Density estimates and encounter rates for forest birds prior to intensive predator control at Martins Bay, Hollyford Valley, Fiordland

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Summary

Forest birds were monitored at Martins Bay, Hollyford Valley, Fiordland, to determine their response to an intensive long term predator control programme managed by the Hollyford Conservation Trust. The programme started in 2015 and uses a network of traps and bait stations to protect and restore 2,500 ha of land surrounding Martins Bay. Prior to the control programme, the Department of Conservation used an aerial application of 1080 across 19,617 ha in the lower Hollyford Valley, resulting in a reduction of possums (*Trichosurus vulpecula*), rats (*Rattus rattus*), stoats (*Mustela erminea*) and mice (*Mus musculus*).

To determine the response of forest birds to the predator control programme and the effectiveness of the chosen management tools, forest bird monitoring was conducted at Martins Bay using two methods: (1) line-transect based distance sampling to estimate population densities and long term density trends for bellbird (*Anthornis melanura*), South Island kaka (*Nestor meridionalis meridionalis*), kereru (*Hemiphaga novaeseelandiae*), rifleman (*Acanthisitta chloris*), South Island tomtit (*Petroica macrocephala*) and tui (*Prosthemadera novaeseelandiae*) , and (2) recording encounter rates for all forest bird species seen or heard from transects to reveal gross changes in population size and composition.

Baseline data shows that bellbird and tomtit were common, kereru numbers were moderate, rifleman and tui were less abundant and kaka were rare. Some species had benefit from the aerial predator control operation; bellbird and tomtit densities increased significantly brown creeper (*Mohoua novaeseelandiae*), kereru, yellow-crowned parakeet (*Cyanoramphus auriceps*) and rifleman detections increased substantially and brown-creeper, kereru, yellow-crowned parakeet and rifleman were more widely distributed throughout the study site following the 1080 operation. Annual bird monitoring is needed to determine whether the ground control methods used by the Hollyford Conservation Trust will be sufficient to suppress and maintain predator numbers to low enough levels to achieve positive population trends for the key bird species.

Introduction

The lower part of the Hollyford Valley/Whakatipu Kā Tuka, consists of a series of unique ecosystems, ranging from dune systems and wetlands to podocarp forests. The flora and fauna in the valley is threatened by introduced species such as possums (*Trichosurus vulpecula*), rats (*Rattus rattus*) and stoats (*Mustela erminea*) through predation and competition. To protect this area, a predator control operation was carried out in November 2014 by the Department of Conservation, using an aerial application of 1080 across 19,617 ha. Following the aerial operation, The Hollyford Conservation Trust has started an intensive long term predator control programme to restore and protect 2,500 ha of land surrounding Martins Bay though a network of traps and bait stations.

To determine the response of forest birds to the predator control programme at Martins Bay, and the effectiveness of the chosen management tools, a forest bird monitoring programme was initiated. To report on the response of a wide range of forest bird species, bird counts were conducted using two methods: (1) line-transect based distance sampling (Buckland et al. 2001; Buckland 2006) to estimate population densities and monitor density trends of six key forest bird species; bellbird (*Anthornis melanura*), South Island kaka (*Nestor meridionalis meridionalis*), kereru (*Hemiphaga novaeseelandiae*), South Island rifleman (*Acanthisitta chloris chloris*), South Island tomtit (*Petroica macrocephala macrocephala*) and tui (*Prosthemadera novaeseelandiae*), and (2) encounter rates (mean number of detections per km) to monitor gross changes in population size and composition for all forest bird species.

The distance sampling methodology (Buckland et al. 2001) was chosen as the primary monitoring tool in this study as it has major advantages over other simple count methods such as five-minute bird counts (Dawson & Bull 1975). Distance sampling can reliably estimate densities for selected forest bird species during a multi-species survey (Broekema and Overdyck 2012). Robust density estimates enables us to comment on short term changes in bird densities as well as on long term population trends for each selected species. This allows us to report on species response to management and the effectiveness of predator control techniques. Encounter rate data should be used to report on gross changes in population size and composition only, preferably over a longer period (5 to 10 years). The advantage of this method is that it allows us to comment on population changes and species composition for all forest birds.

Initial bird monitoring was conducted in the lower Hollyford in September 2014, prior to the application of the aerial 1080. The study site was partly within the area managed by the Hollyford Conservation Trust, partly on adjacent conservation land. Counts were repeated in September 2015, and additional monitoring was conducted in the area managed by the Trust. First, we report on changes in bird density trends and encounter rates within part of the area managed by the Trust, following the 1080 operation. Second, we provide baseline data for long term bird monitoring within the entire area managed by the Trust.

Methods

Study species

Bellbird, kaka, kereru, rifleman, tomtit and tui were monitored more intensively because these species represent several important guilds for the healthy functioning of forest ecosystems and are vulnerable to predation by possums, rats and stoats. Some of the selected species such as rifleman and tomtit have high fecundity and are therefore likely to show a rapid response to predator control. Others including kaka and kereru are expected to respond once pest numbers have been suppressed for significant periods of time and once habitat improves. Other forest bird species were also monitored, although less intensively, to reveal gross changes in population size and composition resulting from management.

Study site

The study site (2,500 ha) encompasses mostly flat land on the true right and true left of the Hollyford River, between the Hokuri Creek and the sea. The vegetation is predominantly lowland podocarp hardwood forest with patches of mixed native shrub and scattered silver beech (*Lophozonia menziesii*).

On the true right the majority of the vegetation is taken up by a mixture of rimu (*Dacrydium cupressinum*), Southern rata (*Metrosideros umbellate*), mahoe (*Melicytus ramiflorus*), kamahi (*Weinmannia racemose*), rough tree fern (*Dicksonia squarrosa*) and supplejack (*Ripogonum scandens*). Kiekie (*Freycinetia banksia*) becomes more common towards the Northern end of the study site, while tanekaha (*Phyllocladus trichomanoides*) is dominant between Hokuri Creek and Jamestown, mixed with emergent rimu trees and dense patches of *Neomyrtus pedunculata*.

