduction plans to enable success to be measured and adapt management actions as needed. For this project, the initial success indicators will be relating to the initial survival and retention of reintroduced populations at sites. The medium-term success indicators will be initiation of breeding and breeding success of released birds at the sites.

Prior to release, captive individuals should meet a set of release criteria to ensure healthy individuals are released to the wild. Specific release criteria should be determined in conjunction with Currumbin Wildlife staff, but should cover aspects such as weight and size, overall condition and disease, foraging ability, and genetic/relatedness to other individuals (both wild and captive birds) (IUCN 2013). Such release criteria should be adhered to, to ensure captive birds do not impact wild sites with novel disease, inappropriate relatedness or genes (for when central genetic supplementation is attempted) and that healthy birds are released with a good chance of survival.

Following release of birds, suggested reintroduction success indicators (for each release attempt) could include:

1. **Short term goal: Released individuals present at site 1-12 months post release.** Survivorship of 50% of individuals recorded at the release site after 1 years will indicate a high success rate for the release protocols, however this will be difficult to determine. The longevity of monitoring individual birds is limited by the available telemetry products available at the time of release. This will demonstrate release sites were appropriate for birds, and that individuals have remained within the area. Survivorship of birds within the release site will also help determine whether additional threats (such as predation) are having a more substantial impact on the birds than currently thought. Post-release population monitoring (initially, every few months) should be used to monitor this indicator. An adaptive approach will be needed to ensure release methods and pre-release site preparation (e.g. fire management or predator control) are effective.
2. **Medium term goal 2-8 years: Breeding** activity is observed within the release site (i.e. nests present). This will indicate that released birds have paired successfully, habitat condition is suitable for breeding and the subpopulation has the potential to grow. Monitoring this success indicator will involve searching for nests, or observing breeding behaviour within territories (e.g. breeding calls) during the breeding season (August - February). (population monitoring either annual (preferred) or biennial (consistent with number 1) needs to be occurring during this period also. This needs to be demonstrating an increase in population size, otherwise the program needs to be amended/paused)
3. **Long term goal >8 years: Genetic enhancement** observed over the long term, compared with baselines obtained prior to reintroduction. Population monitoring also needs to be occurring to determine that the aim of 70-80 breeding pairs has been achieved and is being maintained. Breeding and fledging of young EBB continues.

Prior to the reintroduction taking place, specific measures for determining the success of the program will be agreed. These will include parameters assess outcomes at short, medium and long term timeframes.

Management costs

This section provides a summary of the management actions and associated costs required to achieve the fundamental objectives of this reintroduction strategy. For a complete breakdown of costs, refer to *S2 – Bristlebird reintroduction strategy costs*

The overall cost to implement all actions covered within this reintroduction plan is estimated at $4 million (over 10 years) (Table 4). This includes $314,000 start-up costs to expand the captive breeding and cover initial weed control, $371,000 for annual management costs and $358,000 for biennial (population monitoring) or irregular costs (prescribed burns and genetic supplementation). Note that costs do not currently include additional feral animal control, although this may become necessary based on monitoring results.

Table 4. Implementation costs (excluding management/coordination costs) for the 10 year bristlebird reintroduction strategy to meet fundamental objectives. Details of costs can be found in supplementary information (*S2 - Bristlebird reintroduction strategy costs*)

Year	Action	Cost	Total
1	Habitat management (QLD)	$75,000	
	Habitat management (NSW)	$60,000	
	Captive breeding	$333,195	
	Genetic supplementation	$38,160	**$526,355**
2	Habitat management (QLD)	$50,000	
	Habitat management (NSW)	$60,000	
	Captive breeding	$218,735	
	Reintroductions	$48,474	
	Population monitoring	$27,000	**$404,209**
3	Habitat management (QLD)	$50,000	
	Habitat management (NSW)	$60,000	
	Captive breeding	$218,735	
	Reintroductions	$42,380	**$375,615**
4	Habitat management (QLD)	$24,000	
	Habitat management (NSW)	$63,000	
	Captive breeding	$218,735	
	Reintroductions	$42,380	
	Population monitoring	$27,000	**$438,415**
5	Habitat management (QLD)	$50,000	
	Habitat management (NSW)	$60,000	
	Captive breeding	$218,735	
	Reintroductions	$42,380	**$371,115**
6	Habitat management (QLD)	$50,000	
	Habitat management (NSW)	$60,000	
	Genetic supplementation	$40,300	
	Captive breeding	$218,735	
	Reintroductions	$42,380	
	Population monitoring	$27,000	**$438,415**
7	Habitat management (QLD)	$50,000	
	Habitat management (NSW)	$60,000	
	Captive breeding	$218,735	
	Reintroductions	$42,380	**$371,115**

