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Increased abundance of the bellbird (*Anthornis melanura*) in Christchurch, New Zealand

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Abstract Numbers of bellbird (*Anthornis melanura*), an endemic honeyeater, counted along transects in forest remnants on the Port Hills near the city of Christchurch, New Zealand, increased since the initiation of intensive mammalian pest control in 2006. Bellbird counts also increased along transects in bush reserves and along a 6.5 km cycle route in the city itself, probably as a result of spill-over from source populations on the Port Hills, because few bellbirds breed in the city. In contrast, counts of bellbirds in domestic gardens in the city did not increase, perhaps because of the continued presence of introduced mammalian predators and/or lack of suitable habitat. We suggest the increased abundance of bellbirds in forest remnants on the Port Hills was likely the result of mammalian pest control but the lack of 'no-treatment' areas means we cannot rule out other causes of the increase such as changing habitat and food availability.

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INTRODUCTION

The bellbird (*Anthornis melanura*) is an endemic honeyeater (family Meliphagidae) that occurs throughout New Zealand, but is scarce in the North Island north of Waikato and in the South Island on the Canterbury plains and in Central Otago (Heather & Robertson 1996; Higgins *et al*. 2001; Robertson *et al*. 2007; Spurr 2012). It breeds mainly in native forest and scrub, but also breeds locally in some towns and cities, such as Dunedin and Nelson, that have extensive areas of native vegetation within the city boundaries.

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The species is rare in metropolitan Christchurch (altitude *ca.* 7 m a.s.l.), having declined after Europeans arrived and destroyed the native forest on the surrounding Canterbury plains (O'Donnell 1995). However, it has survived in relatively high numbers in forest remnants on the Port Hills (altitude 270–470 m a.s.l.), approximately 10 km from the centre of the city (Kelly 1972; Rawlence & Tunnicliffe 1978; Burrows 1994; O'Donnell 1995; Freeman 1999; Mortimer 2011). Bellbirds breed in these forest remnants in spring and summer (*ca.* August–January), and in autumn and winter (*ca.* February–July) some (most probably juveniles) disperse into small bush remnants, such as Riccarton Bush (8 ha), and domestic gardens in the

city (O'Donnell 1995; Higgins *et al*. 2001; *pers. obs*.). The following spring, they appear to return to the Port Hills to breed.

Surveys of public opinion have shown that people want to see more native birds, including bellbirds, in towns and cities (Clout & Craig 1998). Furthermore, the Resource Management Act 1991 requires local territorial authorities to have a role in maintaining and enhancing indigenous biodiversity in their regions. As a consequence, since the early 1990s, the Christchurch City Council (CCC) has planted native vegetation on public land it administers and also worked with private landowners to identify and promote protection of significant natural areas in Christchurch. Since 2006, together with Environment Canterbury (ECAN), it has also undertaken intensive large-scale control of mammalian pests, such as brushtail possum (*Trichosurus vulpecula*), ship rat (*Rattus rattus*), ferret (*Mustela furo*), stoat (*M. erminea*), weasel (*M. nivalis*), European hedgehog (*Erinaceus europaeus*), fallow deer (*Dama dama*), feral goat (*Capra hircus*), feral pig (*Sus scrofa*), feral cattle (*Bos taurus*), and feral sheep (*Ovis aries*) in some native forest reserves on the Port Hills. As a result, the densities of most mammalian pests in these reserves have been reduced by at least 85% in the last 5 years (P. Crutchley, CCC, *pers. comm*.).

The objective of this paper is to report the results of 4 separate studies by the authors, monitoring bellbird abundance on the Port Hills and in Christchurch City, coincident with the initiation of intensive control of mammalian pests in the Port Hills reserves. There were no equivalent reserves where pest-mammal control did not take place, so it was not possible to monitor bellbirds in 'no-treatment' areas. However, counts were made in some reserves before and after the initiation of pest-mammal control.

