Assessing natural dispersal of New Zealand bellbirds using song type and song playbacks

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Abstract: New Zealand's managed offshore islands provide sanctuary to endangered and rare fauna but also benefit common native species. These productive islands may facilitate the expansion of mobile species back to the mainland. In northern New Zealand, many mainland protected sites are located on coastal headlands within short distances of these offshore islands. Bellbirds (*Anthornis melanura*), locally extinct on the mainland of this region for >100 years, are capable of dispersing these distances and are occasionally sighted along the coast. Nonetheless, it was unknown whether they had established breeding populations. Natural dispersal events are difficult to assess in terms of their source, structure and likelihood of succeeding. Females are generally more difficult to detect but when present provide conservation practitioners with confidence that a population may establish. Here we test a non-invasive monitoring method for a self-reintroduced population of bellbirds at Tawharanui, a managed coastal headland situated equal distances (20 km) from two potential source populations, Little Barrier and Tiritiri Mātangi islands (LBI and Tiri, respectively). Bellbird song playbacks effectively confirmed the presence of both male and female bellbirds. The male and female song types recorded at Tawharanui were not found on Tiri but matched those of LBI and we propose this as the source population. We tested our playback protocol at other coastal parks and advocate annual playback surveys for detecting new populations at potential mainland sites.

Keywords: dialects; offshore islands; predator control

Introduction

Following the pioneering, although unsuccessful attempt in 1888 by Richard Henry to establish a population of kākāpō on Resolution Island, the use of offshore islands as 'safe' locations for recovering populations of threatened and endangered species has been refined and is now an effective management tool in New Zealand (Saunders & Norton 2001). Many of these islands now support self-sustaining populations of New Zealand fauna suitable as a source for further human-mediated translocations to other safe islands and more recently to mainland 'islands' (Saunders & Norton 2001). These mainland islands are often restored headlands and peninsulas where the combination of appropriate stewardship, defendable boundary, and suitable size make effective invasive predator/pest control feasible. The established conservation island sites now support large and stable avian communities, and although many threatened and endangered species in New Zealand have very limited dispersal abilities, more common and mobile native species such as bellbirds (*Anthornis melanura*) and tūī (*Prosthemadera novaeseelandiae*) are species not necessarily constrained by dispersal. Consequently, islands with these high density populations may have the fortuitous effect of aiding the dispersal of more mobile native species back to mainland New Zealand. Furthermore, patches of protected coastal mainland (especially headlands) are often located near these island reserves, particularly in the Auckland and Northland regions, and provide safe habitat for natural dispersal of some native avian species.

Natural dispersal and founding events are poorly studied and quantified (Sandercock 2006). The frequency, extent, and success of such movements of native avian species to mainland New Zealand are generally unknown**.** Given that many native avian species are capable of dispersing short distances (<50 km), the potential for 'self-reintroductions' to areas previously within a species' range is significant. Such 'self-reintroductions' are often difficult to monitor or assess in terms of their source population, and founding size, age and sex structure, due to the small numbers of individuals involved and the isolation of some sites.

Identifying successful natural dispersal events of a previously locally extinct species to a managed area

is an important measure of conservation success and important for public advocacy. However, one aspect of dispersal that has important conservation implications is that, for many bird species, males often disperse further and more frequently than females (Greenwood 1980, 1983; Marzluff & Balda 1989). In addition, although the presence of males is often much easier to detect, the successful establishment of a founder population relies on the presence of both females and males in sufficient numbers for population viability.

In New Zealand, bird diversity and relative abundance in newly established mainland islands and restoration sites are most often assessed using survey techniques such as 5-min counts and/or line transects (Dawson & Bull 1975). Although considerable effort has been committed to improvement of the technical aspects of land bird surveys, there is relatively little information specifically addressing the methodology of bird surveys aimed at determining the presence or absence of a species in an area when birds may be at low densities.

