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Photo: Adam Stinton

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Current population status of four endemic Caribbean forest birds in Montserrat

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Abstract Deforestation is a major cause of biodiversity loss across the world, but in the Caribbean region the fate of many forest species is poorly known despite ongoing forest loss. Bird populations in Montserrat were affected by the loss of more than 50% of the island's forest cover since 1995 when the Soufrière Hills Volcano started erupting. Today, Montserrat's bird populations appear to be stable but little is known about the status of many of the species. We report on the current population trajectories of four endemic Caribbean forest birds found in Montserrat: Bridled Quail-Dove (*Geotrygon mystacea*), Forest Thrush (*Turdus lherminieri*), Brown Trembler (*Cinclocerthia ruficauda*), and Montserrat Oriole (*Icterus oberi*). We estimated abundance from repeated count surveys around 67 sampling points during 2011–2016 using binomial mixture models and conclude that the Forest Thrush is the most common species (1,174 individuals in 2016; 95% credible interval: 624–2,178), with Bridled Quail-Dove (411; 250–853), Montserrat Oriole (323; 221–510), and Brown Trembler (246; 150–541) less common. Low precision in the estimates limits inference about population trends, but the Montserrat Oriole appears to have increased between 2011 and 2016 (trend estimate = 0.161; 0.032–0.298). We recommend that the current monitoring is continued on an annual basis to understand population trajectories of forest birds. Continued protection of the remaining forests is critical to maintain stable populations of the forest bird species in Montserrat.

Keywords forest birds, Montserrat, population trends

Resumen Estado poblacional actual de cuatro especies de aves de bosque endémicas del Caribe en Montserrat—La deforestación es la causa principal de pérdida de la biodiversidad en todo el mundo; pero en la región del Caribe el destino de muchas especies forestales es poco conocido pese a la pérdida continua de bosques. Las poblaciones de aves en Montserrat fueron afectadas por la pérdida de más del 50% de la cobertura boscosa de la isla desde que en 1995 entrara en erupción el volcán Soufrière Hills. Actualmente, las poblaciones de aves de Montserrat parecen estar estables, aunque se conoce poco sobre el estado de muchas de las especies. Ampliamos la información existente sobre los estados poblacionales de cuatro especies de aves de bosque endémicas del Caribe que se encuentran en Montserrat: *Geotrygon mystacea*, *Turdus lherminieri*, *Cinclocerthia ruficauda* y *Icterus oberi*. La abundancia fue estimada a partir de conteos repetidos en 67 puntos de muestreo durante el periodo 2011–2016 usando modelos binomiales mixtos y concluimos que *Turdus lherminieri* es la especie más común (1.174 individuos en 2016, intervalos de confianza del 95%: 624–2.178), en cambio, *Geotrygon mystacea* (411; 250–853), *Icterus oberi* (323; 221–510) y *Cinclocerthia ruficauda* (246; 150–541) fueron mucho menos comunes. La baja precisión en las estimaciones limita las inferencias sobre las tendencias poblacionales, pero *Icterus oberi* parece haber aumentado entre el 2011 y el 2016 (estimación de tendencia = 0,161; 0,032–0,298). Recomendamos que el monitoreo actual se continúe anualmente para entender las tendencias poblaciones de las aves de bosque. La protección continua de los bosques remanentes es crucial para mantener estables las poblaciones de estas aves en Montserrat.

Palabras clave aves de bosque, Montserrat, tendencias poblacionales

Résumé État actuel de la population de quatre espèces d'oiseaux endémiques des forêts caribéennes de Montserrat—La déforestation est une cause majeure de la perte de biodiversité à travers le monde, mais dans la région Caraïbe, le sort de nombreuses espèces forestières est peu connu malgré la disparition progressive des forêts. Les populations d'oiseaux de Montserrat ont été affectées par la perte de plus de 50% de la couverture forestière de l'île depuis 1995, lorsque le volcan de la Soufrière est entré en éruption. Aujourd'hui, les populations d'oiseaux de Montserrat semblent stables, mais l'état de conservation de nombreuses espèces est peu connu. Nous présentons les trajectoires actuelles des populations de quatre oiseaux endémiques des forêts caribéennes de Montserrat : la Colombe à croissants (*Geotrygon mystacea*), la Grive à pieds jaunes (*Turdus lherminieri*), le Trembleur brun (*Cinclocerthia ruficauda*),