Year	Action	Cost	Total
8	Habitat management (QLD)	$24,000	
	Habitat management (NSW)	$63,000	
	Captive breeding	$218,735	
	Reintroductions	$42,380	
	Population monitoring	$27,000	**$371,115**
9	Habitat management (QLD)	$50,000	
	Habitat management (NSW)	$60,000	
	Genetic supplementation	$4,500	
	Captive breeding	$218,735	
	Reintroductions	$42,380	**$375,615**
10	Habitat management (QLD)	$50,000	
	Habitat management (NSW)	$60,000	
	Captive breeding	$218,735	
	Reintroductions	$42,380	
	Population monitoring	$27,000	**$398,115**
	Total recovery costs		**$4,010,784**

Action: Captive breeding

For a target of 12 breeding pairs to be reached in the captive population, an additional four breeding aviaries are urgently needed. The current three facilities are capable of expanding to include required aviaries, funding dependent. Currumbin Wildlife Sanctuary has space for one additional aviary. Hidden Vale Wildlife Centre has two set up breeding aviaries with space for an additional two depending on success of birds there. David Fleay has a large area where the current three aviaries are located, which is capable of supporting additional aviaries. Aviary construction has varied from $10,000 per aviary (at Currumbin Wildlife Sanctuary) to $30,000 per aviary (at David Fleay Wildlife Park) depending on contractor and volunteer labour costs. In addition to breeding aviaries an additional 14 holding aviaries may be required to hold juvenile birds prior to release. Holding aviaries will have a lower cost to breeding aviaries, and other temporary structures may be able to be utilised (depending on facility). Construction costs for holding aviaries are estimated at $3,000 each.

Start-up costs for expanding the captive breeding population is estimated at $115,000. Annual costs for managing the captive breeding program (including additional collection of individuals for genetic supplementation) is $220,000. As a result the overall cost for a 10-year captive breeding programme for bristlebird recovery is estimated at $2.3 million. This will highly depend on breeding success of captive birds and genetic supplementation. The main component of captive breeding programme costs is labour. The estimates provided above are based on a contract rate of $35/hr (Currumbin Wildlife Sanctuary contract rate).

Action: Genetic supplementation

Genetic supplementation of the population will involve the capture of additional wild northern individuals (eggs) to be incorporated into the captive breeding programme. In addition, collection of four birds from the southern population (Barren Grounds Nature Reserve) is planned for March 2019. During it, additional genetic material will be sampled to complete analysis of the genetic differences between northern and southern populations. The genetic analysis will help guide future genetic supplementation of the bristlebird in terms of acceptable rate of gene flow between southern and northern birds for maintaining genetic diversity. Cost for collection and genetic analysis in the first year will be $11,160 (Capture of individuals and genetic material collection = $9,160, genetic analysis = $2,000). Depending on the results of the genetic analysis, additional collection of southern birds may be required to aid the captive breeding program. The total reintroduction plan costs include an additional collection of southern birds during the plan's duration (year 6). This will be dependent on the success of the first supplementation, and a review of whether follow up supplementation is required should be made when necessary. As a result, total costs allocated towards improving the genetic condition of the captive breeding program are estimated at $22,320.

Action: Habitat management

Habitat management is required across all nine priority release sites to support reintroductions. Sites require varying degrees of habitat management, with the best sites only requiring periodic burns to maintain grassy understorey, with more degraded sites requiring more intensive weed control to increase available grassy habitat to a minimum patch size capable of supporting sustainable bristlebird subpopulations. Overall, habitat management to increase high quality habitat and support the fundamental objectives of this reintroduction plan is expected to be $1.6 million over the ten years. This includes $135,000 of first year costs (for initial intensive weed control – costs could be split over the first 5 years), and an annual habitat management budget of $110-200,000 depending on whether burns are conducted.

For the four Queensland priority sites, habitat management will cost an estimated $848,000 over the ten-year timeframe. This cost includes $75,000 for initial weed control, $50,000 annual weed control and $48,000 for prescribed burns. This would equate to an annual habitat management cost of $50-74,000 depending on whether prescribed burns are conducted.