In this paper we experimentally tested a playback method for surveying mainland sites that have potential for self-reintroductions by birds dispersing from protected offshore islands. Bellbirds were used in this experiment – a species that was at one time found throughout New Zealand, but in the 1860s became virtually extinct in the Auckland and Northland regions, where their populations have not recovered (Heather & Robertson 1996). The cause(s) of this local extinction is unknown but likely to be a combination of predator impacts, habitat loss and/or disease. The specific aims of this study were to test whether song playback is an effective method of early detection of new/establishing populations of bellbirds and whether song types can be used to identify the source population. We used playbacks of sex-specific calls to determine the presence of both males and females within a founding population. The recent establishment of a fence to exclude predators and the successful completion of a predator trapping and poisoning programme in late 2004 saw the establishment of a 588-ha mainland island, Tawharanui Regional Park. Male bellbirds have been occasionally sighted along this coastal area (T. G. Lovegrove, Auckland Regional Council, pers. comm.), but it was not known whether these birds had established breeding populations or were transient. In particular, we aimed to confirm the presence of females in a founding population, which can provide conservation practitioners with confidence that the population may establish.

Methods

Study species

The bellbird is, along with the tūī, one of two endemic honeyeater species (family Meliphagidae) in New Zealand and is the more widespread of the two (Heather & Robertson 1996; Ewen et al. 2006). Both New Zealand species feed on flower nectar, fruits, and insects in different proportions according to availability (Gravatt 1970; Angehr 1984; Rasch 1985; Castro et al. 1994).

Bellbirds are relatively abundant in native forests on both main islands of New Zealand, with the exception of mainland Northland where they have been locally extinct for the last 100 years. Bellbird populations have been seriously affected by the removal of native forests and the introduction of invasive predatory species such as cats (*Felix catus*), mustelids (*Mustela furo, M. erminea, M. nivalis vulgaris*) and rodents (*Rattus norvegicus, R. rattus, Mus musculus*) (Heather & Robertson 1996). Bellbirds also inhabit most forested offshore islands (Heather & Robertson 1996) and are important dispersers and pollinators for many native New Zealand plant species (Ladley & Kelly 1995). On predator-free offshore islands, bellbird densities can reach very high numbers; for example Sagar (1985) found densities of c. 23 pairs per hectare on the Poor Knights Islands.

Male and female bellbirds are easily distinguished in the field by plumage and morphological differences, with the females being smaller, paler grey-green, and with a white cheek stripe. Bellbirds are mainly territorial during the breeding season (September–February). Little is known about bellbird breeding biology (Kendrick 1994; Brunton & Li 2006), although we know that bellbirds exhibit social monogamy and both males and females display territorial and/or resource defense throughout the year. Only females incubate, but they are fed while incubating by their mates and both parents feed the chicks (Kendrick 1994). Outside the breeding period, bellbirds continue to defend their breeding territory, but also periodically form small sex-determined foraging flocks of either adult females and juveniles or adult males (Craig & Douglas 1986).

Study site

The study site was located within a forest fragment (Ecology Bush) in the Tawharanui Open Sanctuary (a 588-ha 'mainland island') within the Tawharanui Regional Park (36°22´S, 174°50´E). This coastal park is a headland, 70 km north of Auckland, New Zealand (Fig. 1). It is almost equidistant from Little Barrier (LBI, Hauturu; 23 km) and Tiritiri Mātangi (Tiri; 24 km) islands, both of which have long-term predator control and support large populations of bellbird. Ecology Bush included edges of regenerating bush: kānuka (*Kunzea ericoides*), mānuka (*Leptospermum scoparium*) and cabbage trees (*Cordyline australis*) surrounding remnant coastal forest of taraire (*Beilschmiedia tarairi)*, pūriri (*Vitex lucens*), and nīkau (*Rhopalostylis sapida)*.