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et l'Oriole de Montserrat (*Icterus oberi*). Nous avons estimé leur abondance en utilisant un modèle binomial mixte, à partir de comptages répétés de 2011 à 2016 autour de 67 points d'échantillonnage, et nous concluons que la Grive à pieds jaunes est l'espèce la plus commune (1.174 individus en 2016, intervalle de confiance à 95% : 624-2.178), suivi de la Colombe à croissants (411 ; 250-853), de l'Oriole de Montserrat (323 ; 221-510) et du Trembleur brun (246 ; 150-541) l'espèce la moins fréquente. La faible précision des valeurs estimées limite la capacité à prédire les tendances des populations, mais l'Oriole de Montserrat semble avoir augmenté entre 2011 et 2016 (estimation de la tendance = 0,161 ; 0,032-0,298). Nous recommandons que le suivi actuel se poursuive sur une base annuelle afin de comprendre l'évolution des populations d'oiseaux forestiers. La protection continue des forêts restantes est essentielle au maintien de la stabilité de l'avifaune forestière de Montserrat.

Mots clés Montserrat, oiseaux forestiers, tendances démographiques

Habitat loss is a major driver of species declines around the world (Brook *et al.* 2008, Laurance *et al.* 2011, Dirzo *et al.* 2014), and in the Caribbean region the loss of native forests is a particular concern for many regionally endemic forest species (Myers *et al.* 2000, Brooks *et al.* 2002, Rivera-Milán *et al.* 2015). Despite widespread forest loss, however, the status of range-restricted forest species is poorly known on many islands (BirdLife International 2017b), and few robust monitoring programs exist to document the decline of populations as a result of habitat loss (Blockstein 1991, Wunderle 1994, Wunderle 2005, Rivera-Milán *et al.* 2015).

Montserrat (16°45'N, 62°12'W; 104 km²) lies at the northern end of the Lesser Antilles in the eastern Caribbean Sea (Fig. 1). More than 140 species of birds have been recorded in Montserrat, of which 33 are resident breeding landbirds and 54 are Neotropical migrants—either on passage or winter visitors (Lepage 2005, Hilton *et al.* 2008, Oppel *et al.* 2015). Of the 34 species restricted to the Lesser Antillean Endemic Bird Area (BirdLife International 2017a), 9 occur in Montserrat (Oppel *et al.* 2015). Two globally threatened species are found in Montserrat: the single-island endemic Montserrat Oriole (*Icterus oberi*; downlisted from Critically Endangered to Vulnerable in 2016; BirdLife International 2017b) and the four-island endemic Forest Thrush (*Turdus lherminieri*; Vulnerable; Parashuram *et al.* 2015, BirdLife International 2017b), which is represented on Montserrat by the endemic subspecies *T. l. montserrati* (Zuccon 2011).

In 1995, an active volcano in the southern part of Montserrat (the Soufrière Hills Volcano) began a phase of eruptions which led to the loss of more than 50% of Montserrat's forest cover (Hilton *et al.* 2003). Recurring ash-fall events up until 2010 negatively affected birds, bats, and their insect food source (Marske 2004, Dalsgaard *et al.* 2007, Pedersen *et al.* 2012). As a result of the volcanic activity, the Centre Hills Protected Forest Area is the largest forested area (1,112 ha) remaining on the island today, and is of international biodiversity importance (Hilton *et al.* 2003, Hilton 2008, Young 2008, BirdLife International 2017a). The Centre Hills are a contiguous block of mostly secondary forest covering the steep-sided valleys of a dormant volcanic cone rising to a maximum elevation of 737 m above sea level. The forest is mostly mesic and wet at higher elevations, with dry forest at lower elevations and mostly outside the protected area. A smaller forest remnant (~250 ha) exists in the South Soufrière Hills, to the south of the active volcano, but access restrictions limit monitoring efforts and very little is known about bird populations in this area (Oppel *et al.* 2014a).

