

National Environmental Science Programme



# Northern bristlebird genetics report: Information for genetic management

Prepared for New South Wales Office of Environment & Heritage - Saving our Species

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#### Disclaimer

This report has been prepared in accordance with the scope and services described in the contract or agreement between The University of Queensland and New South Wales Office of Environment & Heritage. The report includes confidential information obtained from monitoring data and the captive breeding program managed by Currumbin Wildlife Sanctuary. Any findings conclusions or recommendations only apply to the aforementioned circumstances and no greater reliance should be assumed or drawn by NSW OEH. This report has been prepared solely for use by the NSW OEH – Saving our Species program and the Eastern Bristlebird Recovery – Northern Working Group.

Cover image: Northern eastern bristlebird. Photo: Zoe Stone

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# Introduction

The University of Queensland was contracted by the New South Wales Office of Environment & Heritage (NSW OEH) to conduct a review of genetic information available on the eastern bristlebird in regards to a potential genetic rescue of the Critically Endangered northern population, through translocation of wild individuals from the central population into the northern captive breeding program.

This report provides a summary of work conducted for the NSW Office of Environment & Heritage project: *Central Eastern Bristlebird genetics and collection of birds for addition to breeding program.* The main tasks during this project were to:

- 1. Locate existing genetic material for use in genetic assessment for the captive breeding program
- 2. Prepare amendments to NSW OEH Animal Ethics and Scientific License for collecting genetic material and birds for captive breeding program.
- 3. Provide a summary of findings, literature and contacts.

For this summary we review the literature on genetic rescue and relate this to the northern bristlebird as a potential candidate. We also review the available genetic information on the northern bristlebird population (both captive and wild) and provide guidelines for the logistics, timeframe and requirements needed to carry out a proposed genetic rescue project. We provide information on the current availability of genetic material from the central population and include applications and information required for the amendment to current ethics and scientific licenses (131014/01 and SL101293) held by the NSW Saving our Species program for eastern bristlebird work.

Specifically, this report covers:

- Brief background to the project
- Genetic rescue overview
- Current genetic material available and additional material to be collected
- Logistics and requirements
- Ethics amendments (supplementary files)

### **Project background**

The eastern bristlebird (*Dasyornis brachypterus*) is a small, cover-dependant, ground-dwelling, Endangered passerine endemic to south-eastern Australia. Although this species once occurred across coastal south-east Australia (Figure 1), changes in land-use since European settlement, changes in fire regimes and contemporary habitat loss associated with coastal urbanisation have been the key drivers of their decline. Today, the eastern bristlebird is confined to three isolated populations: one southern population on the Victoria–New South Wales border, a central population in New South Wales and a northern population (henceforth 'northern bristlebird') on the Queensland–New South Wales border (Figure 1).

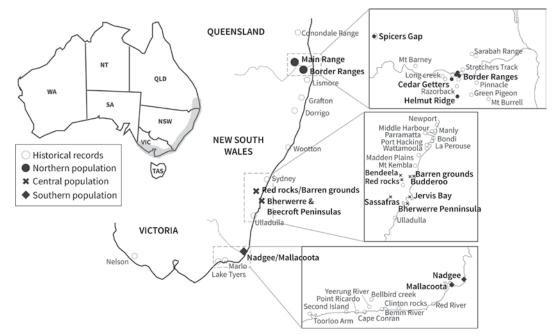


Figure 1. Historic and current extent of the eastern bristlebird across south-east Australia (Stone, 2018).

In the past, the northern population was recognised as a distinct subspecies (Schodde and Mason, 1999) based on plumage colouration and ecological differences. More recent genetic analyses have not supported this subspecies distinction; however, the northern population is still considered a critical management unit for conservation. The Action Plan for Australian Birds 2010, which still recognises the northern population as Critically Endangered, stated that conservation objectives for the species were to increase the population and maintain viable populations at five separate locations, including at the northern range. For the northern population, establishment and maintenance of a *viable* captive breeding population was deemed an urgent management action for recovery.