Playback experiments

Bellbirds were first sighted at Tawharanui in February 2005 and initial recordings of both male and female bellbird songs were made of Tawharanui birds in March 2005.

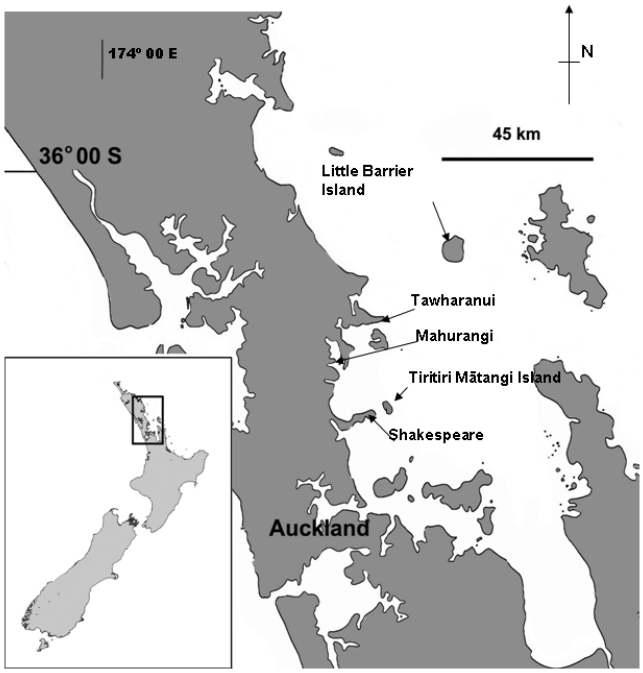

Figure 1. Study areas for bellbird song playback monitoring. The main study location was at the end of Tawharanui Peninsula, within Tawharanui Regional Park, Auckland, New Zealand. The two nearby island sources are Tiritiri Mātangi Island and Little Barrier Island. Shakespeare and Mahurangi regional parks are on nearby headlands.

These initial recordings were collected using LBI song playbacks on a single occasion and by intensive searching and following individual bellbirds. Although bellbirds do counter-sing to novel song types there is no evidence that they song-match these songs (Li 2002) and therefore it is highly unlikely that these birds would have incorporated the pilot LBI playbacks into their repertoires. A Sony Hi MD recorder and a Sennheisser ME80 omni-directional microphone were used for these recordings of bellbirds. Two females and five males were recorded on 5 March 2005. Separate male and female playback tapes were constructed from these recordings using the RAVEN 1.2 program (Charif et al. 2004). Playback experiments were conducted at 11 sites, 100 m apart along a 1-km transect through Ecology Bush. Each male and female playback tape consisted of two different songs repeated four times, giving eight tracks in total. The two male songs were both 2 s long and the two female songs were 2 and 6 s long, respectively. The apparently longer female song was due to the female giving a small introductory note followed by several seconds of silence before the main body of the song.

The four playback sessions (trials), 3–6 weeks apart, were carried out from June to October 2005, before the bellbird breeding season began. Playback trials consisted of the following regime: 2 min of silence; eight tracks played with 10-s intervals between tracks; 2 min of silence. This regime was repeated at each of the 11 sites, with female tracks being played first and then male tracks being played at least 2 h later. All playbacks were conducted between 0830 and 1330 hours. The playbacks were conducted using a Panasonic SL-SX325 portable CD player and a Remote Audio Speak Easy Speaker (powered by a 9V battery). The speaker amplitude was determined by adjusting volume levels of our field speaker so that it matched female song amplitude levels at a distance of 10 m. All playbacks using the speaker were fixed at this standard volume.

The playbacks and the bellbird responses were later examined using RAVEN 1.2 software. Bellbird responses were recorded by three experienced observers during each trial. At the time of our study the bellbird population was not colour banded so we could not be confident that we were seeing different birds unless we had two birds in view at the same time, therefore we measured a binary response. During the first 2-min of silence all bellbirds heard or seen were noted. This constituted the control and the 'before' detections. Detections of bellbirds seen or heard during the playbacks and in the 2 min following the playbacks constituted the 'after' responses. Sex was identified based on plumage and/or song type. As well as the vocal responses of bellbirds, other behaviours such as moving towards the speaker denoted a response.