Forest birds in Montserrat appear to have recovered from past population declines caused by volcanic activity (Hilton *et al.* 2003, Dalsgaard *et al.* 2007, Oppel *et al.* 2014b), and in the absence of significant ash-fall events in the last 6 yr (Scientific Advisory Committee 2017), there is at present less cause for concern for their continued survival as long as all existing forest is retained. Opportunistic species with non-specialist diets, such as many of the forest birds in Montserrat, may be well adapted for recovering from stochastic natural disasters (Rotenberry 1980, Waide 1991, Hilton 2008). Hurricanes play a key role in influencing ecosystem dynamics in the Caribbean (Tanner *et al.* 1991), and bird communities are no exception (Wiley and Wunderle 1993, Lugo 2008, Johnson and Winker 2010). In Montserrat, the passage of Hurricane Hugo in 1989 caused excessive damage to vegetation but few bird populations were thought to have declined (Arendt 1990).

Annual bird surveys have been carried out in the Centre Hills of Montserrat since 1997, but the original point count distance sampling approach was unreliable in dense forest and may have led to biased population estimates (Hilton *et al.* 2003, Alldredge *et al.* 2007a, 2007b). Thus, a new survey protocol was established in 2011 to overcome the complications associated with estimating the distance to a vocalizing bird in dense tropical forest habitat while still addressing the pervasive problem of imperfect detection (Kéry *et al.* 2005, Royle *et al.* 2005).

Here we provide abundance estimates and short-term population trends for four species of Caribbean endemic forest birds since the new survey protocol was implemented: the Bridled Quail-Dove (*Geotrygon mystacea*), the Forest Thrush, the Brown Trembler (*Cinclocerthia ruficauda*), and the Montserrat Oriole. These four species are of particular conservation and management interest, especially the Montserrat Oriole as a single-island endemic, and the Forest Thrush as a globally threatened restricted-range species. Both species have been subject to substantial research over the past decade and are thought to be stable in Montserrat, and in fact Montserrat is considered to be a stronghold for the Forest Thrush (Hilton 2008, Allcorn *et al.* 2012, Oppel *et al.* 2014a, 2014b, Parashuram *et al.* 2015). However, very little is known about the conservation status of other range-restricted forest birds in Montserrat, including the Bridled Quail-Dove and Brown Trembler, although they have been included in annual monitoring since 1997 (Dalsgaard *et al.* 2007). The Bridled Quail-Dove has a wider range, but is considered to be uncommon and possibly declining across the Caribbean (BirdLife International 2017b). No population estimates or trend