The Eastern Bristlebird Recovery–Northern Working Group<sup>1</sup> has been responsible for the management of the northern population. Key conservation actions carried out by the group include the restoration of appropriate fire management to improve habitat condition and implementation of a captive breeding program that aims to reintroduce birds into the wild. The captive breeding program is currently housed and managed by Currumbin Wildlife Sanctuary with a current population of 16 birds comprising of three breeding pairs. Recent issues with breeding success within the captive population have raised serious concerns of genetic inbreeding and infertility problems. For instance, during the most recent breeding season (2017–18), only two chicks were successfully fledged from 18 eggs (11% success rate). This alarming success rate and other factors have prompted a serious need to review the potential for genetic rescue<sup>2</sup> of the northern population.

### **Genetic rescue**

Anthropogenic threats to biodiversity have meant that extensive fragmentation and isolation of natural populations have produced effective population sizes that are substantially smaller than historical conditions (Love Stowell et al., 2017). Population reductions lead to the loss of genetic diversity and can produce highly inbred populations with limited breeding success. Populations that are restricted to small, isolated habitat patches can lose their adaptive potential and may fall into an 'extinction vortex', where low genetic diversity and susceptibility to extreme events (e.g., bush fires) limit population recovery. In such cases, habitat protection or restoration on its own is unlikely to facilitate population increase.

Genetic rescue is the term given to conservation efforts that aim to restore adaptive potential of small, isolated, genetically depauperate populations through the short-term introduction of novel genetic material (Weeks et al., 2011). Recently, genetic rescue has gained support as a valuable conservation strategy, particularly in highly threatened subspecies where the risks of outbreeding depression<sup>3</sup> are lower because of recent genetic divergence<sup>4</sup> (Ralls et al., 2017, Frankham et al., 2011). Although genetic rescue has only recently been developed (Frankham et al., 2017), pioneer applications have indicated early success. For instance, introduction of novel genes to the mountain pygmy possum (*Burramys parvus*) from a larger genetically diverged population resulted in rapid population recovery (Weeks et al., 2017). In New Zealand, genetic rescue of the South Island Robin (*Petroica australis*) using highly inbred donor populations resulted in an increase in juvenile survival and recruitment, sperm quality and immunocompetence<sup>5</sup> of hybrids (Heber et al., 2013). Genetic management is therefore an important new tool for threatened species conservation that has the potential to increase genetic diversity and long-term persistence of populations. For the northern bristlebird, extinction is likely unless serious consideration is given to genetic management of the population.

<sup>2</sup>The 2019–2020 breeding season had six successful chicks fledged (A. Molyneux pers. comms.), two of which are from central birds that were added last year.

<sup>3</sup> Outbreeding depression = the decrease in individual fitness that can arise when two distinct lineages are crossed.

<sup>4</sup> Genetic divergence = the process in which populations of an ancestral species develop independent genetic variation due to reproductive isolation.

<sup>5</sup> Immonucopetence = ability for individuals to have an appropriate immune response to infection or disease. Poor immunocompetence (or immunodeficiency) is common in inbred populations, generally resulting in high juvenile mortality.

<sup>&</sup>lt;sup>1</sup> Established in 1998, the Northern Working Group includes experts from five government agencies (including NSW OEH), conservation and natural resource management non-government organisations, private consultants, three universities, a wildlife park (i.e., a conservation zoo), and private landholders.

### Northern bristlebird genetic rescue potential

Genetic assessment of the eastern bristlebird by Roberts et al. (2011) showed there was a lack of phylogenetic distinctiveness between populations to support a northern subspecies classification. Their research found that both the northern and southern populations are less genetically diverse then the central population, because of their overall smaller population sizes (Weeks et al., 2016).

