

24 **ABSTRACT**—Tropical montane bird species may be vulnerable to climate change as they often
25 have narrow elevational ranges that are expected to shift upslope in response to increasing
26 temperatures. If highland endemics near mountaintops are forced upslope, these species may be
27 especially at risk of local extinction. We investigated the elevational ranges of two species of
28 montane cloud forest warblers, the Slate-throated Redstart (*Myioborus miniatus*) and the
29 Collared Redstart (*M. torquatus*), in Costa Rica between 1980 and 2019. The Collared Redstart
30 is a highland endemic that has been projected to go locally extinct from climate change. We
31 examined 11,856 and 7,366 checklists from sites where the Slate-throated Redstart and the
32 Collared Redstart, respectively, have been reported to eBird, a citizen science project managed
33 by the Cornell Lab of Ornithology. As expected, we found that the two species' elevational
34 ranges were different from each other but overlapped, with the Collared Redstart showing a peak
35 rate of detection at an elevation about 750 m to 1,050 m higher than the Slate-throated Redstart.
36 More important, only the Slate-throated Redstart showed a shift upward in its elevation of peak
37 detection over time. This inconsistent response to climate change reinforces the growing
38 evidence that the impacts of climate change on tropical montane bird species are complex and
39 difficult to forecast. Continuing to study the elevational ranges of tropical montane bird species
40 is vital for our understanding of these birds' responses to climate change.

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42 **Keywords:** climate change, cloud forest, *Myioborus miniatus*, *Myioborus torquatus*, tropics,
43 upslope shifts.

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47 Tropical montane bird species often have narrow elevational distributions and are habitat
48 specialists (Stotz et al. 1996; Jankowski and Rabenold 2007; Jankowski et al. 2009, 2010). These
49 species may be vulnerable to climate change (Şekercioğlu et al. 2008, Jankowski et al. 2010,
50 Neate-Clegg et al. 2021b, Girish and Srinivasan 2022), and climate change may exacerbate the
51 conservation status of already threatened species (Şekercioğlu et al. 2012). Numerous tropical
52 montane species, such as high-elevation specialists endemic to Indonesia and nearly half of the
53 forest bird species in the Tilarán mountains of Costa Rica, have been predicted to decline in
54 abundance or to go extinct (Şekercioğlu et al. 2008, 2012; Gasner et al. 2010; Harris et al. 2012;
55 Velásquez-Tibatá et al. 2013). In addition, population declines have already been observed in
56 some tropical montane bird species (Pounds et al. 1999, 2005; Freeman et al. 2018).

57 Although the direct and indirect effects of climate change on tropical montane bird
58 species' elevational ranges are not fully understood (Pounds et al. 2005, Londoño et al. 2017,
59 Neate-Clegg et al. 2021a), these species are expected to move upslope into reduced geographic
60 ranges in response to increasing temperatures (Parmesan and Yohe 2003, Shoo et al. 2005,
61 Gasner et al. 2010, Forero-Medina et al. 2011, Şekercioğlu et al. 2012, Velásquez-Tibatá et al.
62 2013, Freeman et al. 2018, Neate-Clegg et al. 2021b). If highland endemics and other species
63 that live near mountaintops are forced upslope, they may be especially at risk of local extinction
64 (Pimm et al. 2006, Gasner et al. 2010, Forero-Medina et al. 2011, Şekercioğlu et al. 2012,
65 Rosselli et al. 2017). In addition, if dominant competitors from lower elevations move upslope,
66 high-elevation subordinate species may be forced into smaller ranges, threatening the viability of
67 their populations (Jankowski et al. 2010). Upslope shifts have recently been observed across a
68 range of tropical bird species in the Andes (Forero-Medina et al. 2011, Rosselli et al. 2017),
69 Himalayas (Girish and Srinivasan 2022), East Africa (Neate-Clegg et al. 2020, Neate-Clegg et al.