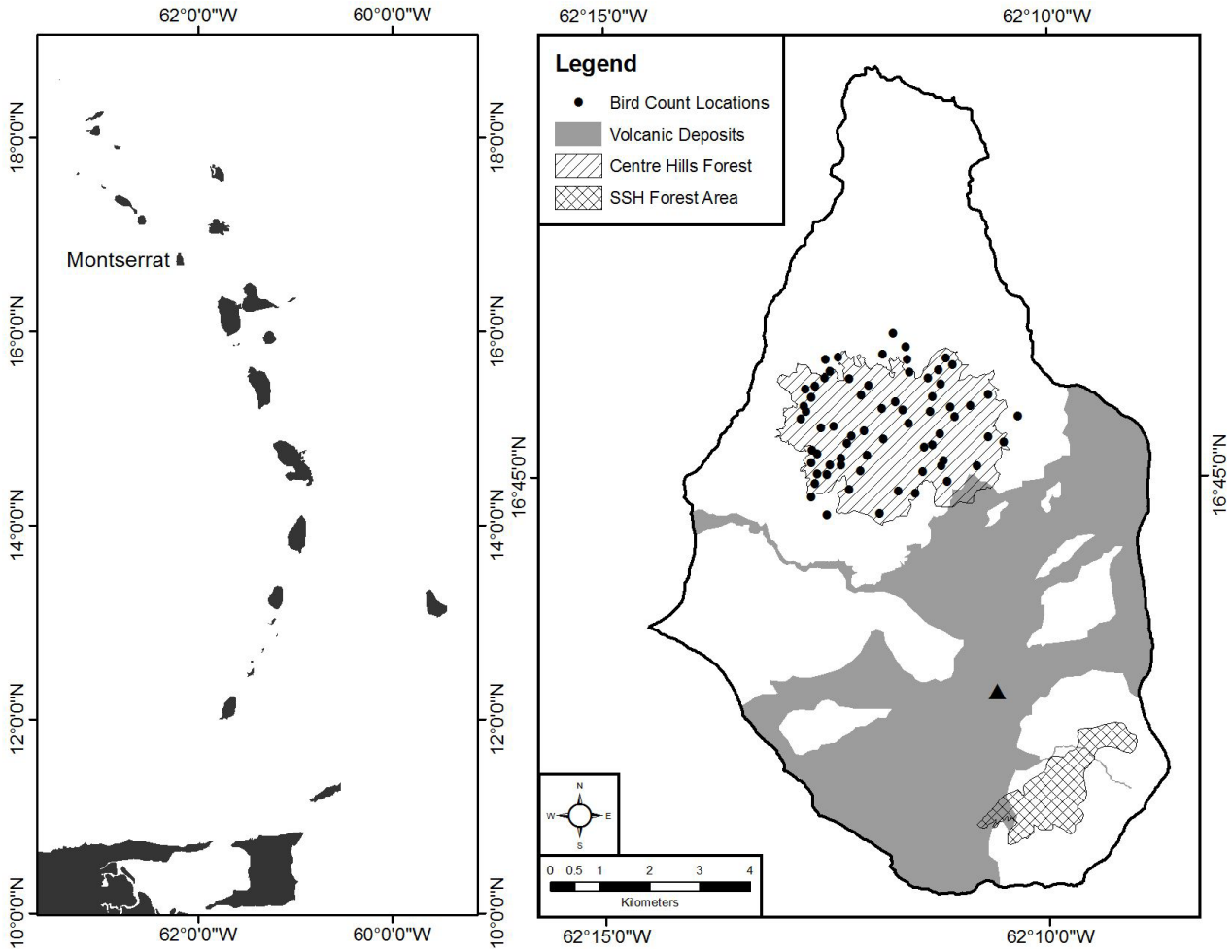

Fig. 1. Montserrat in the Lesser Antilles (left) has two main forest areas (right), the Centre Hills Protected Forest Area and the South Soufrière Hills (SSH) forest area, currently without a protected status. The black triangle indicates the peak of the active Soufrière Hills Volcano. Black dots indicate the sampling points for bird counts in the Centre Hills.

across its range are available for the Brown Trembler (BirdLife International 2017b). The species is uncommon in Montserrat and has possibly declined since 1997 (Dalsgaard *et al.* 2007, Hilton 2008), but there is no recent quantitative information available about the current population trajectory of this species.

Methods

Bird Monitoring

Bird monitoring was conducted in the Centre Hills between late March and early May every year from 2011 to 2016, when most forest birds in Montserrat are breeding. We conducted 10-min point counts, between 0545 and 1400 local time, at 67 sampling points (Fig. 1) that were at least 200 m apart. The counts were repeated 2–3 times at all points within a 3-week period to ensure demographic closure of the target populations and to meet model assumptions (see below). A detailed description of the bird survey method used can be found in Oppel *et al.* (2014a) and Parashuram *et al.* (2015).

Estimation of Population Trends

We estimated abundance and detection probability of forest birds in Montserrat using binomial mixture models (Royle and Nichols 2003, Kéry *et al.* 2005, Royle *et al.* 2005) based on repeated point count data from 2011 to 2016. The models we used estimate both the probability to detect birds, and the number of birds that use the habitat around the sampling point, and are described in more detail in Oppel *et al.* (2014a). Binomial mixture models make two critical assumptions, namely that the sampling points are far enough apart to avoid double counting, and that the population is demographically closed over the period during which the repeat counts are conducted (Royle and Nichols 2003, Kéry *et al.* 2005, Kéry and Schaub 2012). Our monitoring method was designed to ensure that these assumptions are not violated (Oppel *et al.* 2014a).

We estimated trends based on multi-year binomial mixture models described in Kéry *et al.* (2009). To parameterize these models, we drew on previous work of two characteristic forest species, the Forest Thrush (Parashuram *et al.* 2015) and the Montserrat Oriole (Oppel *et al.* 2013, Oppel *et al.* 2014a), to include variables considered influential for the abundance and detection probability of forest birds. Abundance was modeled as a function of elevation, tree height, and canopy cover (Parashuram *et al.* 2015), with a random site effect to account for heterogeneity across the sampling points (Oppel *et al.* 2014a). We

included a trend parameter in the abundance component of the model, indicating whether forest bird abundance had changed over the past 6 yr (Kéry *et al.* 2009). To account for variation in detection probability, we included day of the year, time of day, whether rain had occurred the previous night, and whether the sampling point was located on a ridge or not, as these aspects have been found to affect detection probability of landbird species in past investigations (Schmidt *et al.* 2013, Parashuram *et al.* 2015).