METHODS

Abundance in Port Hills reserves

Bellbird abundance was measured in a study initiated by one of us (EBS) on 14 randomly-located strip transects, 200 m long × 50 m wide, located in 4 Port Hills reserves: 7 transects in Kennedy's Bush (43° 37′ 48″ S, 172° 37′ 12″ E), 5 in Omahu Bush (43° 39′ 36″ S, 172° 37′ 12″ E), 1 in Ahuriri Reserve (43° 40′ 12″ S, 172° 37′ 12″ E), and 1 in Cass Peak Reserve (43° 38′ 24″ S, 172° 37′ 12″ E). Counts in Omahu Bush, Ahuriri Reserve, and Cass Peak Reserve were pooled as 'other Port Hills reserves' for analysis, because of small sample sizes. The transect lines were surveyed 1–4 days per month by S. Rod between February 2004 and January 2005, hereafter called 2004 (before intensive control of mammalian pests started in Kennedy's Bush in 2006 and Omahu Bush in 2007, but after lower intensity control started in Ahuriri and Cass Peak reserves in 2002). The transect lines were surveyed again by K. Tranter between February 2007 and January 2008, hereafter called 2007 (~1 year after initiation of intensive pest-mammal control), and by EBS between January and December 2010 (4 years after initiation of intensive pest-mammal control). The counts of the 3 observers were similar when surveys were conducted together in practice counts. Each observer walked at a slow pace (~0.5 km/h) and recorded the number of bellbirds seen and/or heard within 25 m each side of the transect line. Plastic tape at 10 m intervals assisted estimation of distance. The counts were made on fine, still days where possible, between 1000 h and 1500 h, alternating start times across all reserves.

Mean monthly counts (weighted by the number of days per month) in Kennedy's Bush (7 transects) and other Port Hills reserves (7 transects) in 2004, 2007, and 2010 were compared using a linear model in the R statistical computing environment, version 2.15.2 (R Core Team 2012). Count variance increased with increasing mean, indicating heteroscedasticity, so the data were transformed with $\log_{10}$ for analysis, and then back-transformed for graphing. When significance was found between the 3 years, Tukey multiple-comparisons tests were used to compare counts between 2004 and 2007, and 2007 and 2010.

Abundance in Port Hills compared with Christchurch City reserves

In a separate study (by ACC), bellbird abundance was measured on 10 strip transects (walking tracks ranging in length from 330 m to 1430 m) in Port Hills reserves (2 each in Kennedy's Bush and Omahu Bush and 1 each in Ahuriri Summit, Cass Peak, Sugarloaf, Cavendish Bluffs, Victoria Park, and Jollies Bush), and 10 strip transects (walking tracks ranging in length from 214 m to 810 m) in Christchurch City reserves (1 each in Worseley's Reserve, Ernle Clark Reserve, Upper Heathcote, Botanic Gardens, Riccarton Bush, Horseshoe Lake Reserve, Travis Wetland, Bottle Lake Forest, Styx Mill Basin, and The Groynes)(see map locations in Appendix 1). All transects were walked by ACC monthly for a year in 2 time periods, 1 starting in 2003 (before initiation of intensive pest-mammal control in Kennedy's Bush in 2006 and Omahu Bush in 2007, but after lower intensity control started in Ahuriri and Cass Peak reserves in 2002) and 1 in 2007 (1 year after initiation of intensive pest-mammal control). Intensive pest-mammal control did not occur in the other Port Hills reserves. In Christchurch City, Riccarton Bush was enclosed by a pest mammal-proof fence in 2004 (Burns *et al*. 2012), and pest-mammal control occurred at Travis Wetland but not in the other reserves. The Kennedy's Bush transects were also walked by ACC monthly for a year starting in 2010

(4 years after initiation of intensive pest-mammal control). On all transects, the observer walked at a slow pace (~0.5 km/h) and recorded the number of bellbirds seen and/or heard within 10 m each side of the transect lines.

Mean monthly counts per transect in Kennedy's Bush (2 transects), other Port Hills reserves (8 transects), and Christchurch City reserves (10 transects) in 2003 and 2007 (n = 12 months), and in Kennedy's Bush in 2007 and 2010 (n = 9, because counts were not made in 3 months in 2010) were compared using paired t-tests.