On the true left, the Southern end consists of old podocarps such as rimu and Southern rata, mixed with mahoe, rough tree fern, with an open, mainly supplejack, understory. The area around the lagoons and wetlands is mostly taken up by kahikatea (*Dacrycarpus dacrydioides*) and rimu with a dense kiekie understory mixed with grasses. The Western strip along the coast consist of open and dry forest, with kamahi and supplejack. The lakeshore on both sides is lined with South Island kowhai (*Sophora microphylla*).

The study site lies within the larger lower Hollyford predator control area (19,617 ha) which encompasses the lower half of the Hollyford Valley from the Pyke Junction to the Coast, between the Kaipo River and Big Bay. Aerially distributed 1080 was applied to the management area on November 5, 2014. Some private properties surrounding Martins Bay and Lake McKerrow/Whakatipu Waitai area were excluded from aerial control; 1080 baits were hand laid on these properties, which was completed by December 4, 2014.

Post-operational monitoring showed a reduction in possums, rats, stoats and mice (*Mus musculus*) compared to pre-operational levels. The Residual Trap Catch Index (RTCI) for possums reduced from 28.7% to 1.6%, rodent tracking indexes reduced from 15% to 0%, stoat tracking indexes reduced from 10% to 0% and mouse tracking indexes reduced from 6% to 0.5% (Department of Conservation 2015).

Following the aerial operation, the entire study site will be intensively managed by the Hollyford Conservation Trust, using a network of Philproof rodent bait stations on a 100m x

100m grid and double set DOC 200 stoat traps on a 200m x 400m grid. Management was initiated in September 2015, across 900 ha comprising the northern half of the area on the true right. Management across the entire site will start in March 2016.

Transect establishment

Monitoring was undertaken using line-transects. Thirty-six transects; eighteen on the true right and eighteen on the true left, 450 m in length and at least 200 m apart were sampled (Fig. 1). Transects on the true right were established in 2014; ten transects were located along existing tracking tunnel lines between Jamestown and Jerusalem Creek. To provide a better representation of the study site, five additional bird count transects were established between Jamestown and Hokuri Creek, and three additional transects were established between Jerusalem Creek and the Hollyford river mouth at Martins Bay. Transects on the true left were established in 2015, using a systematic sampling design with a random start point. Transects were marked with pink flagging tape and start and end points of transects were permanently marked with a white plastic triangle.

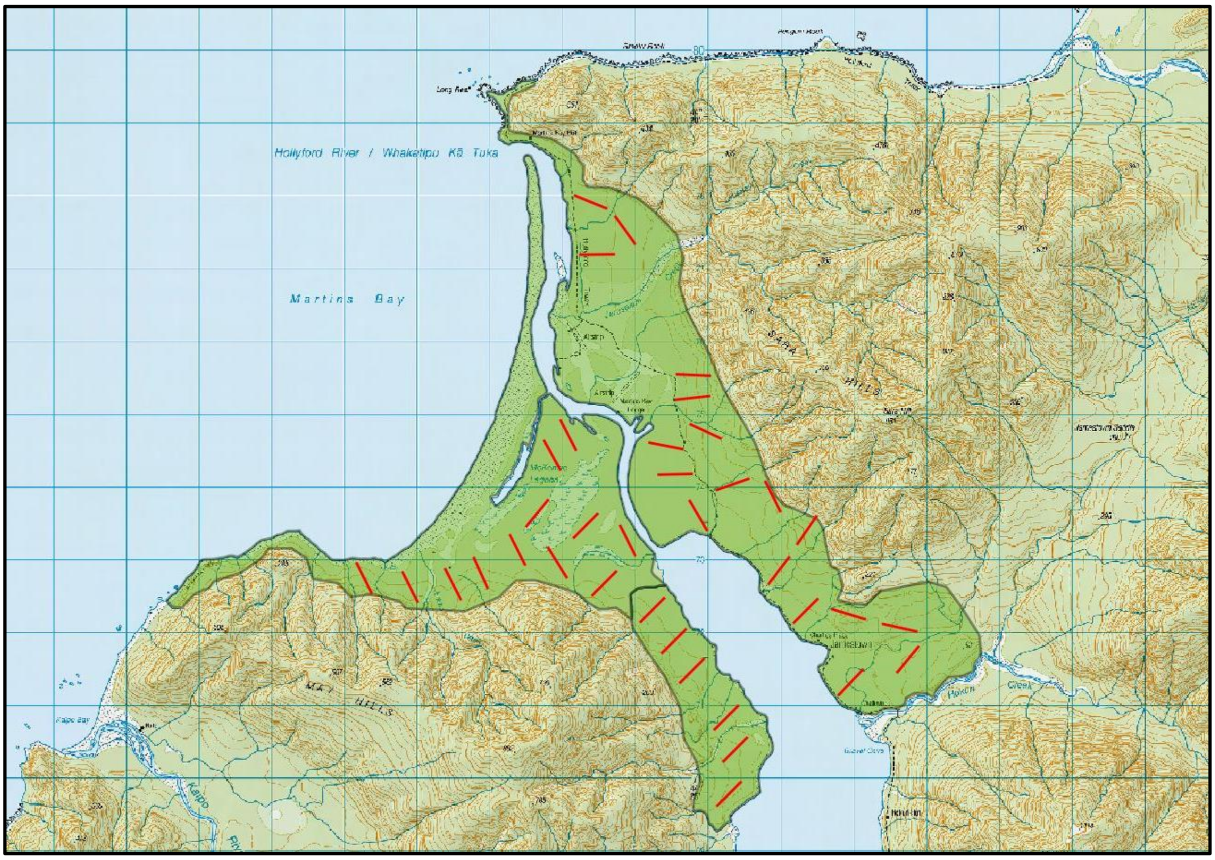

Figure 1. Distribution of bird monitoring transects at Martins Bay. The area shaded in green is managed by the Hollyford Conservation Trust.

Data collection

Initial monitoring on the eighteen transects on the true right was conducted prior to the aerial 1080 operation. Monitoring was completed over 5 days between September 23 and September 27, 2014. Data was collected as part of a larger bird count study conducted for the

Department of Conservation, and included twelve additional transects on Mt Webb. The aim of this study was to compare inter-annual changes in density estimates for selected forest bird species following aerial predator control (Broekema 2016). As part of this study, counts on the true right were repeated after the 1080-operation. Data was collected on September 21 and 22, 2015. Baseline monitoring on the eighteen transects on the true left was completed over 5 days between September 23 and September 27, 2015.