70 2021b), and elsewhere (e.g., Campos-Cerqueira et al. 2017, Williams and de la Fuente 2021).
71 These shifts include not only high-elevation species moving upslope but also lowland species
72 moving into the uplands (Pounds et al. 1999, 2005; Williams and de la Fuente 2021). However,
73 some studied species have not moved upslope, and some even appear to have shifted to lower
74 elevations (Campos-Cerqueira et al. 2017; Neate-Clegg et al. 2021a, 2021b). Species that do not
75 appear to have shifted upslope may be lagging behind warming due to complex responses of
76 ecosystems to climate change (Jankowski et al. 2010, Forero-Medina et al. 2011, Alexander et al.
77 2018, Freeman et al. 2018, Neate-Clegg et al. 2020), though it is also possible that temperature
78 may not be the primary driver in elevational range shifts for many birds (Currie and Venne 2017,
79 Neate-Clegg et al. 2020).

80 Climate change encompasses more than just temperature, and temperature need not be
81 the only feature of climate change influencing bird distributions. For instance, precipitation may
82 be a better predictor than temperature of changing patterns of bird occurrence in some tropical
83 systems (Neate-Clegg et al. 2020). We might particularly expect sensitivity to changing
84 precipitation in tropical montane cloud forests that rely on consistent cloud cover, which
85 provides frequent mists, reduces solar radiation, and suppresses evapotranspiration (Pounds et al.
86 1999, Still et al. 1999, Karmalkar et al. 2008, Nair et al. 2008). With climate change, cloud banks
87 may form at higher altitudes, thus leaving former cloud forests moisture-stressed, especially
88 during the dry season (Still et al. 1999, Karmalkar et al. 2008). Declines in dry season mists in
89 Costa Rican cloud forests have already been implicated in upslope shifts and declines in
90 populations of both the Resplendent Quetzal (*Pharomachrus mocinno*) and the Golden Bellied
91 Flycatcher (*Myiodynastes hemichrysus*) (Pounds et al. 1999, 2005).

92 Two other cloud forest residents in Costa Rica potentially at risk from climate change are

93 the congeneric Slate-throated Redstart (*Myioborus miniatus*) and Collared Redstart (*M.*
94 *torquatus*) (Henderson 2010). The Slate-throated Redstart can be found from Northern Mexico to
95 Peru and is common in Costa Rica at middle elevations from 700 m to 2100 m (Henderson 2010,
96 Garrigues 2014). The Collared Redstart, a high-elevation specialist, is endemic to Costa Rica and
97 Western Panama and is common between 1500 m and timberline (Henderson 2010, Garrigues
98 2014). Rising cloud banks may have forced these species to move upslope to seek out suitable
99 habitat, and the Collared Redstart, as a highland endemic, may be especially at risk of local
100 extinction. Gasner et al. (2010) projected the Collared Redstart would move upslope, go locally
101 extinct, and have one of the largest declines in abundance of all forest birds in Costa Rica. In
102 fact, the Collared Redstart has already disappeared from one 40 hectare cloud forest site in
103 Monteverde (Pounds et al. 2005).

104 We investigated the elevational ranges of the Slate-throated Redstart and the Collared
105 Redstart in Costa Rica between 1980 and 2019, using observations from eBird, a citizen science
106 project of the Cornell Lab of Ornithology. We expected overlap in the elevational ranges of the
107 two species but a higher average elevation for the Collared Redstart. More important, we
108 expected that, due to the effects of a warming climate, the elevational ranges and peaks of
109 occurrence of both species had shifted upward between an earlier time period (1980-2004) and a
110 later time period (2015-2019).

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Methods

113 We identified the elevational distributions of the Slate-throated Redstart and the Collared
114 Redstart in Costa Rica using datasets retrieved from eBird, a citizen science project managed by
115 the Cornell Lab of Ornithology. Although eBird was launched in 2002, observers may submit

116 historical data, and so observations extend to earlier decades (Cornell Lab of Ornithology 2021).
117 eBird is among the world’s largest biodiversity-related science projects, with more than 100
118 million bird sightings contributed annually by birders around the world (Cornell Lab of
119 Ornithology 2021). Birders enter when, where, and how they went birding, and they fill out a
120 checklist of the birds seen or heard during the outing. In addition, experts review checklists to
121 improve data quality (Cornell Lab of Ornithology 2021).

122 From eBird, we accessed data through September 2020, including a sampling event
123 dataset with all of the checklists ever submitted to eBird globally and all of the Slate-throated
124 Redstart and Collared Redstart sightings ever submitted in Costa Rica (Cornell Lab of
125 Ornithology 2020).