Abundance along cycle route in Christchurch City

In the third study, bellbird abundance was measured (by PMS) along a 6.5 km cycle route (essentially a transect), starting from 38A Yardley St in Avonhead, then along Woodbury St, Staveley St, Avonhead Rd, Parkstone Ave, Athol Tce, Homestead Ln, University Dr, Clyde Rd, Hinau St, Miro St, Totara St, Ngahere St, Riccarton Bush, Kahu Rd, Kilmarnock St, Harakeke St, and Mandeville St to 10 Kyle St in Riccarton. This route was cycled by PMS twice daily (morning leaving about 0800 and evening leaving about 1700), Monday to Friday in most months from 1979 to 2012. The journey took about 20 mins each way. Bellbirds heard calling along the route (total 13 km each day) were noted, and formal counts were made from 2005 onwards. Days when the route was not cycled were recorded so that effort could be factored into the analysis.

Mean annual counts were compared using the non-linear least squares procedure in the R statistical computing environment, version 2.15.2 (R Core Team 2012). Two models were fitted to the data; an exponential model of the form $y = a*\exp(b*x)$, where y is the mean count of bellbirds, a is the intercept, b is the slope, and x is years, and a 3-parameter logistic model of the form $y = a/(1+b*\exp(-c*\text{year}.2))$, where y is the mean count of bellbirds, a is the intercept, b is the slope, and c is the shape parameter of the curve. The logistic model had the smaller AIC and thus fitted the data better. A function modelling auto-correlation between successive observations provided no extra explanatory power.

Abundance in domestic gardens in Christchurch City

In the fourth study (initiated by EBS), bellbird abundance was measured in domestic gardens in metropolitan Christchurch as part of the annual New Zealand Garden Bird Survey, which started in 2007 (Spurr 2012). Each year, an invitation was made through the news media for volunteers to count the largest number of individuals of each species seen and/or heard at the same time in their home gardens in a 1-hour period between specified dates in late June and/or early July (approximately midwinter). The number of gardens surveyed varied from year to year (n = 612 in 2007, 273 in 2008, 122 in 2009, 738 in 2010, 247 in 2011, and 434 in 2012). Only 6 gardens surveyed in 2007 were surveyed in all years, but larger numbers surveyed in 2007 were also surveyed in 2008 (n = 88 pairs), 2009 (n = 33 pairs), 2010 (n = 121 pairs), 2011 (n = 55 pairs), and 2012 (n = 78 pairs).

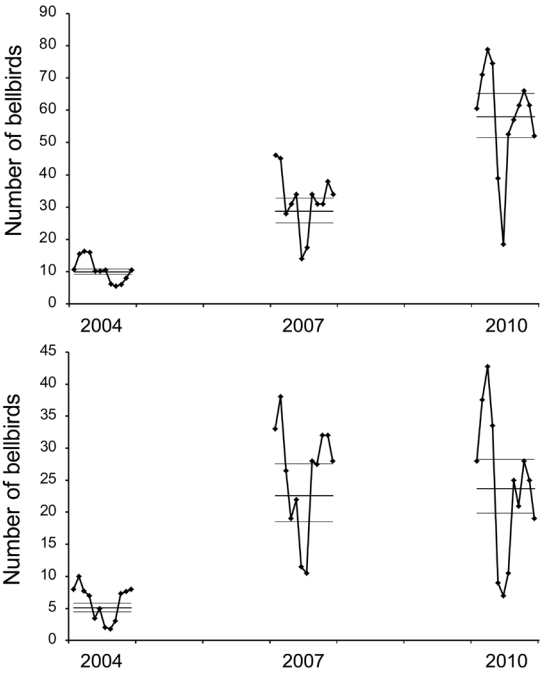

Fig. 1. Number of bellbirds per month (January–December) in Kennedy's Bush (above) and other Port Hills reserves (below) (horizontal lines represent mean ± SE). Intensive pest-mammal control started in Kennedy's Bush in 2006 and in other Port Hills reserves at various times between 2002 and 2007 (see text for details).

Mean annual counts were compared using the linear models procedure in the R statistical computing environment, version 2.15.2 (R Core Team 2012). The number of gardens sampled each year was used as a weighting variable. Counts in gardens in 2008, 2009, 2010, 2011, and 2012 paired with counts in the same gardens in 2007 were compared using paired t-tests. The percentage of gardens with bellbirds present each year was compared using a χ^2 goodness-of-fit test on raw data (number of gardens with and without bellbirds each year).