Data was collected by one observer between 0800 hours and 1800 hours. Transects on the true right were monitored once, transects on the true left were monitored twice, once in the morning and once in the afternoon. Data was collected during fine weather only (no rain or strong winds). The observer approached each transect with caution to avoid flushing undetected birds at or near the transect start point. Transects were walked at a slow and constant speed. Each time a transect was walked, a selection of weather variables including temperature, rain, wind and cloud cover were recorded at the end of the transect according to guidelines outlined in Dawson and Bull (1975).

Horizontal distances perpendicular from the transect line to each bird were recorded to the nearest meter within 30 m of either side of the defined line, using a laser rangefinder with built-in inclinometer. Distances less than 5 m (minimum focal distance for a rangefinder) were estimated visually. Distances to those birds only heard, or not clearly seen, were estimated by measuring the distance to vegetation at an equivalent distance to the estimated position of the bird. The observer did not move away from the transect for more than a few meters to locate a heard bird. This was to ensure that birds on or near the transect were not missed. To prevent estimating distances to the same birds more than once, the observer paid attention to the movements of the birds seen. Particular attention was paid to ensure that distance estimates were made to their first position of detection. Birds that flew into or over the transect area were ignored to avoid overestimating densities.

All other forest bird species seen or heard from the transect were counted regardless of their distance from the transect. If a bellbird, kaka, kereru, rifleman, tomtit or tui was seen or heard beyond 30 m of either side of the transect, this was also recorded.

Data analysis

First, density estimates and encounter rates measured before and after the aerial 1080 operation were compared with the area managed by the Hollyford Conservation Trust. Data collected outside the area managed by the Trust were excluded from analysis. These analyses include bird count data collected in 2014 and 2015 on the true right only.

Second, bird count data was analysed for all (36) transects within the area managed by the Trust. These analyses include bird count data collected in 2015 on the true right and true left. This data will used as a future baseline; data collected after the initial 1080 operation conducted by the Department of Conservation, but before intensive predator control started within the area managed by the Trust.

Limited detections make estimation of a useful detection function difficult and may bias density estimates; for this reason, only distance sampling data collected for bellbird and tomtit were used in the comparative analysis, and data collected for bellbird, kereru and tomtit were used in the baseline analysis.

Distance sampling data was analysed in the software Distance 6.2 (Thomas et al. 2009) using Conventional Distance Sampling (CDS) with independent detection functions. No distinction was made between male or female birds or birds detected by sight or their call during data analysis. Data were not truncated more than the limit set in the field (30 m) as further truncation did not improve model fit. Data were not grouped into interval classes for analysis. Detection probability histograms were constructed for each species and survey. Robust detection functions were fitted to the histograms based on guidelines in Buckland et al. (2001), and population density estimates were derived.

The following details were compared for each analytical approach: Akaike's Information Criterion (AIC), visual inspection of the detection probability histograms, Q-Q plots, accuracy of calculated density estimates and corresponding confidence intervals and Cramer-von Mises (CvM) GoF statistics, from which a preferred model was selected, and a density estimates were derived. Density estimates from pre- and post-operational counts were then compared for each species.

Simple indices of relative abundance were estimated for all species by calculating the mean number of birds counted per km using the software R version 3.1.2 (R Core Team, 2013). Frequency of detection for all species were summarised by calculating the percentage of transects at which a given species was detected.

Results

Comparison of pre- and post-operational data

Post-operational monitoring (2015) showed an increase in estimated densities for bellbird and tomtit compared to pre-operational monitoring (2014, Table 1, Fig. 2). Once data from Mt Webb was removed, the number of detections were too low for kaka (2014; n=0, 2015; n=2), kereru (2014; n=8, 2015; n=13), rifleman 2014; n=7, 2015; n=20) and tui (2014; n=10, 2015; n=15) to reliably estimate their population densities.

A comparison of pre- and post-operational encounter rate data (detections per km) showed a substantial increase in detections for bellbird, brown creeper (*Mohoua novaeseelandiae*), kereru, yellow-crowned parakeet (*Cyanoramphus auriceps*), rifleman and tomtit in the year following the 1080 operation (Table 2, Fig. 3). Mean encounter rates significantly declined for silvereye (*Zosterops lateralis,* Table 2, Fig. 3).

Brown-creeper, kereru, yellow-crowned parakeet and rifleman were more widely distributed throughout the study site following the 1080 operation, the number of transects from which they were detected increased substantially (Table 2, Fig. 4).

Some small changes were seen in encounter rates and detection frequencies for introduced species, the biggest change was the increase in redpoll detections (Table 2, Fig. 3 and 4).

Table 1. Population density estimates ($\hat{D}$) for bellbird and tomtit on the true right of the Hollyford River at Martins Bay in September 2014 and September 2015.

Species	Year	Samples	Total transect length (km)	n	Model (key+adjust)	GoF CvM (cos) P	$\hat{D}$	$\hat{D}$ 95% CI
Bellbird	2014	18	8.1	31	Unif+cos	0.8	1.23	0.71-2.11
	2015	18	8.1	79	Unif+cos	0.3	2.49	1.78-3.5
Tomtit	2014	18	8.1	42	Hnorm+cos	0.8	1.23	0.85-1.78
	2015	18	8.1	117	Unif+poly	0.8	3.22	2.7-3.86

[1] Model consisting of a key function (half-normal or uniform) with a cosine or simple polynomial adjustment term.