Habitat management on remaining five New South Wales priority sites will cost an estimated $786,000 over the ten-year timeframe. This cost includes $80,000 of first year weed control to reduce shrub and weed presence in degraded habitat, $60,000 for annual weed control costs to maintain grassy habitat areas and $126,000 for prescribed burns. This equates to an annual habitat management cost across New South Wales sites as $80-145,000 depending on whether burns are conducted. Table 4 lists prescribed burn costs in a single year for all sites (years 4 and 8). In these years, habitat management costs are only for prescribed burn costs, so exclude costs for weed control. However timing of burns will be subject to individual site condition, therefore these costs may be split across years, rather than all sites burnt in the same year. In addition, pre burn or follow up weed control work may be required, depending on the effectiveness of burns and the environmental conditions that year. As such, weed control costs may be required during a burn year, but annual weed control costs have been overestimated to cover this. Land managers should use these habitat management costs as a guideline for how much work needs to be undertaken on sites, and adjust yearly budgets according to individual site conditions.

Habitat management costs include initial weed control to restore degraded areas, annual weed control to maintain good habitat and prescribed burns (every 3 or 4 years). Weed control costs have been estimated based on contractor quotes of $1000/ha for first year, more complete weed control on private property, and $500/ha estimates for public land. Prescribed burn costs vary depending on land tenure, with contract quotes at $15,000/burn on private property, and estimates of $3000/burn on park land. The habitat management cost estimates include all weed control and prescribed burns on park land ($904,000 total cost, $80-92,000 annual cost), but some may be covered by existing investment by park management. Park costs have been included in the overall estimate to demonstrate the direct bristlebird management actions that are required within park boundaries to support the fundamental objectives of this plan.

Habitat management is critical to achieving the fundamental objectives and supporting an increased bristlebird population. Habitat management costs will likely be needed past the period of this reintroduction plan, however depending on the level of weed control achieved at sites, regular prescribed burns may be adequate to maintain good quality habitat once shrubs and weeds have been reduced. As such, annual habitat management costs at each site could be reduced, depending on success of initial weed control and follow up weed requirements and facility for prescribed fires to replace weed control. This does not include costs associated with feral animal management but this will be considered closer to reintroduction.

Action: Reintroduction

Reintroductions will cost an estimated $42,000 per reintroduction (annual cost) with an additional $6,094 of start up costs to cover necessary equipment purchases. As such, the overall cost of reintroductions, under the assumption that they will occur every year following successful captive breeding is expected to be $430,000. This is the cost required to carry out 10 reintroductions, however it is unlikely that reintroductions of 12 individuals will be possible in the first years after increasing the captive breeding program, and will depend on the success of genetic management. It also covers tracking and monitoring costs for each reintroduction. This may be unnecessary for all reintroductions once methodology and establishment success is determined, and useful monitoring information such as dispersal distances is known.

Action: Population monitoring (biennial surveys)

Population surveys currently cost AUD$27,000 per survey based on 2018 contractor quotes. Over the 10-year reintroduction plan, biennial population surveys will cost $135,000. This is additional to post release monitoring costs, which are included in the reintroduction estimates. Population monitoring will be a vital action for this recovery plan to monitor the success indicators of this reintroduction plan. Population monitoring costs is likely to be an ongoing cost that should be continued past the time frame of this reintroduction plan.

Funding opportunities

To implement this reintroduction plan, specific funds are still required. Remaining costs include habitat management within QLD priority sites, habitat management across NSW priority sites, collection of additional wild individuals from QLD, captive breeding expansion and ongoing management, and reintroduction and monitoring costs.

Potential sources of funding include:

- State Government department funding (QLD & NSW)
- Federal funding (e.g. National Landcare Program, Threatened Species Recovery Fund)
- NGO contribution (e.g. BirdLife Australia, Bush Heritage)
- National or international philanthropic sources

The estimate for funding this reintroduction plan is $410,000 annually over the 10 year timeframe. Depending the success of improving captive breeding rates, it is likely that funding this reintroduction plan in its entirety could secure the bristlebird population from extinction. A large proportion of the implementation cost is labour costs for the management of the captive breeding program ($200,000 annually). This cost was calculated based on hourly contract rates, however could be minimised with the appointment of a bristlebird specific permanent position. Priorities for funding should be the expansion of the captive breeding program and improvement of breeding success through wild egg collection and southern translocations, and habitat management to prepare priority sites for reintroductions.