RESULTS

Abundance in Port Hills reserves

Bellbird counts in Kennedy's Bush increased significantly between 2004 and 2007 (t_{33} = 6.65, P < 0.001) and between 2007 and 2010 (t_{33} = 3.98,

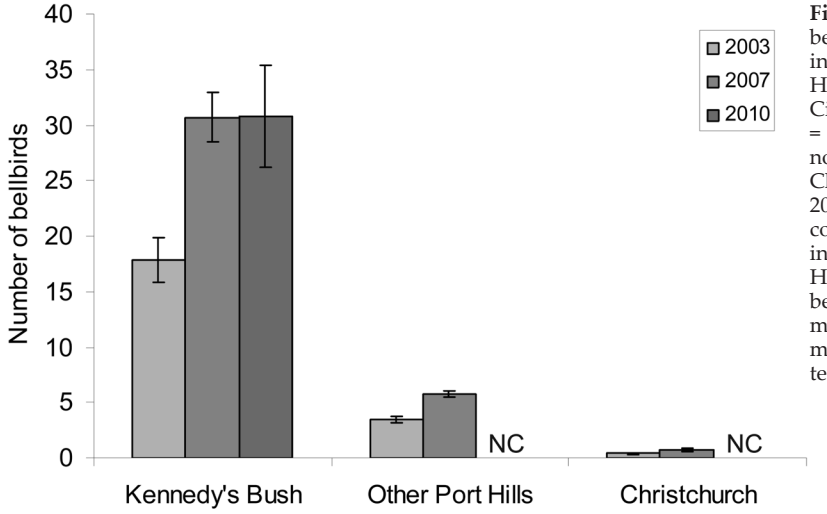

Fig. 2. Annual numbers of bellbirds per transect per month in Kennedy's Bush, other Port Hills reserves, and Christchurch City reserves (mean ± SE). (NC = not counted; *i.e.,* counts were not made in other Port Hills or Christchurch City reserves in 2010). Intensive pest-mammal control started in Kennedy's Bush in 2006 and in some other Port Hills reserves at various times between 2002 and 2007. Pest-mammal control did not occur in most Christchurch reserves (see text).

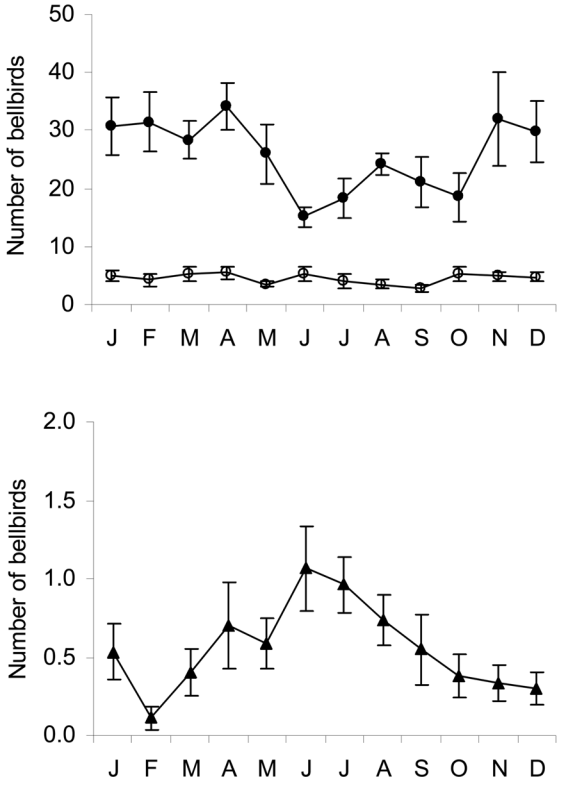

Fig. 3. Monthly numbers of bellbirds per transect in Kennedy's Bush (●) and other Port Hills reserves (○) (above) and Christchurch City reserves (▲) (below), 2003–2010 (mean ± SE).

$P = 0.001$; Fig. 1). Counts in other Port Hills reserves also increased between 2004 and 2007 ($t_{33} = 6.24$, $P < 0.001$) but not between 2007 and 2010 ($t_{33} = 0.18$, $P = 0.94$). Counts were highest in autumn (February, March, April) and lowest in winter (May, June, July).