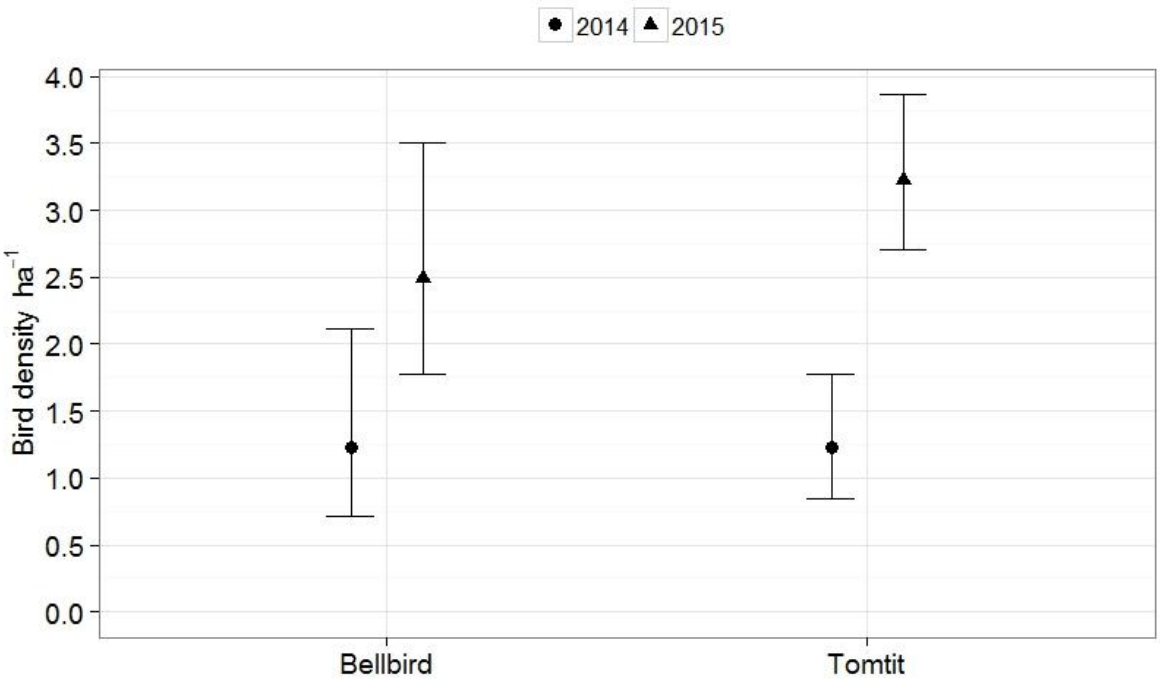

Figure 2. Population density estimates for bellbird and kereru (birds ha–1 ± 95% CI) on the true right of the Hollyford River at Martins Bay in September 2014 and September 2015.

Table 2. Mean encounter rates (detections/km ± SE) and detection frequencies (%) for forest bird species detected from transects on the true right of the Hollyford River at Martins Bay in September 2014 and September 2015. Encounter rates are presented as the mean number of birds detected per kilometre and include all birds seen or heard regardless of their proximity from the transects. Detection frequency is presented as the percentage of transects from which one or more individuals of each species was seen or heard.

	Mean encounter rate (detections/km ± SE)		Detection frequency (%)	
Species	2014	2015	2014	2015
Bellbird	17.04 (±1.82)	27.53 (±1.75)	100	100
Brown_creeper	0.37 (±0.37)	1.85 (±1.23)	6	28
Fantail	4.57 (±0.63)	4.69 (±1.33)	100	56
Fernbird	0.25 (±0.25)	0.00 (±0.00)	6	0

Grey_warbler	15.19 (±1.27)	13.58 (±0.84)	100	100
Kaka	1.48 (±0.57)	0.86 (±0.37)	33	28
Kea	0.12 (±0.12)	0.00 (±0.00)	6	0
Kereru	0.99 (±0.41)	1.98 (±0.62)	28	50
YC_parakeet	0.12 (±0.12)	1.48 (±0.76)	6	28
Rifleman	0.86 (±0.48)	2.47 (±1.15)	17	33
Silvereye	17.16 (±2.50)	3.21 (±0.92)	94	61
Tomtit	11.36 (±1.31)	18.52 (±1.40)	100	100
Tui	2.35 (±0.79)	2.96 (±0.98)	50	56
Blackbird	1.48 (±0.44)	1.11 (±0.48)	50	28
Chaffinch	1.60 (±0.71)	1.48 (±0.70)	28	33
Greenfinch	0.12 (±0.12)	0.00 (±0.00)	6	0
Redpoll	1.36 (±0.41)	2.96 (±1.27)	44	50
Song_thrush	0.74 (±0.44)	0.37 (±0.27)	17	11