126 We filtered the data to eliminate entries inappropriate for our analyses. We first filtered
127 for the protocol type (method of observation/data gathering) for each checklist. We only included
128 protocols that we expected to have a low probability of bias, including traveling, stationary,
129 historical, random, and area counts (see Appendix A for a list of eBird protocols). These
130 protocols all produced lists of species regardless of whether our target species were detected,
131 therefore allowing us to compare lists with and without our target species to determine rates of
132 detection at different elevations. We excluded data from the ‘incidental’ protocol because
133 submissions of these lists are more likely to depend on the species detected.

134 In addition, we filtered the data for the locality type recorded with each checklist and
135 only included locations in the ‘hotspot’ category (see Appendix B for a complete list of eBird
136 locality types). Hotspots are frequent birding locations nominated by eBird users. When eBird
137 users are presented with a map and asked to identify their birding location, one option is to select
138 an existing hotspot. Therefore, each hotspot typically has multiple checklists associated with it,

139 and so we could treat each list from a given hotspot as a separate sampling event at that location
140 and compare proportions of detections of our target species across elevations or time periods.
141 Also, each hotspot is defined by a single latitude and longitude coordinate and, therefore, a single
142 elevation. Of course, the birding area associated with each hotspot varies in elevation, especially
143 at the montane sites in our study, but we assumed that the range in reported elevations among
144 hotspots is much greater than the typical range of elevations explored by birders within hotspots.
145 We found the elevation of each hotspot at which at least one of the two focal species was
146 observed at least once using GPS Visualizer at <https://www.gpsvisualizer.com/elevation>
147 (Schneider 2019).

148 To examine the possibility of elevational range shifts over time, we created an earlier
149 time period from 1980-2004 and a later time period from 2015-2019. The scope of our data for
150 the earlier time period was shaped by the availability of data, which was dramatically sparser
151 further back in time. We excluded checklists from prior to 1980 because there were so few. The
152 later time period spans 5 years, while the earlier time period includes 25 years to ensure similarly
153 large datasets from both periods. In addition, we excluded checklists from 2005-2014 to allow
154 for a 10 year gap to increase our ability to detect changes in elevational ranges between the
155 earlier and later periods.

156 We created four datasets for analysis. Two datasets, one with data from the earlier time
157 period (1980-2004) and one with data from the later time period (2015-2019), included all
158 hotspots at which at least one of the two focal species was observed at least once during the
159 relevant time period. These two datasets included the number of checklists at each hotspot and
160 the number of checklists each species was detected in at each hotspot. Two additional datasets,
161 one with data on the Slate-throated Redstart and one with data on the Collared Redstart, included

162 all of the hotspots at which at least one member of the relevant species was detected in at least
163 one of the two time periods. These two datasets included the number of checklists at each
164 hotspot in each time period and the number of checklists the relevant species was detected in at
165 each hotspot in each time period.

166 We compared the elevational ranges between the two species in two separate analyses,
167 one with the dataset from the earlier time period (1980-2004) and one with the dataset from the
168 later time period (2015-2019). We used a generalized linear model with binomial error and a
169 logit link. The dependent variable was the ratio of the number of checklists in which each species
170 was detected to the number of checklists for which each species was not detected at each hotspot
171 during the given time period. The independent variables were species, elevation, elevation²,
172 species×elevation, and species×elevation². The quadratic term for elevation accounted for the
173 expected humped shape of the relationship between elevation and detections. We included the
174 interaction terms to assess the likely possibility that the slope of the relationship between
175 elevation and detections differed between the two species. We used the predict function in R to
176 generate predicted detection rate and accompanying standard error values based on our fitted
177 statistical models across the range of elevations in our data set. We then graphed these values to
178 visualize the elevational ranges of both species.

179 We compared the elevational range of each of the focal species between the earlier time
180 period (1980-2004) and the later time period (2015-2019) in two separate analyses, one for each
181 species. We used the same type of generalized linear model with binomial error and logit link as
182 the previous analyses. The dependent variable was the ratio of the number of checklists in which
183 the relevant species was detected to the number of checklists the relevant species was not
184 detected in at each hotspot during each time period. The independent variables were time period,

185 elevation, elevation², time period×elevation, and time period×elevation². The interaction terms
186 assessed the possibility that the relationship between elevation and detections differed between
187 the two time periods for each of the species. We used the predict function in R to generate
188 predicted detection rate and accompanying standard error values based on our fitted statistical
189 models across the range of elevations in our data set. We then graphed these values to visualize
190 the elevational ranges of both species in both time periods.