Abundance in Port Hills compared with Christchurch City reserves

Bellbird counts increased significantly in Kennedy's Bush, other Port Hills reserves, and Christchurch City reserves between 2003 and 2007 (Kennedy's Bush: $t_{11} = -5.13$, $P < 0.001$, other Port Hills reserves: $t_{11} = -8.05$, $P < 0.001$, Christchurch City reserves: $t_{11} = -5.02$, $P < 0.001$; Fig. 2). Most bellbirds on the Port Hills were in Kennedy's Bush, and most in Christchurch City were in Riccarton Bush. Bellbird counts did not increase significantly in Kennedy's Bush between 2007 and 2010 ($t_8 = -0.03$, $P = 0.98$). Counts varied seasonally, with numbers lowest in Kennedy's Bush and highest in Christchurch City reserves in Jun (mid-winter; Fig. 3).

Abundance along cycle route in Christchurch City

Bellbirds were heard very rarely along the 6.5 km return cycle route in Christchurch City between 1979 and 2005. Subsequently, the number of bellbirds heard increased significantly ($t_5 = 4.65$, $P = 0.006$) (Fig. 4). Most (77%) were heard in Riccarton Bush. However, the number of locations where they were heard increased over the years (including University of Canterbury campus, Ilam Homestead gardens, and a small patch of trees at the corner of Riccarton Road and Mandeville Street). There appeared to be no seasonal pattern in the counts (Fig. 5).

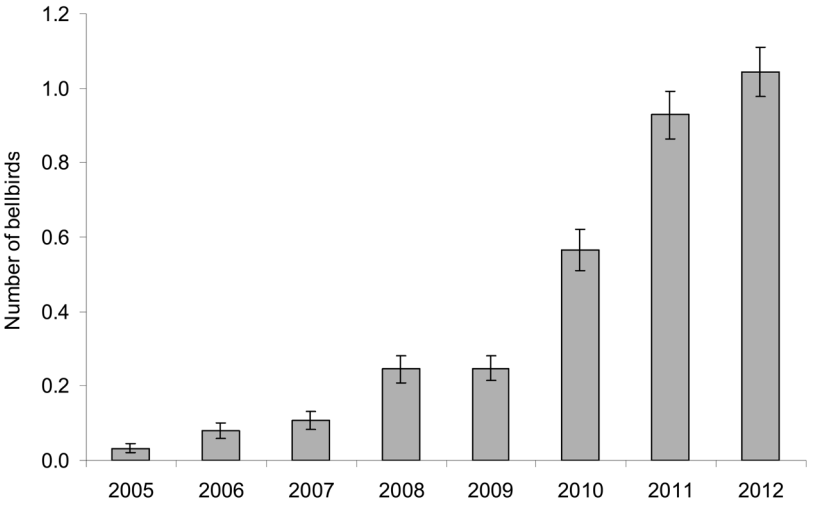

Fig. 4. Annual numbers of bellbirds per day (adjusted for effort) counted along a 6.5 km return cycle route in Christchurch City (mean ± SE).

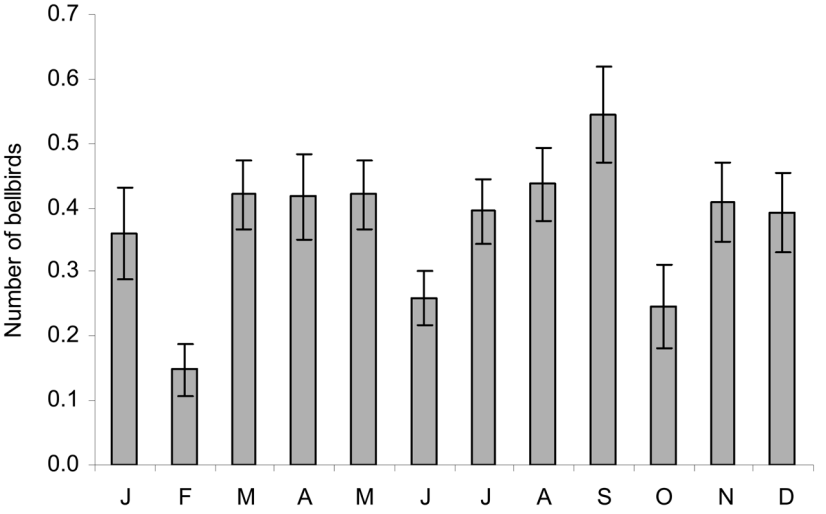

Fig. 5. Monthly numbers of bellbirds per day (adjusted for effort) counted along a 6.5 km return cycle route in Christchurch City, 2005–2012 (mean ± SE).