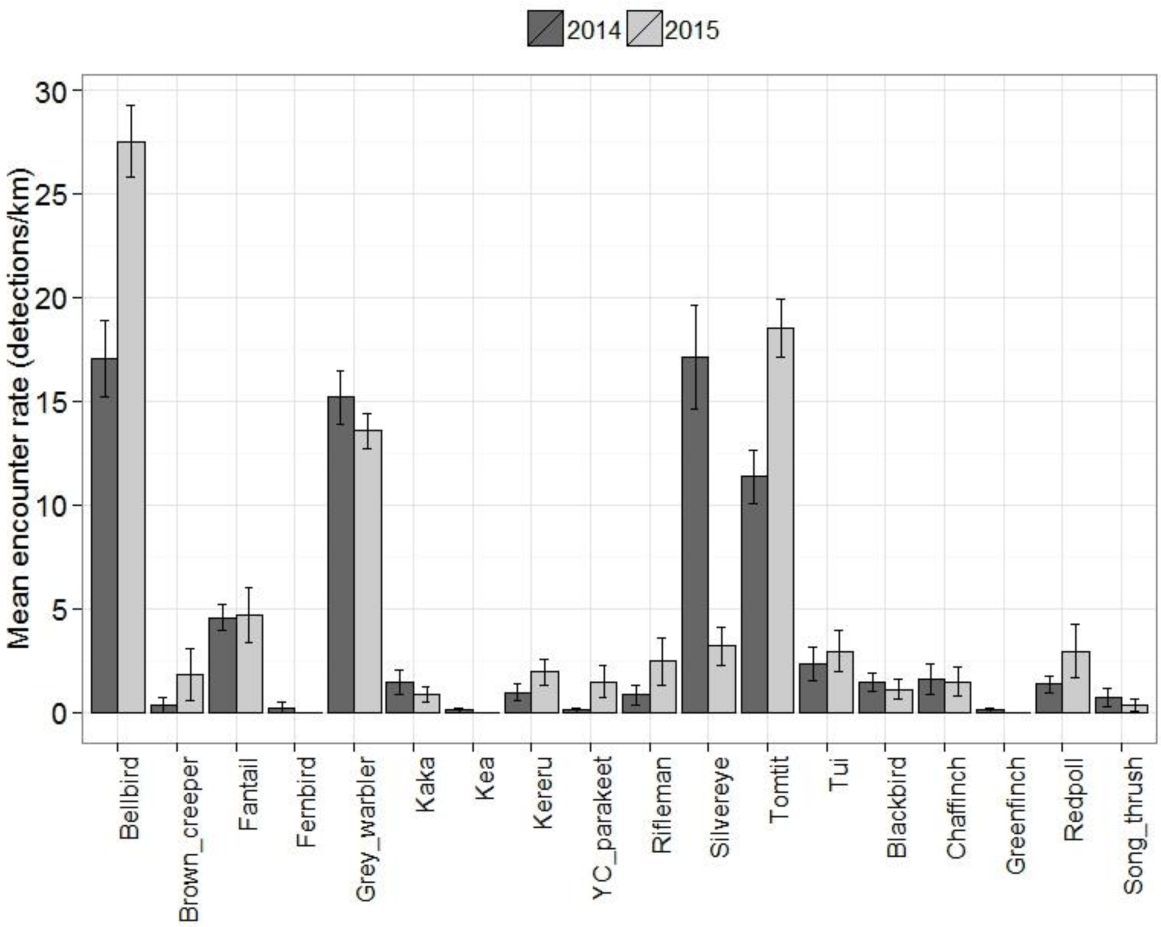

Figure 3. Mean encounter rates for forest bird species detected from transects on the true right of the Hollyford River at Martins Bay in September 2014 and September 2015. Encounter rates are presented as the mean number of birds detected per kilometre and include all birds seen or heard regardless of their proximity from the transects.

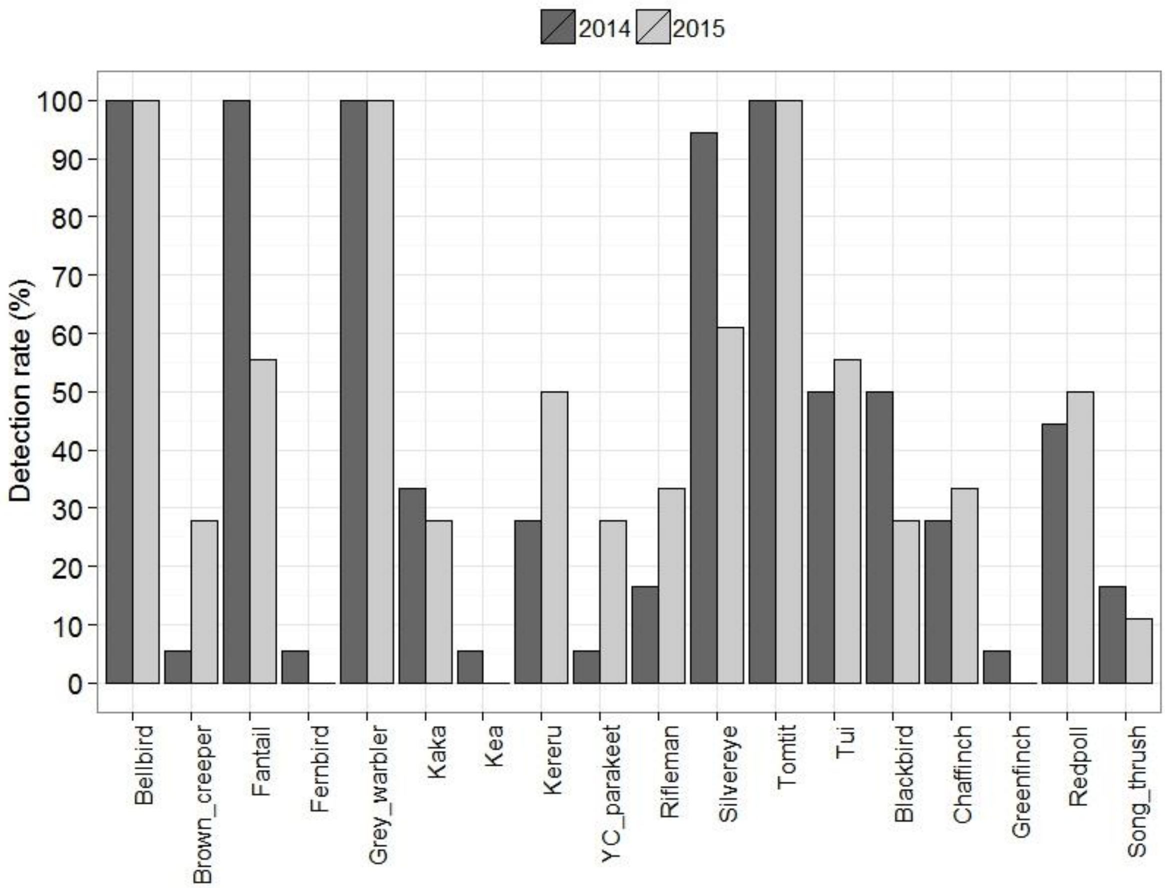

Figure 4. Detection frequencies for forest bird species seen or heard from transects on the true right of the Hollyford River at Martins Bay in September 2014 and September 2015. Detection frequencies are presented as the percentage of transects from which one or more individuals of each species was seen or heard.

Baseline analysis

Bellbird and tomtit were common throughout the study site and kereru were also present in reasonable numbers. Rifleman and tui were less abundant and kaka were rare. Population densities were estimated for bellbird, kereru and tomtit (Table 1, Fig. 5). Bellbird and tomtit density estimates were similar; kereru densities were lower (Table 1, Fig. 5). The number of detections were too low for rifleman (n=22), tui (n=17) and kaka (n=2) to reliably estimate their population densities.

Bellbird, grey warbler and tomtit were common, they were detected from all transects (Fig. 7, Table 2). Bellbird encounter rates (detections per km) were highest, followed by tomtit and grey warbler (Fig. 6, Table 2). Fantail (*Rhipidura fuliginosa*), kereru and silvereye were also abundant, they were detected from ≥50% of the transects (Fig. 7, Table 2). Brown creeper, New Zealand falcon (*Falco novaeseelandiae*), fernbird (*Bowdleria punctata*), kaka, kea (*Nestor notabilis*) and rifleman were the least common of the native species (Fig. 6 & 7, Table 2). Redpoll (*Carduelis flammea*) was the most common introduced bird (Fig. 6 & 7, Table 2) they were most abundant around the wetlands and lagoons.