We conducted a Bayesian posterior predictive check to evaluate whether the binomial mixture trend models fit the data (Gelman *et al.* 2004). This check serves as an indicator of model fit and we report the Bayesian *p*-value (Kéry and Schaub 2012). We fit the trend models for each species by running three Markov chains with 100,000 iterations each, of which we discarded the first 25,000 as burn-in. We report total annual abundance summed across all sampling points and annual detection probability averaged across sampling points and repeat counts based on posterior mean estimates. All models were run in JAGS 3.3.0 via the R2jags package (Plummer 2012) called from R 3.2.5 (R Core Team 2016).

Results

Raw Count Data

The raw count data of the four focal species indicate some strong annual fluctuations with up to five-fold changes between two subsequent years (Bridled Quail-Dove), and increases from roughly 1 bird per two sampling points to > 1 bird at every sampling point in 2015 and 2016 (Bridled Quail-Dove and Montserrat Oriole) (Table 1).

Estimates of Abundance and Population Trends

Of the four focal species, the Forest Thrush was the most abundant with annual estimates ranging from 776 (95% credible interval: 402–1,233) to 1,174 (624–2,178) birds around the 67 sampling points (Fig. 2). Bridled Quail-Dove (mean abundance in 2016 = 411; 95% credible interval: 250–853), Montserrat Oriole (323; 221–510), and Brown Trembler (246; 150–541) were approximately equally common with estimated mean abundances of ~200–400 birds (Fig. 2). There was no evidence for a lack of fit for any of the trend models, with Bayesian *p*-values of 0.37 (Bridled Quail-Dove), 0.54 (Forest Thrush), 0.39 (Brown Trembler), and 0.41 (Montserrat Oriole), but the annual population estimates for the four species were fairly imprecise. Nonetheless, we found a positive trend for the Montserrat Oriole (mean trend = 0.161; 95% credible interval: 0.032–0.298), while the credible intervals of trend estimates for the other three species overlapped zero: Bridled Quail-Dove (0.082; −0.182–0.315), Forest Thrush (0.099; −0.095–0.254), and Brown Trembler (−0.064; −0.295–0.015).

Mean detection probabilities for the different species ranged from 0.05 to 0.26 across all species and years (Fig. 3), indicating that less than a third of the birds using the area around a sampling point were detected. While one species had strongly fluctuating detection probabilities among years (Bridled Quail-Dove, range: 0.05–0.23; Fig. 3), others had relatively consistent detection probabilities (Forest Thrush, 0.10–0.14; and Montserrat Oriole, 0.19–0.26; Fig. 3). For the Brown Trembler, the higher detection probability in 2016 (0.16; Fig. 3) appeared to explain the high raw counts (Table 1), despite estimated abundances being lower than in previous years (Fig. 2).

Table 1. Mean number of individuals (*N*) of four forest bird species encountered during repeated 10-min point counts across all sampling points (*n* = 67) over 6 yr (2011–2016) of monitoring in the Centre Hills, Montserrat.

Species	Year	Mean *N* per Point	Standard Deviation
Bridled Quail-Dove	2011	0.25	0.61
	2012	0.69	0.78
	2013	0.63	0.76
	2014	0.33	0.68
	2015	1.51	1.37
	2016	1.73	0.99
Forest Thrush	2011	1.67	1.42
	2012	1.34	1.42
	2013	2.19	1.43
	2014	1.51	1.26
	2015	2.18	1.54
	2016	3.06	1.80
Brown Trembler	2011	0.66	0.91
	2012	0.48	0.64
	2013	0.51	0.64
	2014	0.34	0.57
	2015	0.48	0.79
	2016	0.72	0.88
Montserrat Oriole	2011	0.69	0.89
	2012	0.57	0.92
	2013	0.58	0.68
	2014	0.75	0.94
	2015	1.21	1.29
	2016	1.19	1.06

Discussion

Very little information exists on the population status of Montserrat's avifauna prior to the start of regular monitoring in 1997. Terborgh *et al.* (1978) commented on a high density of Scaly-breasted (*Allenia fusca*) and Pearly-eyed Thrashers (*Margarops fuscatus*) in Montserrat, but did not provide population estimates. According to Butler (1991), the Montserrat Oriole population density was 'somewhat low,' and the species was only reported from the Soufrière Hills and one area in the Centre Hills. Arendt and Arendt (1984) provided a pre-Hurricane Hugo Montserrat Oriole population estimate of 1,000–1,200 individuals.