We were confident of sampling independence between adjacent stations as we had at least 20 min between playbacks and the playbacks from the neighbouring stations were not detected by an observer recording using a

microphone at the next station. Thus, we feel it is unlikely that birds were 'following' the researchers.

Song comparisons

Initial recordings, and recordings of female and male calls made during the playback trials, were compared with the published repertoire of bellbird song types from Tiri (Brunton & Li 2006). The song types were also compared with a small sample of recent recordings from LBI (collected December 2004) using RAVEN spectral analysis software. This software was also used to generate spectrograms of songs from Tawharanui, Tiri, and LBI bellbirds from which visual comparisons could be made by independent observers.

Playback monitoring at other sites

Shakespeare Regional Park is administered by the Auckland Regional Council and has extensive predator control. This park is a headland within 4 km of Tiri. The same protocol was used as at Tawharanui but the calls were sourced from the large population of bellbirds found on Tiri; a distance of c. 4 km. Playbacks were conducted at 10 points c. 100 m apart along a 1-km transect. In addition, this protocol was used at Mahurangi Regional Park, another nearby headland with native forest patches.

Statistical analyses

The Tawharanui playback data were analysed using a log-likelihood model (PROC CATMOD in SAS 9.1; SAS Institute, Cary, NC, USA; Agresti 1990), where the response was presence or absence of bellbirds before and after playbacks (i.e. the number of males or females detected out of 11). Males and females were analysed separately and the four trials were considered replicates. Heard and seen responses by male or female bellbirds were analysed separately. A significance level of $\alpha = 0.05$ was used for all models. The predicted probability (± standard error) values for sightings before and after playbacks were calculated from the log-likelihood model using maximum likelihood (PROC CATMOD in SAS 9.1; SAS Institute, Cary, NC, USA).

For the three other sites monitored, sample sizes were too small to use statistical comparisons and the results are briefly presented in the text. SAS 9.1 (SAS Institute, Cary, NC, USA) was used for all statistical analyses.

Results

Overall, the Tawharanui playbacks of male and female songs resulted in responses (seen or heard) from both male and female bellbirds across the entire transect (Fig. 2). For both male and female song playbacks, male bellbirds responded at least once out of the four playback trials for 10 of 11 transect points. In contrast, females responded at least once to male song playbacks at 5 of 11 transect points and to female playbacks at 9 of 11 transect points.

Male song playbacks ($n = 44$) resulted in significantly more males being seen ($\chi^2_1 = 5.01$, $P = 0.025$; Fig. 3a) and heard ($\chi^2_1 = 4.34$, $P = 0.046$; Fig. 3b). However, male song playbacks did not alter the very low level of females seen ($\chi^2_1 = 1.65$, $P = 0.199$; Fig. 3a) or heard ($\chi^2_1 = 0.33$, $P = 0.57$; Fig. 3b). In contrast, female song playbacks ($n = 44$) resulted in significantly more males and females being seen (males $\chi^2_1 = 10.14$, $P = 0.001$; females $\chi^2_1 = 7.76$, $P = 0.053$; Fig. 4a) and heard (males $\chi^2_1 = 6.28$, $P = 0.012$; females $\chi^2_1 = 4.76$, $P = 0.048$; Fig. 4b).