Roberts et al. (2011) also found that while the northern bristlebird only retained a small proportion of the microsatellite variation present in the central population, they did contain nuclear allelic, genotypic and haplotypic variation that is absent in the central population. In other words, they found broad-scale genetic subdivision by region that may aid local adaptations in populations. As a result of their findings, Roberts et al. (2011) cautioned against mixing genetics across regions to preserve genetic integrity of the local populations. However, it has been suggested that this study was underpowered and management recommendations were not based on gene flow between units and time of divergence (P. Sunnucks pers. comm.). Both these factors highly affect the genetic rescue potential of a population or subspecies. Genetic distinction in the northern population is likely due to random genetic drift that has resulted because of the historically recent fragmentation and small population size, rather than a reflection of longer-term evolutionary adaptation (Sunnucks, 2013). Because of this, it is likely that a small degree of cross-breeding between the genetically similar southern and northern populations will have little risk of outbreeding depression.

Conservation of the northern population is important for maintaining genetic diversity and potential local adaptations within the eastern bristlebird species as a whole. Species' long-term persistence in a changing climate relies on having evolutionary resilient species in which evolutionary potential is maintained (Sgrò et al., 2011). Evolutionary potential in a species has been positively linked to genetic diversity (Harrisson et al., 2016). For eastern bristlebirds, loss of the genetic diversity at the northern range limit may mean the loss of any local adaptations that may occur there, and potential reduction in the species' ability to persist under varying environmental conditions. Although this means caution must be exercised when introducing individuals from the central or southern populations (to avoid 'genetic swamping' or loss of unique adaptations), there would be substantial benefits for increasing genetic diversity within the northern population through genetic rescue. Based on estimates of past gene flow, risk of outbreeding depression can be predicted, and admixing rates can be determined accordingly to minimise potential harmful effects (Frankham et al., 2017, Ralls et al., 2017, Frankham et al., 2011).

The northern bristlebird population is now at a critical level, where evidence of inbreeding depression in both the wild and captive populations (D. Charley & A. Beutel pers. coms.) means genetic rescue may be needed to help prevent their extinction. The potential benefits of assisted gene flow for northern bristlebirds may be high, particularly if undertaken at low levels to dilute foreign genes and decrease risk of outbreeding depression and loss of local adaptations.

### Information required for genetic rescue

When developing a genetic rescue plan, Pavlova et al. (2017) outlined four main considerations to guide the decision-making process:

- 1. Level of genetic variation in population that triggers need for genetic rescue
- 2. Source population
- 3. Outbreeding depression risk
- 4. Level of gene flow required

We provide a summary of each of these considerations for the northern bristlebird based on existing information, and outline areas where uncertainty remains.

### 1. Northern bristlebird population size and genetic variation

Increasing the wild population to a minimum of 100 breeding individuals is likely to improve breeding success. The current wild population of the northern bristlebird consists of only 38 individuals, of which only five known breeding pairs have been confirmed. This very small population size is far below the recommended effective population size  $(N_e)$  of  $\geq$  100 individuals for preventing inbreeding depression and fitness loss, or  $\geq$  500 individuals for maintaining long-term adaptive potential (Frankham et al., 2014). Since the total population has been below 150 birds since the 1980s, it is highly likely that the wild population is undergoing inbreeding depression. Frankham et al. (2017) suggested that populations that have known inbreeding coefficients of at least 10% or have a 10% reduction in genetic diversity are candidates for genetic rescue (F < 0.1)<sup>6</sup>. An important step in determining the populations inbreeding coefficient is to analysis both wild and captive birds.

Genetic analysis has already been conducted on the captive population. Genetic assessment of the captive birds by Weeks (2017) used three times the number of microsatellite markers (18) than Roberts et al. (2011) used. Weeks (2017) found no evidence of inbreeding within the captive sub-population ( $F_{\rm IS}$  =-0.041<sup>7</sup>). However, they concluded that the captive breeding program does not contain enough unrelated individuals to support increased breeding and long-term success of the program. They recommended that even though the current captive population shows no genetic sign of inbreeding, future breeding will be compromised by the lack of non-related individuals. All isolated populations lose genetic diversity through random drift, and those with small effective population sizes lose genetic diversity at a significantly faster rate (Frankham et al., 2017). Considering the northern bristlebird is likely to have reduced genetic diversity, reduction in genetic diversity will likely continue if steps are not made to manage gene flow. As such, serious consideration should be given to introducing individuals from the southern population.