After the start of regular monitoring, Arendt *et al.* (1999) estimated the Montserrat Oriole population to be around 4,000 individuals (95% confidence interval: 1,500–7,800), the Forest Thrush population to be 3,100 individuals (1,400–5,400), and the Brown Trembler population to be 11,500 individuals (no 95% CI provided) based on data collected in December 1997. Hilton

(2008) estimated population sizes for the same species at 5,200 (95% confidence interval: 2,700–10,100), 3,100 (1,900–5,200), and 410 (200–870), respectively, based on data collected in December 2004. Hilton *et al.* (2003) reported a rapid decline in Montserrat Orioles between 1997 and 2000, but pointed out that this may have been an artifact of the survey and analytical methods used, and that the behavior of Montserrat Orioles may have violated some assumptions of the distance sampling approach. Alternatively, the emigration of forest birds from the formerly extensive Soufrière Hills forest during the phase of volcanic eruptions may have temporarily increased bird populations in the adjacent Centre Hills, leading to observed population declines in subsequent years as populations relaxed to the carrying capacity of the environment (Oppel *et al.* 2014a). A comprehensive analysis of the Montserrat Oriole population trajectory since 2000 (Oppel *et al.* 2014a, 2014b), combined with our finding reported here indicating a recent increase between 2011 and 2016, provided reassurance that the current extinction risk of this endemic species is no longer sufficiently high to classify the species as Critically Endangered. The Montserrat Oriole was therefore downlisted to Vulnerable in December 2016 (BirdLife International 2017b).

Our current estimates are surrounded by considerable uncertainty and estimated trends are therefore too imprecise to infer whether populations of the three other forest bird species have increased or decreased in the past 6 yr. Caution is therefore required when interpreting the conservation status of these species, as our data will not have the power to detect slow declines, but may only detect fairly substantial changes, such as the increase in Montserrat Orioles. Although the current population estimates are equally imprecise as previous extrapolations based on a different statistical technique, the implementation of a different survey design in 2011 generally increased the reliability of forest bird population estimates in Montserrat because the new approach rests on fewer assumptions and is not vulnerable to differences among observers in estimating the distance to a vocalizing bird (Alldredge *et al.* 2007a, 2007b). Our new approach allows the estimation of detection probability from repeated counts rather than from estimated distances between birds and the observer (Royle and Nichols 2003, Kéry *et al.* 2005, Royle *et al.* 2005), and these models generally yield reliable estimates of abundance and population trends (Kéry *et al.* 2005, Kéry *et al.* 2009, Chandler and King 2011). The lack of precision is likely an inherent property of the forest ecosystem on Montserrat, where the breeding season of most species is less constrained than in many temperate regions, and annual changes in the amount and seasonality of rainfall have significant influence on bird activity (Oppel *et al.* 2013, Parashuram *et al.* 2015).