Other bird species detected from the transects included paradise shelduck (*Tadorna variegata*), Canada goose (*Branta canadensis*), New Zealand scaup (*Aythya novaeseelandiae*) and morepork (*Ninox novaeseelandiae*). These species have not been reported on here as they are either non-forest birds, or are nocturnal, and this study is not designed to accurately monitor changes in their abundance.

Table 1. Population density estimates ($\hat{D}$) for bellbird, kereru and tomtit at Martins Bay in September 2015.

Species	Samples	Total transect length (km)	n	Model[1] (key+adjust)	GoF CvM (cos) P	$\hat{D}$	$\hat{D}$ 95% CI
Bellbird	36	24.3	233	Unif+cos	0.15	2.65	1.88-3.73
Kereru	36	24.3	43	Hnorm+cos	0.50	0.44	0.26-0.72
Tomtit	36	24.3	251	Unif+cos	0.60	2.39	1.90-3.02

[1] Model consisting of a key function (uniform, half-normal) with a cosine adjustment term.

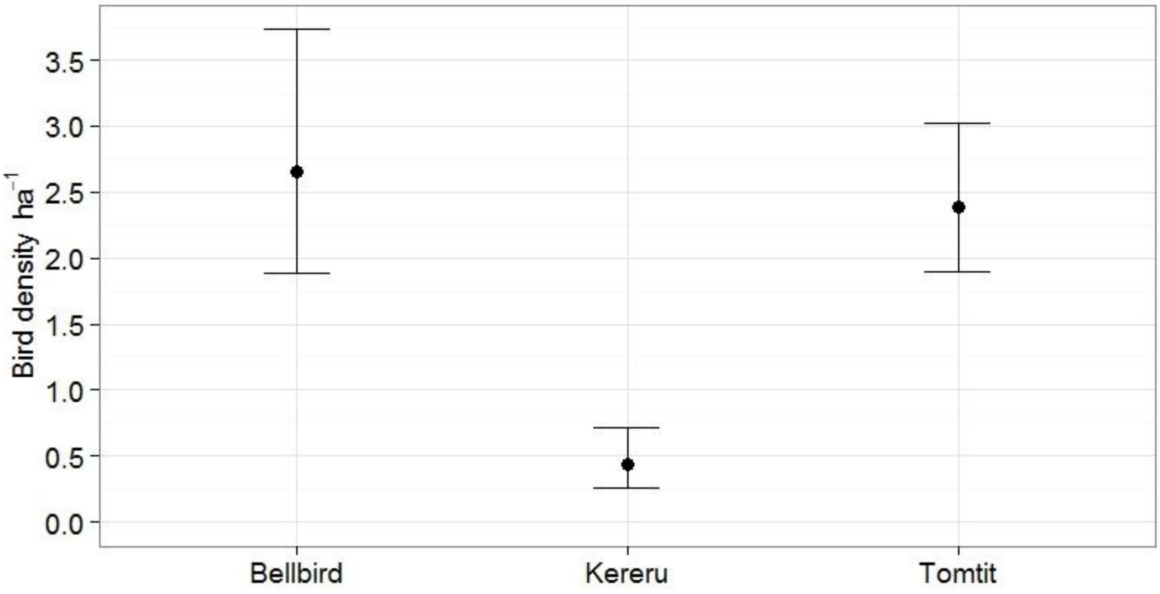

Figure 5. Population density estimates for bellbird, kereru and tomtit (birds ha^{-1} ± 95% CI) at Martins Bay/Lake McKerrow in September 2015.

Table 2. Mean encounter rates (detections/km), standard error (SE) and detection frequencies (%) for forest bird species at Martins Bay in September 2015. Encounter rates are presented as the mean number of birds detected per kilometre and include all birds seen or heard regardless of their proximity from the transects. Detection frequency is presented as the percentage of transects from which one or more individuals of each species was seen or heard.

Species	N	Mean encounter rate (detections/km ± SE)	Detection frequency %
Bellbird	36	26.42 (±1.78)	100
Brown_creeper	36	0.99 (±0.63)	17
Falcon	36	0.06 (±0.06)	3
Fantail	36	3.49 (±0.73)	61

Fernbird	36	0.25 (±0.15)	8
Grey_warbler	36	12.78 (±0.56)	100
Kaka	36	0.68 (±0.21)	25
Kea	36	0.06 (±0.06)	3
Kereru	36	2.06 (±0.41)	50
YC_parakeet	36	1.57 (±0.43)	42
Rifleman	36	1.36 (±0.60)	22
Silvereye	36	5.03 (±0.90)	69
Tomtit	36	15.62 (±0.97)	100
Tui	36	1.91 (±0.55)	44
Blackbird	36	1.39 (±0.31)	42
Chaffinch	36	1.76 (±0.47)	39
Greenfinch	36	0.31 (±0.31)	3
Redpoll	36	4.91 (±1.05)	69
Song_thrush	36	0.37 (±0.17)	14