Remaining research priorities

Habitat loss from infrequent fire is a key threat to bristlebird persistence. Recent attempts to address this issue through habitat management and prescribed fires are achieving marked improvements in habitat condition (Wildsearch Environmental Services, 2016a), and early signs of bristlebird population stabilisation at sites where management has been undertaken (Charley, unpublished data). As a consequence, the recovery team is relatively confident about the management actions needed to restore habitat and increase habitat availability for bristlebirds. However, four areas of uncertainty remain:

1. Understorey tussock regeneration

One of the key determinates of bristlebird recovery is the ability to restore overgrown, shrubby habitat to high quality grassy forest. Intensive weed control followed by prescribed burns by land managers at some sites has been effective at clearing the mid-story of problematic shrubs and improving grass cover. However in most cases, areas of bare soil often remain where weed or shrub infestations were dense, or grass regrowth has been dominated by non-tussock species. As bristlebirds rely on tall tussock grasses for nest building, additional research into appropriate methods to restore tussock grass species in these degraded areas is needed. This research would be relatively simple, involving a few experimental treatments conducted at burn sites to determine whether methods such as seeding of tussock species, or strategically planting tubestock within bare areas may assist the regeneration process of a high quality tussock dominated understorey for bristlebirds. Such research could be undertaken either by land managers or by Honours or Masters research students interested in restoration ecology. Costs needed to support such research would be minimal ($5-10,000).

2. Captive breeding

Given the current issues present in the captive breeding program, research into improving captive breeding may be warranted. Some research may be more suitable to breeding facility staff as part of an adaptive approach, given additional funds, or undertaken by specific research students or staff. Useful information that may help improve the captive breeding program that could be undertaken by breeding facility staff includes trials of varying food and environmental conditions that may improve breeding success or manipulation of breeding aviary structure. Bristlebirds are highly territorial, and some key behavioural traits may be missing in captive bred birds. Captive bred birds at Currumbin Wildlife Sanctuary have demonstrated different behaviours to those observed in wild caught founder birds, suggesting that some wild behaviours important for successful breeding and survival may have been lost (A. Beutel pers. comm.). In particularly, wild birds had longer settling in times, and appear to have different calls to captive birds (A. Beutel pers. comm.). Research by Jessie Oliver at QUT has already demonstrated the high diversity of calls within the bristlebird repertoire. Differences in calls between wild and captive, as well as southern and bristlebird populations may have important implications for captive breeding and release. Research into possible loss of important breeding behaviours and calls between wild caught and captive bred birds may help assist the captive breeding program in identifying whether behavioural issues are present and whether attempts need to be made to teach young individuals.

Learned behaviours could be taught through more systematic pairing of wild and captive birds, playback calls for vocal displays, predator awareness training or modifying captive breeding management to encourage certain wild behaviours. Southern bristlebirds may not be adapted to northern environments, and may have different behavioural traits or dialects that may impact cross-breeding potential. Following the introduction of southern birds, comparisons of northern and southern behaviours will be important to determine compatibility of the different populations for breeding, prior to birds being mixed.

3. Genetics

Most of the remaining uncertainties regarding bristlebird recovery is related to captive breeding and genetic viability of the population. The planned genetic analysis will give important insights into the differences between northern and southern bristlebird populations to guide incorporating southern genetics and establishing appropriate levels of gene flow. Following the collection of this genetic material and the trial introduction of southern birds into the northern captive breeding program the opportunity should be taken to test how breeding success may be affected. The recovery team should focus research on comparing breeding success before and after introduction of new genes, and a genetic analysis of crossed offspring would help provide information on outbreeding depression risk and long-term viability of crossed individuals.

4. Reintroductions

While the trial reintroductions were relatively successful in the short term, there are still uncertainties regarding long-term mortality rates, movement patterns, breeding success and the scale of predation threat to released birds. A vital part of the reintroduction process will be post-release monitoring to ensure release methodology is appropriate, and to determine long-term mortality rates of released birds. Additional post-release monitoring that would be beneficial is tracking of individuals to determine fine-scale habitat use and movement patterns. We still have little knowledge of how bristlebirds use the landscape, and how well they are capable of moving between grassy forest patches through rainforest habitat. Learning this information would be valuable for adaptive management of bristlebirds and their habitat. Population growth estimates used to determine the best alternative action for bristlebird recovery (Table 1) were based on captive breeding demographic information. While it is extremely difficult to assess wild breeding success and mortality rates, tracking of released individuals, along with ongoing population monitoring will provide evidence on release birds responses which may be used to update population models. IUCN translocations guidelines suggest updating population models as reintroductions occur based on new information will help improve recovery actions. Monitoring and reassessing actions based on updated population information is a critical step in the conservation translocation cycle (Figure 2). The costs included in this reintroduction plan cover 6 weeks of monitoring following release, which may be adequate to collect relevant data to assist bristlebird recovery. However, additional monitoring may still be needed. Therefore, a review of monitoring requirements should be conducted prior to releases to decide whether there is additional data that could be collected to aid management.