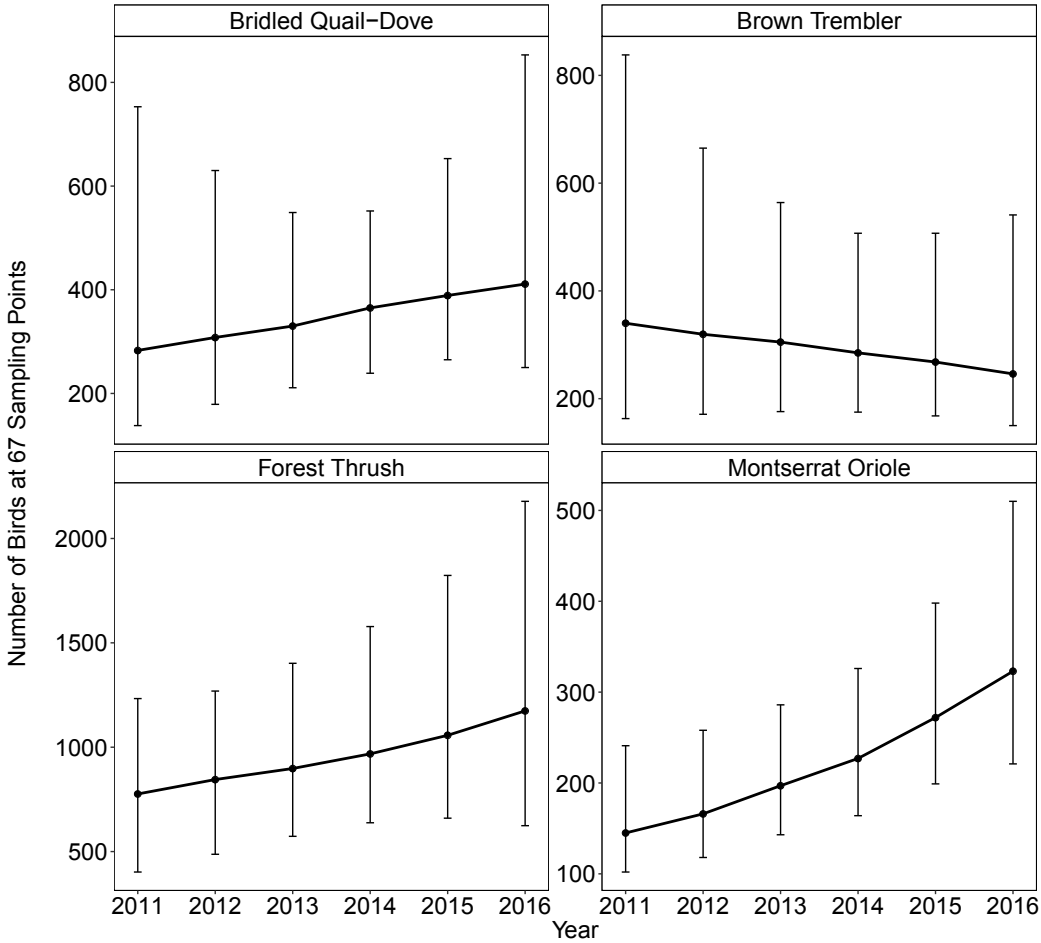

Fig. 2. Estimated abundance of four forest bird species across all sampling points (n = 67) over 6 yr of monitoring (2011–2016) in the Centre Hills, Montserrat. Estimates are derived from binomial mixture models based on repeated counts at the same sampling points.