Despite no evidence of inbreeding in genetic analyses of the captive population, breeding records since 2014 indicate that the northern bristlebird is suffering from high rates of infertility and nest failure. Since captive breeding began in 2014, only nine chicks have successfully fledged from the 123 eggs laid and > 40% of all eggs laid have been confirmed infertile(Table 1).

Year	Nests	Eggs	Egg failure	Confirmed infertile	Chick deaths	Egg thrown	Successful fledgling	% Egg failure	% Infertile (all eggs)	% Chick failure (all eggs)	% Fledging success (all eggs)
2014	4	7	3	0	4	0	0	42.86	0.00	57.14	0.00
2015	10	19	10	3	5	1	3	52.63	15.79	26.32	15.79
2016	20	38	31	22	0	4	3	81.58	57.89	0.00	7.89
2017	23	45	39	19	3	2	1	86.67	42.22	6.67	2.22
2018*	8	14	9	7	1	0	2	64.29	50.00	7.14	14.28
TOTAL	65	123	92	51	13	7	9	74.80	41.46	10.57	7.32

Table 1. Breeding success of captive northern bristlebird population between 2014 and 2018 at Currumbin Wildlife Sanctuary. Based on confidential data obtained from Currumbin Wildlife Sanctuary.

\* Does not include second season expected from August 2018

It is clear that in addition to fertility issues there are fitness issues as several of the hatched chicks did not survive due to physical abnormalities or failure to thrive. Inexperienced young birds also have demonstrated some nesting issues that need to be resolved for the captive breeding program to be successful (C. Hall, A. Beutel pers. comm.). The current goals of the Eastern Bristlebird Recovery Team–Northern Working Group is to increase the captive breeding population from the three current breeding pairs to at least six breeding pairs (Charley, 2010). In captivity, despite the low fertility, northern bristlebirds readily re-nest during a lengthy breeding up to eight times during this period (A. Beutel, pers. comm.). A target of 6–12 breeding pairs was estimated to theoretically be capable of generating 120–300 birds for release over a five-year captive breeding program (Charley, 2010). If fertility and nesting problems can be addressed, the captive breeding program has the potential to increase the wild population above the suggested 100 breeding individuals necessary for long-term persistence.

<sup>&</sup>lt;sup>6</sup> F is the inbreeding coefficient of an individual, or a population mean. In this case the northern bristlebird population mean (wild and captive 'sub-populations')

<sup>&</sup>lt;sup>7</sup> FIS is the inbreeding coefficient within a population fragment or sub-populations. In this case, the captive breeding 'sub-population' of the northern bristlebird

Further genetic comparisons of northern and southern birds are still needed to determine current effective population size  $(N_e)$  and overall inbreeding within the northern bristlebird population (*F*). Considering the known wild population is 38, the effective population size is almost certainly dangerously low. Estimating the inbreeding coefficient within the entire northern population will guide appropriate genetic management goals for the northern bristlebird and level of gene flow needed to prevent or reduce inbreeding effects (see Section 4. Suggested gene flow).

#### 2. Source population

To minimise outbreeding depression risks, donor populations should only have been isolated within the last 500 years (Frankham et al., 2017). In addition, donor populations that are outbred (have higher genetic diversity) will produce lower inbreeding coefficients during the  $F_2 cross^8$ . This means that the donor population for a genetic rescue of the northern bristlebird should only have been separated in recent history, and come from the population with the highest genetic diversity.

Roberts et al. (2011) found that mtDNA of the northern and central populations were polyphyletic to each other, with the southern population monophyletic, or more closely related, to the central population then the northern. They found that all populations were genetically distinct, and the northern population had a relatively high genetic diversity. As previously mentioned, this study was limited by number of markers tested. It also did not estimate gene flow between populations, which provides key information for determining source population and number of migrants for genetic rescue. To reduce the risk of outbreeding, donor populations should be closely related, therefore based on current knowledge, the central population is likely to be a better donor source then the southern population. The central population is also the largest, increasing population (D. Bain pers comm.) of the eastern bristlebird, with roughly 2000 individuals, split across multiple locations. Removing individuals from the central population is likely to have a negligible impact on the healthy population. To maximise the benefits of genetic rescue, it may be worth including genetics from both main central populations to reduce inbreeding coefficient across generations (Frankham et al., 2017).