Ethics and permits

For the implementation of this plan, ethics and permits will be required for a number of the management actions.

For genetic management, an ethics application was submitted and approved for the translocation of up to 10 individuals from the southern population over a three year period. Ethics has been approved for the collection of wild chicks or eggs (SA 2016/03/550) and scientific licenses have been acquired for the collection of wild chicks or eggs from New South Wales (SL101293) and Queensland (WA0012528) sites. The New South Wales license is valid until 31st January 2020 and allows for the collection of up to 20 chicks or eggs from in and around the Border Ranges -. The Queensland license is valid until 5th May 2019, and allows for the collection of two chicks or eggs per year. A nest survey was conducted in January 2019 by Wildsearch Environmental Services at the QLD breeding site, however no nests were found. A recommendation of the report was for a follow up survey towards the end of the breeding season (Wildsearch Environmental Services, 2019). If nests are still not discovered, the ethics and scientific license will need to be renewed for another breeding season (until February 2020) as the addition of genetic material from QLD sites is a critical component of the captive breeding program.

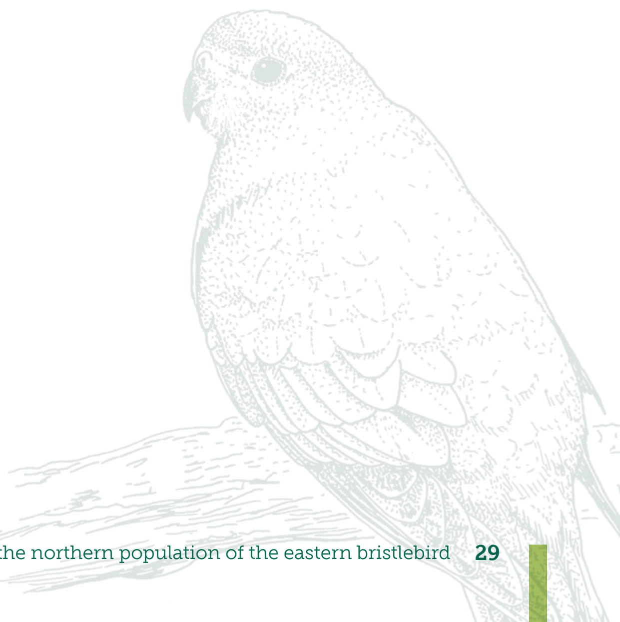
Ethics approval is still required for reintroduction of captive bred individuals into bristlebird habitat. It may be possible to amend the current translocation approval to include reintroductions; otherwise, a new application will need to be submitted. If so, the reintroduction information presented in this report can be used to develop an application by relevant stakeholders.

Conclusion

Based on the objectives of the eastern bristlebird recovery team's northern working group, captive breeding plus genetic supplementation by central birds is the recommended management action suggested in this report. Alternative actions that were assessed did not meet the criteria for increasing the population and long term persistence of this important population of eastern bristlebird. While the recommended management action will be the most costly, it is unlikely that habitat management or captive breeding alone will be adequate for allowing long term persistence. Habitat management is a critical step for the recovery of both bristlebirds and their declining grassy forest habitat, but given the current fragmentation of sites and small population size, bristlebirds are unlikely to be able to reoccupy restored habitat fragments. Genetic analysis has revealed that the bristlebird population has reduced genetic diversity than southern populations, particularly within the captive northern population which has 43% less allelic diversity than central birds (Weeks, 2019). Reduced genetic diversity in both the captive and wild northern population suggests that a captive breeding involving northern birds alone, even with additional wild supplementation, will be limited. Evidence to date shows high levels of egg and chick mortality and birth defects (Stone, 2019) within the captive population. It is clear that genetic supplementation is required if there is any chance to establish a successful captive breeding and reintroduction programme. Genetic analyses of northern and central populations suggest there is a low risk of outbreeding effects if central birds are used for genetic supplementation.