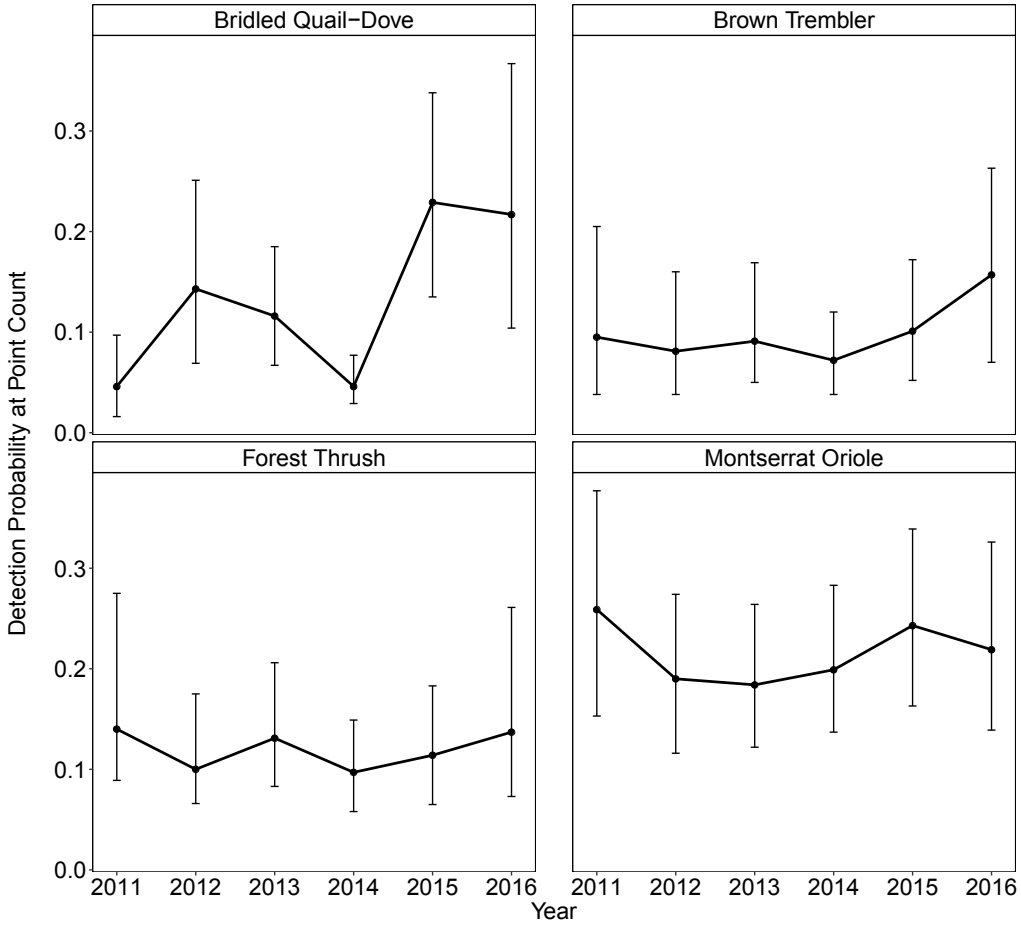

Fig. 3. Estimated detection probability of four forest bird species across all sampling points (n = 67) over 6 yr of monitoring (2011–2016) in the Centre Hills, Montserrat. Estimates are derived from binomial mixture models based on repeated counts at the same sampling points.

Both annual variability in rainfall regimes as well as short-term fluctuations in weather likely affect the vocalization activity of many forest birds, resulting in high and low counts at the same location on different days. This inherent variability in the observation process often leads to fairly low detection probabilities, which can result in low precision in abundance estimates (Banks-Leite *et al.* 2014, Yamaura *et al.* 2016). Given this substantial variability in both detection probability and abundance estimates among years and sampling points, the rather short time series of 6 yr limits our ability to detect whether bird populations are increasing or decreasing in the longer term. More reliable trend estimates will become available in the future, and we therefore recommend the annual forest bird monitoring is maintained in Montserrat.

The apparent mismatches between the raw count data (Table 1) and the estimated abundances (Fig. 2) can be explained by variation in detection probability (Kéry 2008), but care needs to be taken when interpreting the abundance estimates. The figures we present are the estimated abundances of the focal species in the area effectively surveyed by our repeated point counts, and this area likely differs among species. Oppel *et al.* (2014a) were able to derive total population estimates for the Montserrat Oriole by estimating the area effectively surveyed to comprise 19.6% of the Centre Hills. However, we are not able to determine what this proportion would be for the other focal species and are therefore unable to estimate total population sizes for them, which are likely to be higher than the estimated abundances reported here.

Today, the main threats to Montserrat's forest birds are the continuing volcanic activity (Hilton *et al.* 2003, Oppel *et al.* 2014b), and invasive alien species such as cats (*Felis catus*), rats (*Rattus rattus* and *R. norvegicus*), and ungulates (goats [*Capra aegagrus hircus*], cattle [*Bos taurus*], and pigs [*Sus scrofa*]) (Dawson *et al.* 2015). A feral livestock control program has been implemented by the Department of Environment since 2010, but more work is needed to control other invasive alien species in the Centre Hills Protected Forest Area. Ensuring stable forest bird populations will also require the protection and retention of an intact forest environment in Montserrat and on other islands in the Caribbean. Despite several ongoing threats, our assessment indicates that four important forest bird species have not declined dramatically over the past 6 yr in the remaining forest on Montserrat.

However, due to the low precision of the estimates, additional years of data are needed to increase our confidence in the trends reported here, and to estimate trends for other forest bird species on Montserrat. Annual forest bird monitoring data are important for tracking the status of Montserrat's forest bird

populations, and can act as a proxy indicator of the health of the forest ecosystem as a whole. We therefore encourage the adoption and continuation of robust forest bird monitoring approaches, such as the one presented here, across the Caribbean region to better understand population fluctuations in response to habitat alteration and climate change in the future. More detailed demographic and ecological information on some of the less well-known species of forest birds in Montserrat (e.g., the Brown Trembler) would also benefit future conservation efforts.

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