191 To promote transparency, we registered our analyses prior to conducting them (Steinmetz
192 and Parker 2021). Deviations from our registration are small and are due to an error on our
193 registered model specification. The function of the code remained the same as we intended in our
194 registration because after our corrections, the response variable was weighted by default
195 according to the number of observations. In addition, we did not register the curves we fitted
196 based on the parameter estimates to visualize the outcomes of the model. The rest of our methods
197 are consistent with our registration (Steinmetz and Parker 2021).

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199

Results

200 We first compared the elevational ranges between the two species in two separate analyses, one
201 with data from the earlier time period (1980-2004) and one with data from the later time period
202 (2015-2019). During the earlier time period, there were 115 hotspots at which at least one of the
203 two species was observed at least once. From those 115 hotspots, there were 9,352 total
204 checklists. Out of these checklists, 1,345 contained the Slate-throated Redstart, and 872
205 contained the Collared Redstart. During the later time period, there were 280 hotspots at which at
206 least one of the two species was observed at least once. From those 280 hotspots, there were
207 119,664 total checklists. Out of these checklists, 10,511 contained the Slate-throated Redstart,

208 and 6,494 contained the Collared Redstart. The graphed curves of the rate of detection of each
209 species across elevations substantially differed between the two species during both the earlier
210 and later time periods (Table 1, Fig. 1). Both species had a peak rate of detection at intermediate
211 elevations. The Collared Redstart had a peak rate of detection about 1,050 m higher than the
212 Slate-throated Redstart during the earlier time period and about 750 m higher during the later
213 time period.

214 We compared the elevational range of the Slate-throated Redstart between the earlier
215 time period (1980-2004) and the later time period (2015-2019). There were 270 hotspots at
216 which the Slate-throated Redstart was observed at least once during at least one of the time
217 periods. From those 270 hotspots, there were 63,799 total checklists, and of those checklists,
218 11,856 contained the Slate-throated Redstart. The graphed curves of the rate of detection of the
219 Slate-throated Redstart across elevations substantially differed in shape between the two time
220 periods (Table 1, Fig. 2). The curve for the later time period showed some evidence of a shift
221 upward into higher elevations. The Slate-throated Redstart had a peak rate of detection at an
222 intermediate elevation during both of the time periods, and this peak rate of detection was about
223 150 m higher during the later time period than during the earlier time period. However, the curve
224 for the later time period indicated a narrower elevational range than the curve for the earlier time
225 period, and the maximum elevation for detection during the later time period was lower than the
226 maximum elevation for detection during the earlier time period.

227 We compared the elevational range of the Collared Redstart between the earlier time
228 period (1980-2004) and the later time period (2015-2019). Across both time periods, there were
229 163 hotspots at which the Collared Redstart was observed at least once. From those 163 hotspots,
230 there were 43,301 total checklists, and of those checklists, 7,366 contained the Collared Redstart.

231 The graphed curves of the rate of detection of the Collared Redstart across elevations
232 substantially differed in shape between the two time periods (Table 1, Fig. 3). However, the
233 curve for the later time period did not show a clear shift upward into higher elevations. The
234 Collared Redstart had a peak rate of detection at an intermediate elevation during both of the
235 time periods, but this peak rate of detection was about 150 m lower during the later time period
236 than during the earlier time period. The curve for the later time period indicated a narrower
237 elevational range than the curve for the earlier time period, and the maximum elevation for
238 detection during the later time period was lower than the maximum elevation for detection
239 during the earlier time period.

240

241 **Discussion**

242 We found that Collared Redstarts were detected at higher elevations on average than Slate-
243 throated Redstarts over several decades, but only the Slate-throated redstart appeared to have
244 shifted its elevation of peak detection upslope over time. The clear difference in elevations
245 between the two species was expected, and is a valuable validation of our method of using eBird
246 hotspot records to detect patterns in these species' elevational ranges. Thus, despite our surprise
247 in failing to find a shift upward in the elevational range of the highland endemic Collared
248 Redstart over time, we are confident in this result. Further, recent work with other bird species in
249 tropical highlands around the world suggests that our finding of inconsistent elevational shifts
250 among species may be the norm (Neate-Clegg et al. 2020; Neate-Clegg et al. 2021a, 2021b).