At Shakespeare Regional Park, a single trial was conducted on 27 June 2005. The same protocol was used as at Tawharanui using randomly chosen songs from male and female bellbirds from Tiri. Because of small sample sizes we combined seen and heard responses. No responses (seen or heard) were observed for male playbacks (0/10), whereas responses to female playbacks occurred for males

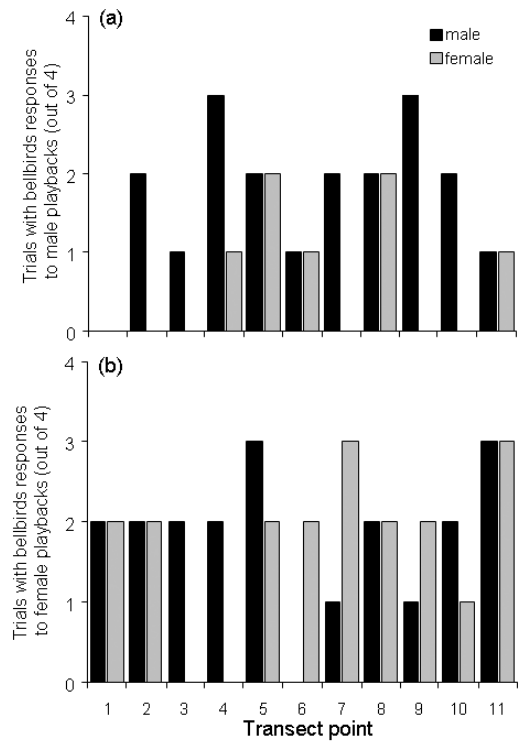

Figure 2. Number of trials where responses (heard/seen) were recorded by male and female bellbirds at each sampling point along a 1.2-km transect line at Tawharanui in June–October 2005. Sampling points were 100 m apart and playbacks were temporally separated. Responses were recorded after separate playbacks of (a) male song and (b) female song.

(heard 1/10) and females (heard 2/10; seen 2/10). One trial was conducted at Mahurangi on 3 July 2005 and produced no bellbird responses to our playbacks.

Songs from four females and six males were recorded at Tawharanui Regional Park between April and August 2005 and were visually compared with the published song types for Tiri bellbirds (Brunton & Li 2006). All songs recorded from Tawharanui varied from the Tiri types. For both male and female, however, song types recorded from LBI in December 2004 (Brunton unpubl. data; Fig. 5) matched extremely well. The female song in particular was indistinguishable from the LBI song (Fig. 5).

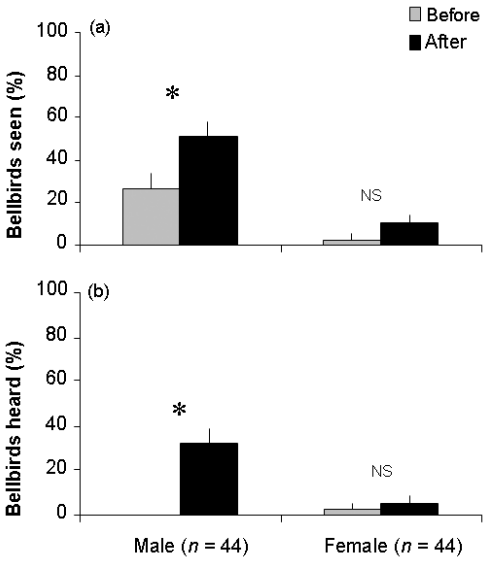

Figure 3. Male song playback experiment: percentage of trials (n = 44) where bellbird males and females were either seen (a) or heard (b) before and after playbacks at Tawharanui in June–October 2005. Categorical data analysis with chi-squared (maximum likelihood) was used to test for before and after differences. Predicted values (± SE) were calculated using Proc CATMOD (SAS v 9.1). * indicates a significant difference ($P < 0.05$).