### 3. Outbreeding depression risk

The northern bristlebird has been classified as a separate population for management purposes. As mentioned, Roberts et al. (2011) concluded that the northern bristlebird genetics had genotypic and haloptypic variation that differed from southern populations. However Sunnucks (2013) questioned this conclusion, proposing contradictory conclusions based on the data presented in Roberts et al. (2011) to suggest that variation was only a result of random drift and did not identify the northern as a separate genetic unit. Based on the interpretation of the data outlined by Sunnucks (2013), the low genetic distinction observed between northern and southern populations indicate that the risk of outbreeding depression is likely to be minimal.

There are, however, morphological and ecological differences between the populations that should be attempted to be preserved. There is still concern that genetic rescue may cause the loss of unique characteristics within the rescued populations or sub-species following genetic management. However, populations with severely limited genetic diversity and isolation are at risk of extinction if genetic management is not undertaken, which will ultimately lead to the loss of those features and any local adaptations they may have (Ralls et al., 2017).

If outbreeding depression risk is minimal, a remaining question that may influence genetic rescue is behavioural compatibility between the populations. Northern bristlebirds in captivity are known to undertake aggressive courtship behaviours, particularly males towards females (A. Beutel pers. comm.). In addition, it appears that males play an important role in teaching young females incubation behaviours (A. Beutel pers. comm.). Breeding behaviours and courtship in the southern populations have not been observed. Because of this, there is a small chance that unidentified differences in courtship behaviours may exist between northern and southern populations. Common incubation failure is observed by females in captive northern bristlebirds, particularly young females (Table 1). Introduction of wild southern birds may benefit breeding success by improving courtship and nesting behaviours that may have been lost from captive population. Following introduction of southern birds, it will be important to monitor interactions between southern and northern birds if genetic rescue occurs.

### 4. Suggested gene flow

Frankham et al. (2017) suggests that when a recipient population is inbred, any immigrants adding to the population is better than none, however the goal of a genetic rescue project will influence how many migrants should be incorporated. These goals can include 1) avoiding fixation of alleles; 2) preventing damaging inbreeding; 3) reversing existing inbreeding; or 4) providing variation for adaptation. In the case of the northern bristlebird, Weeks (2017) found no evidence of current inbreeding (but has yet to compare genetic diversity to southern populations); however, the size of the population means inbreeding is likely to be occur. Suggested goals for a northern bristlebird genetic rescue would therefore aim to prevent or reverse existing inbreeding, dependant on final results from genetic analysis.

Current recommendations for the *prevention* of inbreeding state five effective migrants per generation are needed to prevent accumulation of inbreeding effects in sub-populations (Frankham et al., 2017).

For *reducing* inbreeding effects in a population already suffering, the number of migrants needed can be calculated based on source population inbreeding level, the desired inbreeding coefficient after migration (F < 0.1) and the current inbreeding coefficient of the recipient population (Frankham et al., 2017). Once planned genetic analyses are completed, the northern bristlebird (recipient population) inbreeding coefficient will be known and can be incorporated into this equation to determine number of migrants required.

If the population can't increase to >1000 individuals within several generations after translocation it has been suggested that gene flow should not exceed one migrant per generation (Weeks et al., 2011). Because of their high breeding potential in captivity, it is likely that northern bristlebirds will be able to accommodate a greater level of gene flow without risking inbreeding depression. Based on current knowledge, four migrants per generation is likely to be a conservative addition and is unlikely to negatively affect the integrity of the northern bristlebird (A. Weeks pers. comm.).