251 As expected, our two study species had different elevational ranges that overlapped, and
252 the Collared Redstart was observed at higher elevations than the Slate-throated Redstart
253 consistently over several decades. Our graphs showed elevational ranges for both species that are

254 consistent with Costa Rican field guides (Henderson 2010, Garrigues 2014). Again, this finding
255 shows that our method of using eBird hotspots and checklists is reasonable and sufficient to
256 detect patterns in these species' elevational ranges.

257 More important, our results did not show consistent shifts upward in the two species'
258 elevational ranges over time. Although the peak rate of detection of the Slate-throated Redstart
259 was at a higher elevation during the later time period than during the earlier time period, the
260 maximum elevation for detection was lower for both species during the later time period, and the
261 peak rate of detection of the Collared Redstart was at a slightly lower elevation during the later
262 time period. These results lend only mixed support to the projected upslope shifts of tropical
263 montane bird species in response to climate change (Parmesan and Yohe 2003, Gasner et al.
264 2010, Forero-Medina et al. 2011, Şekercioğlu et al. 2012, Velásquez-Tibatá et al. 2013).
265 However, our results are in line with a growing body of work showing inconsistent shifts in
266 elevation by tropical montane bird species in response to climate change (Neate-Clegg et al.
267 2020; Neate-Clegg et al. 2021a, 2021b). Interestingly, of our two study species, it was the
268 endemic Collared Redstart that had been forecasted to be particularly susceptible to climate
269 change (Gasner et al. 2010), but it was the widespread Slate-throated Redstart that showed signs
270 of upslope movement. The Slate-throated Redstart's shift upslope in its elevation of peak
271 detection of about 150 m is equivalent to between 15 m per year (if we consider only the 10 year
272 gap between our two sampling periods) and 5 m per year (if we consider the full 30 year span of
273 our data). These estimates are within the range of values reported in other recent studies of
274 tropical montane birds (Neate-Clegg et al. 2020; Neate-Clegg et al. 2021a, 2021b).

275 When bird species do not show predicted upslope shifts as the climate warms, it may be
276 that they are instead responding to other climate variables, or to ecological variables impacted by

277 climate in complex ways (Currie and Venne 2017, Neate-Clegg et al. 2020). The potential
278 mechanisms behind climate change impacts on our two study species are not well understood,
279 and species' responses may depend on complex interactions within the cloud forest ecosystem
280 (Pounds et al. 2005, Londoño et al. 2017). It is reasonable to hypothesize that birds often respond
281 to the distribution of tree species, which of course are relatively long-lived and thus are
282 presumably limited to shift their distributions more slowly in response to climate change
283 (Forero-Medina et al. 2011, Alexander et al. 2018, Neate-Clegg et al. 2020). Of course, redstarts'
284 upslope movements may also especially depend on the availability of insects (Forero-Medina et
285 al. 2011, Şekercioğlu et al. 2012), their main food source (Henderson 2010), or complex biotic
286 interactions, such as interspecific competition (Terborgh and Weske 1975, Jankowski et al. 2010,
287 Forero-Medina et al. 2011, Şekercioğlu et al. 2012). It is also unclear what the direct impact of
288 temperature on these birds might be. Such direct effects might be weak if endothermy allows a
289 flexible response to temperature changes (Forero-Medina et al. 2011). More detailed study of
290 these redstarts' ecological niches, their tendencies to disperse, and the responses of the Costa
291 Rican cloud forests themselves to climate change may be required to better forecast the
292 responses of these bird species to climate change (Neate-Clegg et al. 2020, Neate-Clegg et al.
293 2021a).