Abundance in domestic gardens in Christchurch City

The mean number of bellbirds counted in domestic gardens in Christchurch City did not change significantly over the 6 years from 2007 to 2012 (t_4 = -0.06, P = 0.95; Fig. 6). Counts in 2008 through 2012 paired with counts in 2007 were also not significantly different (2008: t_{87} = 0, P = 1; 2009: t_{32} = 0, P = 1; 2010: t_{121} = 0.13, P = 0.89; 2011: t_{54} = 1.77, P = 0.083; 2012: t_{77} = 0.59, P = 0.56). Furthermore, the number of gardens in which bellbirds were recorded did not change significantly over the years (χ^2_5 = 5.42, P = 0.37; Fig. 6).

DISCUSSION

Our surveys indicate that bellbird numbers have increased in Kennedy's Bush, other forest reserves on the Port Hills, and bush reserves in Christchurch City since at least 2003. The disparity in results between the 2 studies in Kennedy's Bush (1 showing an increase in bellbird numbers from 2007 to 2010 and the other showing no increase) is difficult to explain. Counts in the 2 studies were made on different transects and by different observers, and the second study also had some missing counts in 2010. However, counts in both studies in 2010 were higher than those in 2003 and 2004.

The increased number of bellbirds counted in Kennedy's Bush and other Port Hills reserves is presumably the result of increased breeding success there rather than movement from elsewhere because the only potential source populations are other similar reserves on Banks Peninsula without pest-mammal control. On the other hand, the increased abundance of bellbirds in Christchurch City reserves

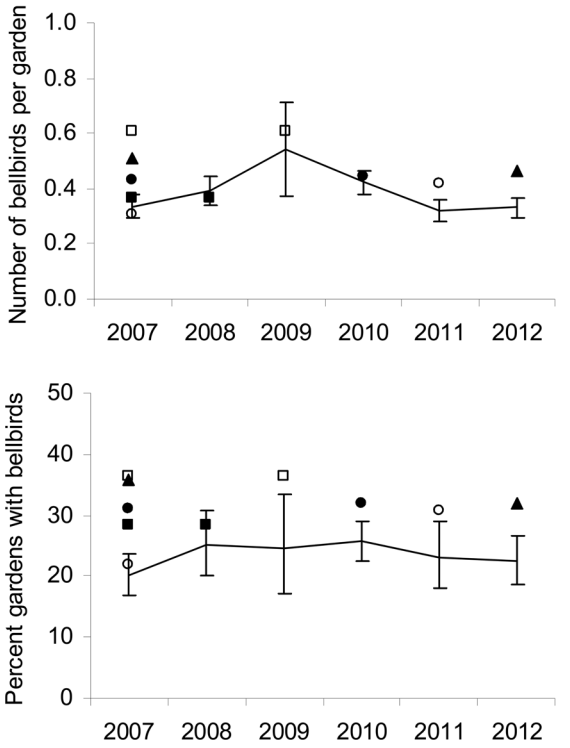

Fig. 6. Number of bellbirds per garden (above) and percentage of gardens with bellbirds (below) in Christchurch City (— all gardens 2007–2012; ■ same gardens 2007 and 2008; □ same gardens 2007 and 2009; ● same gardens 2007 and 2010; ○ same gardens 2007 and 2011; ▲ same gardens 2007 and 2012) (mean ± SE).

is presumably the result of movement from elsewhere because few bellbirds breed in the city (see below).

The increased abundance of bellbirds in the city may be a result of spill-over from populations on the Port Hills. It is known that bellbirds breed in forest reserves there in summer and move to the city in winter (O'Donnell 1995; Spurr *et al*. 2010). The observed seasonal decline in number of bellbirds counted in Port Hills reserves and the observed increase in Christchurch City reserves in winter support the suggestion of such movements. The lack of an observed increase in number of bellbirds counted along the cycle route in the city in winter may be a consequence of the time of day the counts were made, relative to the time of sunrise and sunset. The counts in June (midwinter) were made about the time of sunrise and sunset (0800 and 1700), but in December (midsummer) were about 2 hours after sunrise and 4 hours before sunset. Thus, the midwinter counts may have missed the diurnal peaks of singing, and underestimated the number of bellbirds along the cycle route.