### Non-genetic management actions

### Complete captive population

If genetic rescue is not undertaken other options will need to be considered to increase captive breeding potential. Tenhumberg et al. (2004) found that once wild populations reach < 20 females, the entire wild population should be captured and moved into captivity, even if the wild population is growing. Small populations are highly susceptible to random disturbance events and environmental stochasticity (Tenhumberg et al., 2004, Clark et al., 1989). Complete capture of small, fragmented populations into captivity reduces the risk of extinction and allows for quick growth of the captive population (Tenhumberg et al., 2004). While this option is controversial, removal of the entire population from the wild (or as close as) can allow complete habitat restoration of threat management to be conducted while increasing captive breeding genetic diversity and ensuring individual survival. For northern bristlebirds, this option will be dependent on expanding the captive breeding facilities, which are currently at capacity. This would require additional funding sources and space for additional aviaries. This would also be logistically difficult and expensive due to the fragmented geographical locations, terrain and low numbers of birds in any one location.

For breeding programs, 20–50 founding individuals are needed in order to capture 95% of the standing genetic variation (Weeks et al., 2011). The current captive breeding population for the northern bristlebird includes a total of seven wild caught individuals and captive bred offspring. Based on this, the captive breeding population is likely to represent a small amount of the wild genetic variation. If this action is undertaken, incorporating wild individuals as soon as possible into the captive breeding will increase the chance of preserving as much of the remaining wild genetic diversity as possible.

### Translocation of southern birds into northern habitat

If funding cannot be secured for expanding the current captive breeding program, translocations of wild individuals from the central population directly into northern habitat may need to be considered. This management action will still involve the mixing of central and southern genetics, which is currently the key concern with genetic rescue.

In addition, translocation is a highly stressful activity for individuals and has a high influence on immediate mortality and translocation success (Letty et al., 2007). Different habitat and environmental conditions present between the central (34°S) and northern (26°S) bristlebird locations may impact post-release stress and survival of adult birds that are unused to the novel environment (Parlato and Armstrong, 2013). Current IUCN guidelines for translocations and reintroductions recommend recipient locations meet seasonal needs of the species (IUCN, 2013). Seasonal conditions in northern habitat are likely to differ and this may place additional stress on central individuals when released. Integrating central birds into the northern captive breeding program may be an effective strategy of acclimatising central birds to the new environment (Dickens et al., 2010), and then releasing offspring, which will be pre-conditioned to northern conditions.

# Potential barriers to increasing captive population

Genetic management and increasing the captive breeding program are highly dependent on the availability of breeding aviaries and captive breeding facilities that can accommodate birds without adverse risk. At present, the captive breeding facilities available to northern bristlebird recovery is at capacity (three breeding aviaries and four holding pens), and is unable to host more individuals to create a viable captive breeding population. If more individuals are required to be brought into the captive breeding program, funding will need to be acquired to increase aviaries and support staff to conduct husbandry and management. As of July 2018, efforts are being made to secure use of an additional five aviaries for the captive breeding program.

Captive breeding costs:

Action	Cost	
Additional aviaries refurbishment	\$300	
Additional aviaries operations & management	\$29,894 / year (\$82/day)	
New aviary construction	\$10,000 / aviary	

# Existing eastern bristlebird genetic material

Contact with David Roberts (lead author, Roberts et al., 2011) has been established to determine location and condition of existing genetic material that was collected for their original genetic analysis. For their study, Roberts et al. (2011) used a number of existing collections of DNA, pin feathers (Perrin and Roberts, 2010) or blood samples. These samples covered a total of 118 individuals (106 of which were sequenced) to be genotyped, consisting of 58 (48 sequenced) from Jervis Bay, 47 (32 sequenced) from Barren Grounds, 7 (6 sequenced) from the southern population and 13 (5 sequenced) from the northern population (specific location unknown for southern and northern samples). Attempts previously have been made to locate this genetic material to use in a new analysis by Andrew Weeks (using improved genetic techniques) to determine genetic diversity coefficients between southern and northern birds and assess time of divergence between populations. This will guide selection of appropriate gene flow for genetic rescue.

According to Dave Roberts, samples were stored at the University of Wollongong, although confirmation of this, and their condition, is still needed.<sup>9</sup> Confirmation is expected in early July. If samples are still in a viable condition for analysis, samples will need to be shipped to Cesar (293 Royal Parade, Parkville, VIC 3052) where Andrew Weeks will conduct final analyses.