294 Also notable was our observation that the elevational range curves for both species were
295 narrower in the more recent time interval. These narrower elevational ranges during the later
296 decades matched those in field guides for both species (Henderson 2010, Garrigues 2014).
297 Interestingly, previously observed reductions in elevational ranges of tropical montane birds
298 have been associated with upslope shifts (Freeman et al. 2018), but of course we observed a shift
299 upward in only one of our two species. Instead, the indicated reductions in the two species'

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330

331

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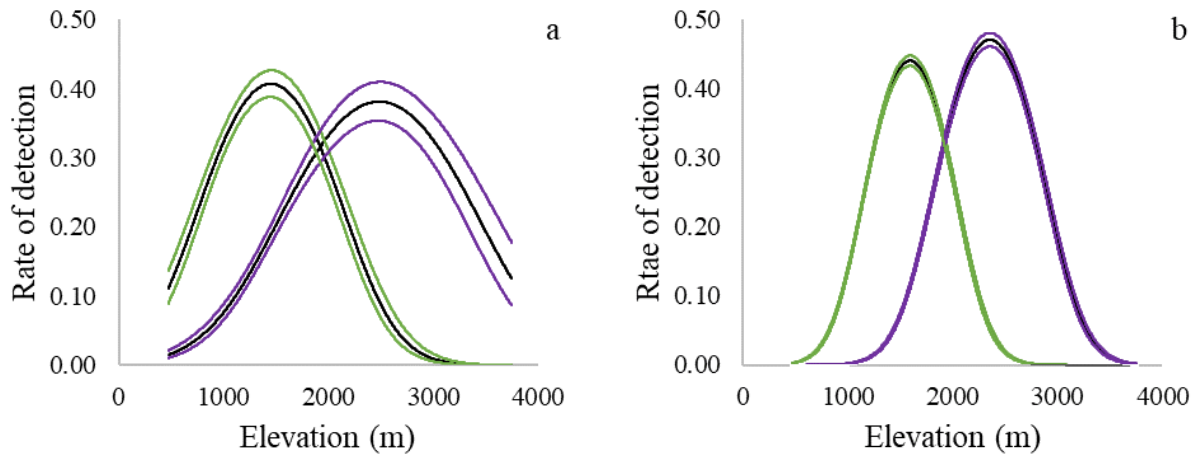
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438 Table 1. The results of four analyses of the rates of detection of the Slate-throated Redstart and
 439 the Collared Redstart across elevations in Costa Rica. These analyses are generalized linear
 440 models with binomial error and logit link. The first analysis compares the elevational ranges
 441 between the Slate-throated Redstart and the Collared Redstart during an earlier time period from
 442 1980-2004. The second analysis compares the elevational ranges between the two species during
 443 a later time period from 2015-2019. The third and fourth analyses compare the elevational range
 444 of each species separately between the two time periods.

Analysis	Variable	Estimate	Standard error	z	P-value
Time period: 1980-2004	Intercept	-6.11	0.32	-19.3	<0.0001
	Species	1.98	0.40	4.9	<0.0001
	Elevation	4.53×10^{-3}	3.25×10^{-4}	13.9	<0.0001
	Elevation ²	-9.12×10^{-7}	7.66×10^{-8}	-11.9	<0.0001
	Species \times elevation	6.39×10^{-4}	4.76×10^{-4}	1.3	0.18
	Species \times elevation ²	-8.70×10^{-7}	1.39×10^{-7}	-6.3	<0.0001
Time period: 2015-2019	Intercept	-18.56	0.27	-69.5	<0.0001
	Species	6.79	0.30	22.4	<0.0001
	Elevation	1.57×10^{-2}	2.55×10^{-4}	61.5	<0.0001
	Elevation ²	-3.33×10^{-6}	5.87×10^{-8}	-56.6	<0.0001
	Species \times elevation	-1.19×10^{-3}	3.18×10^{-4}	-3.7	0.0002
	Species \times elevation ²	-1.22×10^{-6}	8.51×10^{-8}	-14.3	<0.0001
Slate-throated Redstart	Intercept	-4.50	0.24	-18.7	<0.0001
	Time period	-7.13	0.28	-25.5	<0.0001
	Elevation	5.53×10^{-3}	3.35×10^{-4}	16.5	<0.0001
	Elevation ²	-1.87×10^{-6}	1.14×10^{-7}	-16.5	<0.0001
	Time period \times elevation	8.69×10^{-3}	3.86×10^{-4}	22.5	<0.0001
	Time period \times elevation ²	-2.57×10^{-6}	1.29×10^{-7}	-19.9	<0.0001
Collared Redstart	Intercept	-5.56	0.33	-17.1	<0.0001
	Time period	-12.01	0.42	-28.3	<0.0001
	Elevation	4.03×10^{-3}	3.32×10^{-4}	12.1	<0.0001
	Elevation ²	-8.10×10^{-7}	7.79×10^{-8}	-10.4	<0.0001
	Time period \times elevation	1.09×10^{-2}	4.21×10^{-4}	25.8	<0.0001
	Time period \times elevation ²	-2.37×10^{-6}	9.80×10^{-8}	-24.2	<0.0001