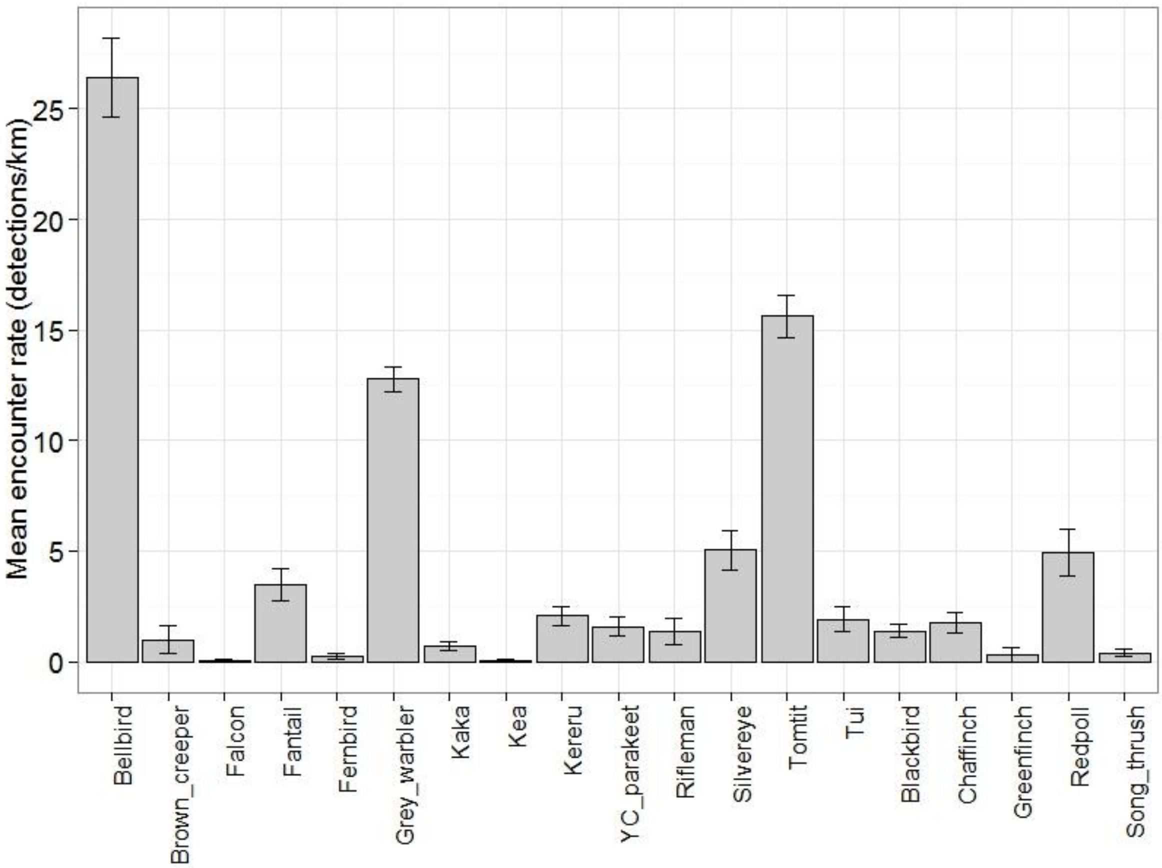

Figure 6. Mean encounter rates for forest bird species detected from transects at Martins Bay in September 2015. Encounter rates are presented as the mean number of birds detected per kilometre and include all birds seen or heard regardless of their proximity from the transects.

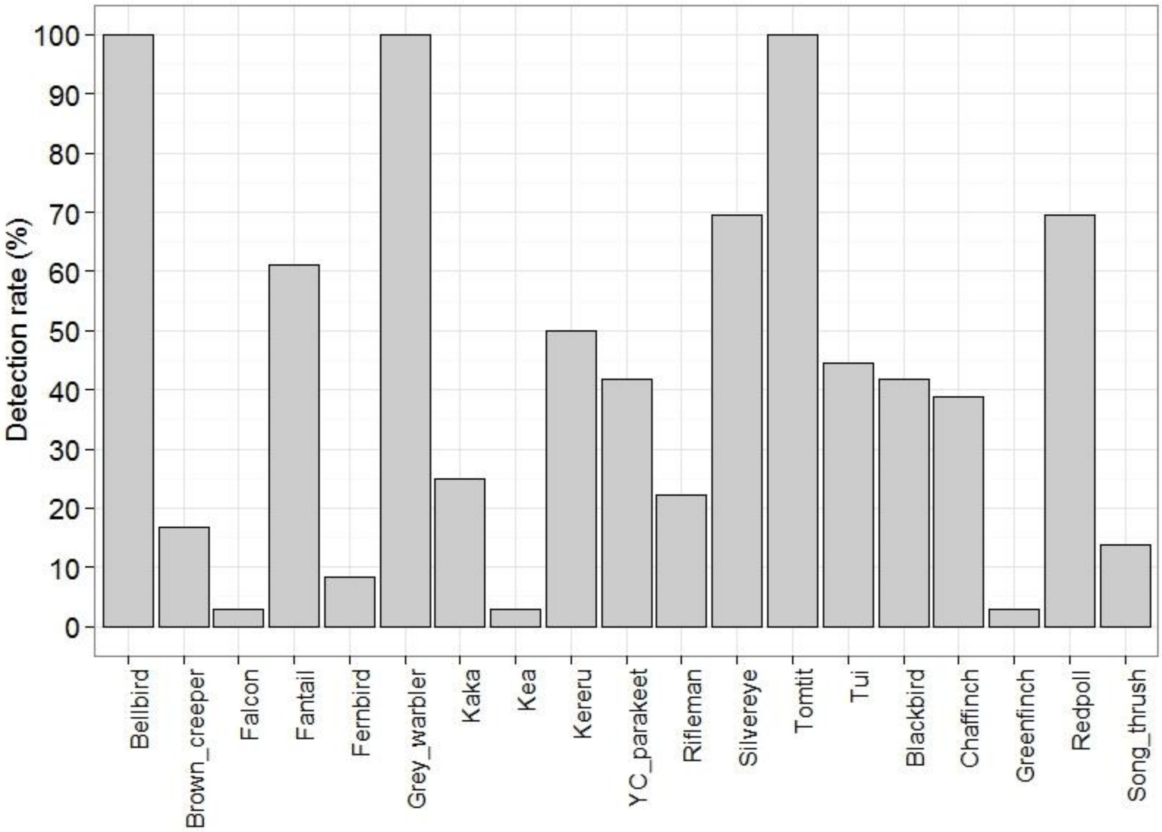

Figure 7. Detection frequencies for forest bird species seen or heard from transects at Martins Bay in September 2015. Detection frequencies are presented as the percentage of transects from which one or more individuals of each species was seen or heard.

Rare species

Two Australasian bittern (*Botaurus poiciloptilus*) were seen on McKenzie lagoon. Fernbirds were found on the edges of the wetlands on the true left and in shrub land bordering the sand dunes, around the airstrip, and near Martins Bay hut. They were most common on the true left.