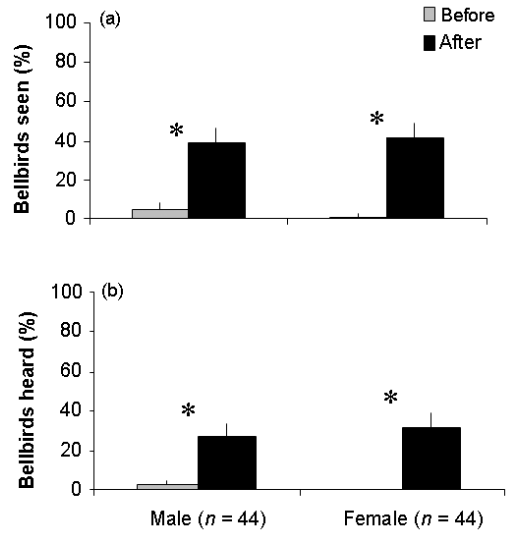

Figure 4. Female song playback experiment: percentage of trials (n = 44) where bellbird males and females were either seen (a) or heard (b) before and after playbacks at Tawharanui in June–October 2005 Categorical data analysis with chi-squared (maximum likelihood) was used to test for before and after differences. Predicted values (± SE) were calculated using Proc CATMOD (SAS v 9.1). * indicates a significant difference ($P < 0.05$).

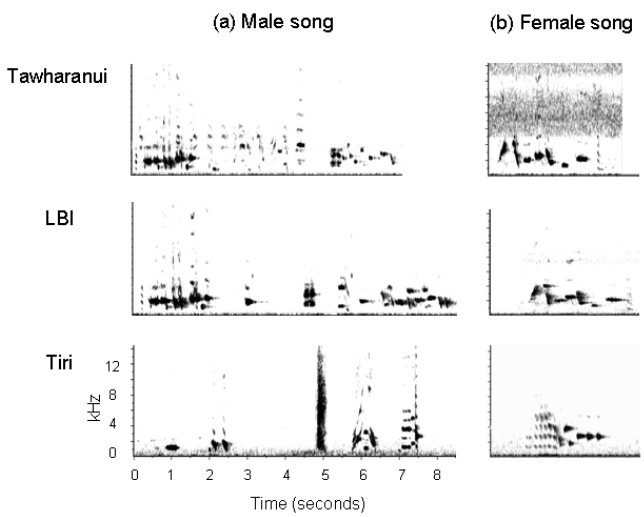

Figure 5. Spectrograms of (a) male and (b) female bellbird songs from Tiritiri Mātangi (Tiri), Tawharanui, and Little Barrier Island (LBI). The song types found at Tawharanui and LBI do not match any known song type recorded from Tiri (Brunton & Li 2006).

Discussion

The apparently rapid dispersal of bellbirds to Tawharanui Regional Park within months of the completion of a predator-proof fence and intensive predator control suggests that dispersal of bellbirds is more common than previously thought. Presumably this species has dispersed to this region in the past but has been unable to establish. If the eradication of kiore (*Rattus exulans*) from LBI in 2004 resulted in increased productivity in bellbird populations there then this could be a potential influence in the current dispersal from LBI to Tawharanui. Numbers of bellbirds on LBI have not been quantified, but they are one of the commonest species on this large island (3083 ha). Dispersal is generally considered to be a process in which animals leave their natal or breeding sites and move in more or less random directions and settle in the first appropriate habitat found (Greenwood 1980, 1983; Waser 1985; Johnson & Gaines 1990). Although dispersal is likely to be significant to species living in fragmented or isolated landscapes such as islands (Hansson et al. 1992; Stacey & Taper 1992; McCullough 1996; Hanski et al. 2004), the role of dispersal within the New Zealand context has been largely neglected.

Our results suggest that the new bellbird population at Tawharanui, with its widespread occurrence of both sexes, and the current predator control regime in the area, is a viable founding population and likely to grow rapidly. Using playbacks significantly increased the chances of detecting bellbirds at the Tawharanui site and enabled us to confirm the presence of females throughout Ecology Bush as opposed to isolated sightings. Previous research on this species has found that females generally do not sing in response to male song but that males do sing in response to female song (Brunton & Li 2006; Brunton et al. 2008). Indeed, the current study found that female song elicited strong responses by both sexes. Generally, the responses to playbacks were very high and it is likely that the time of year we chose to conduct the experiment may have contributed to this level of response.