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447 Figure 1. The estimated rates of detection of the Slate-throated Redstart (left curve in each
 448 figure, with green confidence intervals) and the Collared Redstart (right curve in each figure,
 449 with purple confidence intervals) as a function of elevation from a generalized linear model
 450 during (a) an earlier time period from 1980-2004 and (b) a later time period from 2015- 2019.
 451 The green and purple curves show the lower and upper bounds of the 95% confidence interval.
 452 The shapes of the curves differed between the two species during both of the time periods. Both
 453 species had a peak rate of detection at an intermediate elevation during both of the time periods.
 454 (a) During the earlier time period, the Slate- throated Redstart had a peak rate of detection at
 455 about 1,450 m, and the Collared Redstart had a peak rate of detection at about 2,500 m. (b)
 456 During the later time period, the Slate- throated Redstart had a peak rate of detection at about
 457 1,600 m, and the Collared Redstart had a peak rate of detection at about 2,350 m.

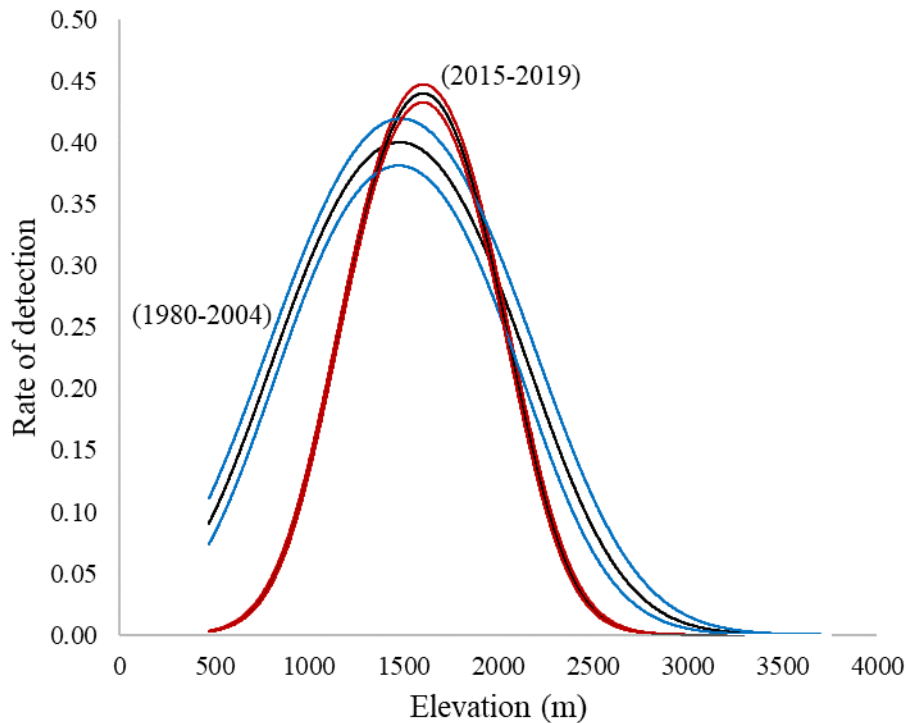
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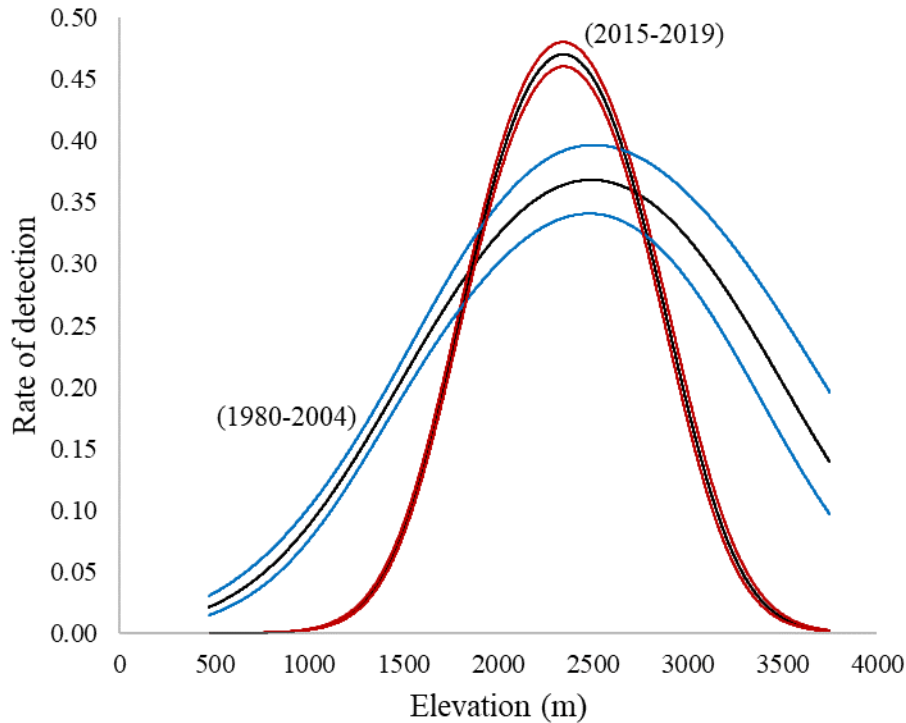
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 464 Figure 2. The estimated rate of detection of the Slate-throated Redstart as a function of elevation
 465 from a generalized linear model during an earlier time period (1980-2004) and a later time period
 466 (2015-2019). The blue and red curves show the lower and upper bounds of the 95% confidence
 467 interval for the earlier and later time periods, respectively. The shapes of the curves differed
 468 between the two time periods. The Slate-throated Redstart had a peak rate of detection at an
 469 intermediate elevation during both of the time periods: at about 1,450 m during the earlier time
 470 period and higher during the later time period at about 1,600 m. The curve for the later time
 471 period indicated a narrower elevational range than the curve for the earlier time period, and the
 472 maximum elevation for detection during the later time period was lower than the maximum
 473 elevation for detection during the earlier time period.