Northern eastern bristlebird nestlings. Photo: Currumbin Wildlife Sanctuary

<sup>9</sup> UPDATE February 2019 - Original DNA samples could not be located. Collection of new samples by the recovery team is planned for March 2019 at Barren Grounds.

# **Final recommendations**

Decision trees have been developed by both Ralls et al. (2017) and Weeks et al. (2011) for managers in the beginning stages of determining whether genetic rescue actions should be carried out. Based on information detailed in throughout this report, northern bristlebirds should be considered for genetic recue (Fig. 2 and 3).

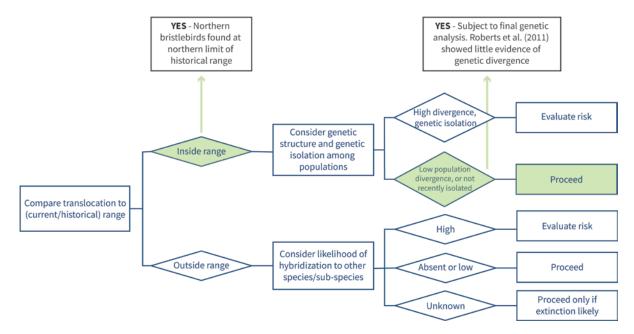


Figure 2. Decision tree to determine species suitability for genetic rescue recommended by Weeks et al. (2011) completed according to the northern bristlebird. Adapted from Weeks et al. (2011)

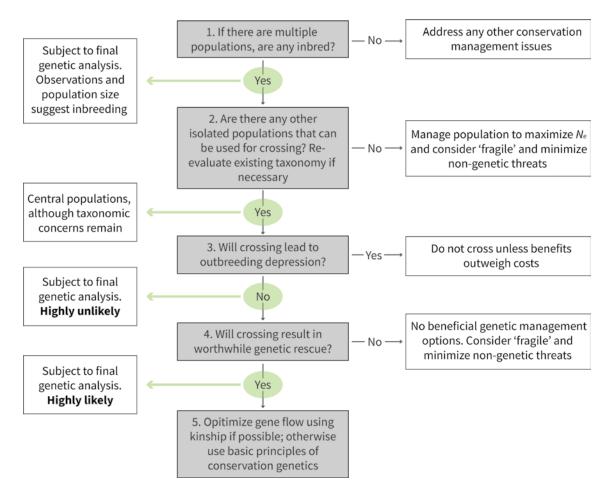


Figure 3. Decision tree to determine species suitability for genetic rescue recommended by Ralls et al. (2017), completed according to the northern bristlebird. Adapted from Ralls et al. (2011)

# Suggested timeframe

Genetics report complete	July 2018
Submission of ethics application	July 2018
Confirmation of existing genetic material	July 2018
Collection of Queensland eggs/nestlings	September/October 2018
Preparation for translocation of southern bristlebirds	January–May 2019
Translocation of southern bristlebirds	May–June 2019
Integration of southern and northern bristlebirds	June–July 2019
First breeding season under genetic rescue	November 2019–February 2020

# **Relevant contacts**

Name	Expertise	Organisation	Contact
Lynn Baker	Northern recovery & management	NSW OEH	Lynn.baker@environment.nsw.gov.au
Dr David Bain	Southern translocations	NSW OEH	David.Bain@environment.nsw.gov.au
Allison Beutel	Northern captive breeding	Currumbin Wildlife Sanctuary	abeutel@cws.org.au
Dave Charley	Northern ecology & monitoring	Wildsearch Environmental Services	dcharley@optusnet.com.au
Prof. Martine Maron	NESP TSR Hub Deputy Director, Australian bird conservation	University of Queensland	m.maron@uq.edu.au
Anthony Molyneux	Northern captive breeding	Currumbin Wildlife Sanctuary	amolyneux@cws.org.au
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Prof. Paul Sunnucks	Genetic conservation, Australia threatened species	Monash University	paul.sunnucks@monash.edu
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# Additional supporting information

Further references are available from the author on request. Contact Zoe Stone: zoelstone@gmail.com.

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