The erection of a pest mammal-proof fence around Riccarton Bush in the centre of the city in 2004 (Burns *et al*. 2012) has not (yet) resulted in bellbirds breeding in the reserve. The only locations in the city that bellbirds have been reported breeding are the Botanic Gardens in the centre and Bottle Lake Forest on the north-eastern boundary, and possibly also in Horseshoe Lake Reserve and along the Lower Styx River, both in the north-east of the city (ACC, *pers. obs*.). However, reports of breeding in the city are few.

The purported spill-over of bellbirds from the Port Hills into city bush reserves has not (yet) resulted in a measurable increase in the abundance of bellbirds in domestic gardens. This may be because of a lack of suitable vegetation and other habitat resources and/or the presence of predators, especially rats and domestic cats (*Felis catus*). The relative impact of rats and cats is unknown, but a study in Dunedin showed cat predation alone accounted for the loss of at least 15%, and perhaps as much as 46%, of the total urban bellbird population (van Heezik *et al*. 2010). The authors of the study suggested that the continued presence of bellbirds in Dunedin may be reliant on 'source' populations on the city fringe that may experience less predation and/or better resources. This may be the same in Christchurch, with the city acting as a 'sink' for bellbirds from the neighbouring Port Hills forest reserves. This suggestion needs testing.

The increased abundance of bellbirds in the Port Hills and Christchurch City bush reserves coincided with the initiation of intensive control of mammalian pests (especially predators such as stoats and ship rats, and competitors such as possums). We cannot say that the increase was a result of the mammalian pest control because no 'non-treatment' areas were monitored. However, there is ample evidence from other studies in New Zealand that reduction in number or absence of mammalian predators and competitors results in increased breeding success, survival, and abundance of bellbirds (and other bird species) (Anderson & Craig 2003; Kelly *et al.* 2005; Sagar & Scofield 2006; Elliott *et al.* 2010; Innes *et al.* 2010). Furthermore, bellbird numbers have increased in Wellington City bush reserves following intensive possum, rat, and stoat control there (Miskelly *et al*. 2005). Consequently, it is highly likely that the increase in abundance of bellbirds that we observed was a direct result of a reduction in the abundance of mammalian predators and competitors in bush reserves on the Port Hills. Nevertheless, further studies are needed to determine whether changes in the composition of the vegetation or food availability, in both the Port Hills and within the Christchurch city limits, may have also affected bellbird populations.

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Appendix 1. Locations of bird count transects in study comparing Port Hills with Christchurch City reserves.

Transect	Latitude	Longitude
Port Hills		
Ahuriri Summit Reserve	43° 39′ 59″ S	172° 37′ 24″ E
Omahu Bush B	43° 39′ 48″ S	172° 36′ 31″ E
Omahu Bush A	43° 39′ 41″ S	172° 37′ 16″ E
Cass Peak Reserve	43° 38′ 14″ S	172° 37′ 25″ E
Kennedy's Bush A	43° 37′ 55″ S	172° 37′ 21″ E
Kennedy's Bush C	43° 37′ 46″ S	172° 37′ 17″ E
Sugarloaf	43° 36′ 15″ S	172° 39′ 02″ E
Cavendish Bluffs	43°35′ 25″ S	172° 43′ 03″ E
Victoria Park	43° 35′ 23″ S	172° 38′ 31″ E
Jollies Bush	43° 35′ 14″ S	172° 44′ 20″ E
Christchurch City		
Worseley's Reserve	43° 34′ 31″ S	172° 37′ 00″ E
Ernle Clark Reserve	43° 33′ 47″ S	172° 38′ 02″ E
Upper Heathcote	43° 33′ 23″ S	172° 34′ 46″ E
Botanic Gardens	43° 31′ 50″ S	172° 37′ 09″ E
Riccarton Bush	43° 31′ 38″ S	172° 35′ 48″ E
Horseshoe Lake Reserve	43° 30′ 08″ S	172° 40′ 21″ E
Travis Wetland	43° 29′ 14″ S	172° 41′ 17″ E
Bottle Lake Forest	43° 28′ 26″ S	172° 42′ 49″ E
Styx Mill Basin	43° 27′ 55″ S	172° 36′ 08″ E
The Groynes	43° 27′ 00″ S	172° 36′ 30″ E