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478 Figure 3. The estimated rate of detection of the Collared Redstart as a function of elevation from
 479 a generalized linear model during an earlier time period (1980-2004) and a later time period
 480 (2015-2019). The blue and red curves show the lower and upper bounds of the 95% confidence
 481 interval for the earlier and later time periods, respectively. The shapes of the curves differed
 482 between the two time periods. The Collared Redstart had a peak rate of detection at an
 483 intermediate elevation during both of the time periods: at about 2,500 m during the earlier time
 484 period and lower during the later time period at about 2,350 m. The curve for the later time
 485 period indicated a narrower elevational range than the curve for the earlier time period, and the
 486 maximum elevation for detection during the later time period was lower than the maximum
 487 elevation for detection during the earlier time period.

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491 Appendix A. A partial list of the current, active protocol types available in eBird for data entry.
 492 More common protocols are at the top of the list. For our analyses, we included the protocols
 493 traveling, stationary, historical, random, and area counts, but excluded incidental and specialized
 494 protocol types not listed here. For additional information about these protocols and for a
 495 complete list of more specialized protocol types, see
 496 [https://support.ebird.org/en/support/solutions/articles/48000950859-guide-to-ebird- protocols](https://support.ebird.org/en/support/solutions/articles/48000950859-guide-to-ebird-protocols).

Protocol	Description
Traveling	Observations made over a known period of time while traveling a known distance
Stationary	Observations made over a known period of time at a single, fixed location (the observer did not go more than 30 m in any direction from the starting point)
Historical	Observations made when birding was the primary focus, but without a known start time, duration, or distance
Incidental	Observations made when birding was not the primary focus, resulting in an incomplete checklist
Area	Observations made for targeted, specialized surveys that exhaustively search a specific area
Random	Observations made at a randomly selected location over a period of at least five minutes

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506 Appendix B. When eBird contributors submit data, they define the type of location by choosing
507 from a list of locality types: hotspots (H), specific locations/personal (P), town (T), postal code
508 (PC), county (C), state (S). For our analyses, we only included data from hotspots because
509 hotspots are already existing locations on eBird maps that eBird has approved, making them
510 more reliable than locations that contributors submit themselves. In addition, each hotspot is
511 defined by a single latitude and longitude coordinate from which we found a single elevation for
512 each hotspot.

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