This report recommends:

- Supplement the captive population with both wild northern individuals and central birds to increase genetic diversity and improve breeding success.
- Genetic analysis should be conducted of captive population following genetic supplementation prior to release of central-northern crossed individuals (as recommended by Weeks, 2019). This will help determine whether genetic supplementation has been effective at increasing genetic diversity and will guide release protocols for cross-bred individuals.
- Continue with habitat management across all priority release sites, with the goal of increasing size of grassy forest patches to at least 40ha of high quality habitat, and undertake habitat management actions to increase connectivity between sites.
- Once the captive breeding programme is producing enough chicks, reintroductions of birds should be undertaken following protocols suggested in this report at the identified priority release sites. Re-evaluation of these sites closer to release of birds should be undertaken by the recovery team to make sure sites meet habitat requirements, and an adaptive approach should be followed that is suitable for future site conditions, captive breeding output and genetic supplementation results.
- Funding needs to be secured for the continuation and development of the captive breeding programme. As stated throughout this report, bristlebird recovery depends highly on the success of the captive breeding programme. Without supplementation, the wild bristlebird may not persist due to reduced genetic diversity, fragmentation and low resilience to stochastic events. It is critical that habitat management continues within both NSW and QLD sites, and that the captive breeding programme is expanded to provide enough individuals to allow recovery in the wild.
- Ongoing sustained and coordinated effort is required for bristlebird and this must extend to monitoring and onground action, e.g., extension support to private landholders.



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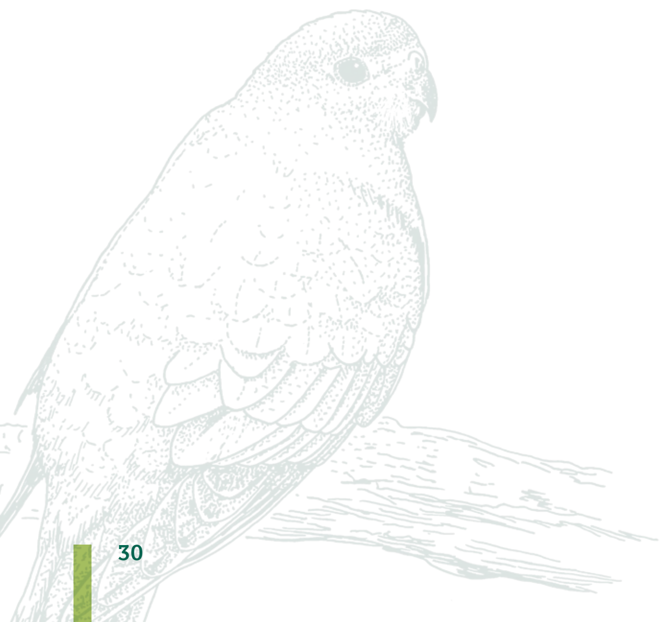

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Further information:

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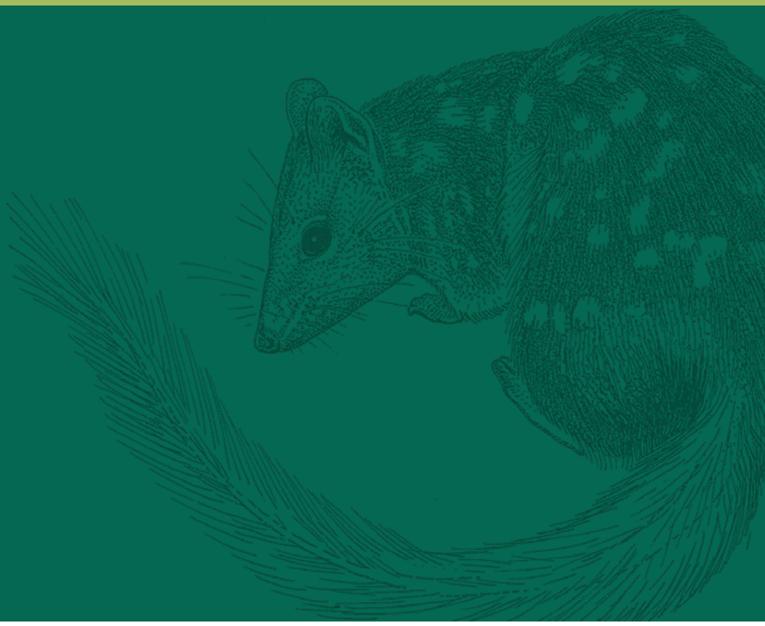

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