Discussion

Comparison of pre- and post-operational data

- A comparison of pre- and post-operational density estimates for bellbird and tomtit within the area managed by the Hollyford Conservation Trust shows that these populations were not negatively affected by the aerial 1080 operation.
- Density estimates for bellbird and tomtit within the area managed by the Trust increased following the aerial predator control operation and a season of low predator numbers. Both species have high fecundity and therefore show rapid response to predator control.
- Pre-operational density estimates for bellbird and tomtit were lower in the area managed by the Trust compared to the wider lower Hollyford study area including Mt

Webb (bellbird $\hat{D}$=1.23 compared to $\hat{D}$=2.11, tomtit $\hat{D}$=1.23 compared to $\hat{D}$ =2.05, Broekema 2016). Predator densities are generally higher in podocarp lowland forests compared to high altitude beech forests, and bird densities on the flat land surrounding Lake McKerrow and Martins Bay (predominantly podocarp, area managed by the Trust) could therefore have been lower compared to bird densities on the higher altitude transects on Mt Webb (primarily beech).

- Post-operational density estimates for bellbird were lower in the area managed by the HCT compared to the wider study area, however post-operational tomtit density estimates were similar (bellbird $\hat{D}$=2.49 compared to $\hat{D}$=2.91, tomtit $\hat{D}$=3.22 compared to $\hat{D}$ =3.10, Broekema 2016).
- The increase in density estimates for bellbird and tomtit within the area managed by the Trust was greater than the increase seen within the wider study area. Predator numbers, and therefore pressure from introduced predators on forest birds, was likely to be higher in the podocarp forest (area managed by the Trust) compared to the higher altitude beech forest in the wider study area (Mt Webb). A season of low predator numbers in the podocarp forest is therefore likely to have resulted in a greater increase in bird densities compared to the high altitude beech forest.
- A comparison of pre- and post-operational encounter rate data (detections per km) showed a substantial increase in detections for bellbird, brown creeper, kereru, yellow-crowned parakeet, rifleman and tomtit in the year following the 1080 operation.
- Brown-creeper, kereru, yellow-crowned parakeet and rifleman became more widely distributed following the 1080 operation.
- Mean encounter rates significantly declined for silvereye. These birds show a considerable amount of local movement, mainly seeking fruit or nectar (Heather & Robertson 1996) and the decline in detections for this species is more likely to be related to seasonal movements rather than effects of the aerial 1080 operation.

Baseline analysis

Data collected in 2015 within the area managed by the Hollyford Conservation Trust (true right and true left) should be used as baseline data for long term forest bird monitoring at this site.

- Bellbird and tomtit were common throughout the study site and kereru were present in reasonable numbers. Rifleman and tui were less common and kaka were rare.
- Detections were too low for kaka, tui and rifleman to accurately estimate their pre-operational densities.
- The sampling effort may need to be increased in 2016 (e.g. all transects may need to be walked twice) to reach sufficient detections for bellbird, kereru, rifleman, tomtit and tui to reliably estimate their densities.
- The number of detections for kaka however needs to increase significantly before reliable density estimates can be made, this may not happen for several years. Kaka may also be better counted from points opposed to lines due to their cryptic nature (Greene et al. 2010).

- Once more data has been collected for rifleman and tui, their pre-operational densities can be estimated by using a global detection function, which can be derived by pooling the data across multiple surveys to increase the sample size, followed by post-stratification to estimate population densities for each survey.
- Long term density data should be graphed separately for bellbird, kereru, rifleman, tomtit and tui so that a simple linear regression model can be fitted to the data from each species to determine the population trend.
- If South Island robins (*Petroica australis*) are introduced to Martins Bay, and their numbers increase sufficiently to reliably estimate their densities, distance sampling data should be collected for this species. The line-transect distance sampling methodology has successfully be used to monitor robins and their response to different management tools (Broekema et al. in prep.).
- Baseline encounter rate data has provided a species list for forest birds present at Matins Bay, as well as an overview of species relative abundance and species composition.
- Long term encounter rate data should be graphed separately for each species so that a simple linear regression model can be fitted to the data from each species to determine their population trend.

Future monitoring and management

Annual bird monitoring is needed to determine whether the ground control methods used by the Hollyford Conservation Trust will be sufficient to suppress and maintain predator numbers to low enough levels to achieve positive population trends for the key bird species (bellbird, kaka, kereru, rifleman, tomtit and tui). The Trust should aim to keep rodent and stoat numbers below 5% tracking, and possum numbers below 5% RTCI. It is critical that predator control is timed accordingly so that predator numbers are low at the start and during the bird breeding season (August till January). Control techniques need to be altered accordingly if bird population will not benefit from the current predator control regime.

Surveying and monitoring rare bird species

Lagoons and wetlands take up a significant part of the area managed by the Hollyford Conservation Trust. Bird species within these areas are currently not monitored. Without spending significant time and funds monitoring a wide variety of wetland birds, we suggest monitoring the Australasian bittern (nationally endangered), within McKenzie lagoon, and fernbird (nationally declining) around the edges of the wetlands and in shrub land. Although we have reported on the encounter rate of fernbirds detected from the monitoring transects, the forest bird study is not designed to accurately monitor changes in fernbird abundance. Species specific monitoring of bittern and fernbird can be conducted in conjunction with the annual forest bird counts (September) for little additional time and cost.

We suggest to undertake an inventory and monitoring programme for Australasian bittern on McKenzie lagoon to: (1) determine the distribution and relative abundance of Australasian bittern in McKenzie lagoon, (2) measure the response of bittern to predator control programmes and the effectiveness of the chosen management tools, and (3) use bittern as an indicator species to measure wetland health within the area managed by the Hollyford Conservation Trust as bittern rely on good water quality, productive food webs, and healthy, fluctuating water regimes (O'Donnell & Williams 2015).

Bittern can be monitored by conducting evening counts of booming males using observers in quiet watercraft who approach and map birds (O'Donnell et al. 2013). Counts can be repeated annually in September to monitor changes in (1) the mean number of birds detected and (2) the number/location of booming bittern (O'Donnell & Williams 2015). Bittern monitoring can be conducted in conjunction with the annual forest bird counts (September) by conducting three repeat counts on McKenzie lagoon around sunset.

Annual fernbird counts can be undertaken along the edges of wetlands and lagoons and in areas of low shrub. Fernbirds are vulnerable to predation, mainly by mustelids, and as such, may be used as an indicator species for (successful) management.

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