Establishing the presence of females helps determine whether or not the population is likely to breed. Our method works well for bellbirds and may be applicable to other species where females sing or are attracted to male song. At Shakespeare Park we confirmed the presence of both males and females, albeit in low numbers. Given the increasing predator management at this site, it has good potential as a mainland breeding site for bellbirds. Furthermore, given that bellbirds exist elsewhere on mainland New Zealand in the presence of invasive predators, it is likely that the protected mainland populations described here have the potential to facilitate the further spread of this species. Despite the fragmentation of much of New Zealand's forests, bellbirds are clearly capable of dispersal and should be able to move between fragments.

Geographic variations in song types are a well-studied phenomenon in Northern Hemisphere systems and considerable research has been conducted on male song dialects (Baker 1982; Catchpole & Slater 1995). Species that have distinct geographic song dialects, whether for males, females or both, provide an ideal opportunity to determine source populations when recordings are taken early after dispersal and when song types from likely source populations are known. In our case the song types of one potential source population, Tiri, have been comprehensively described (Brunton & Li 2006) and recent song recordings of birds from the other potential source, LBI, had been collected (Brunton unpubl. data). This made matching the song types from Tawharanui very straightforward. For other species, where songs are unknown or not yet quantified, song matching may be more problematic. Nonetheless, this type of comparison provides a non-invasive method for determining source and can act as a surrogate for genetic relationships in simple situations such as the one outlined here.

Recommendations and management implications

For most temperate Northern Hemisphere species, song has been seen as an exclusively male activity, functioning in territoriality and mate attraction (Catchpole & Slater 1995). However, for many Southern Hemisphere and tropical species, female singing can be a normal feature of female behaviour and our method could be applied in such cases.

In most populations, females and males establish territories and choose mates during the months before the breeding season starts. Intense interactions between the sexes at this time should result in maximum responses and high detection rates to playbacks. In addition, at this time of year adult birds may be less likely to be transients. Later, during incubation, females do not respond strongly to playbacks (Brunton et al. 2008). Therefore, we advocate that future playback monitoring for bellbirds be conducted using female song during the pre-breeding season so as to maximise the possibility of detection. We also recommend annual monitoring following our protocol at potential sites where some pest/predator control exists, where suitable forest is available, and where a potential source population is nearby. If bellbirds are detected, then conservation managers have the option of increasing local predator control if the resources to do so are available.

Limitations

There are some limitations of this method as a general approach. To design an appropriate playback monitoring system (including song type used for playback and distance between playback locations) for a target species, knowledge of the social behaviour, including territory size and any geographic dialects, is needed (Burt & Beecher 2008). Playback monitoring will also be more appropriate

where males and/or females are cryptic or live in dense vegetation and where a species is a year-round resident in an area.

Source of the playback material may be an important consideration if responses vary with geographic location, i.e. dialects. We did not play back calls from other areas and our method would be more flexible if males and females respond to bellbird playbacks regardless of the source of the recordings. Future comparisons of bellbird responses to different dialects are planned.

Even with the effectiveness of this playback method, its use by different researchers may result in less standardised methodology than those for 5-min bird counts. Playback equipment and the quality of recordings potentially add to the variance in the responses by focal birds. In our study we used a 2-min 'silent' control period and for future surveys we would we recommend that playback counts should be preceded by 5-min counts to allow direct comparisons. Nonetheless, we consider the use of playbacks of sex-specific calls for bellbird surveys conducted at potential dispersal sites to be a useful means of early detection of founding populations. This early detection can facilitate both public advocacy of conservation successes and assessment of current management practices, and/or decisions concerning rapid deployment of additional conservation measures to maximise the probability of a population establishing.

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