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Survival and extinction of breeding landbirds on San Cristóbal, a highly degraded island in the Galápagos

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Summary

We documented the consequences of large-scale habitat loss on a community of Galápagos native bird species on San Cristóbal island, based on point counts conducted between 2010 and 2017. Surprisingly, despite considerable habitat change and a variety of other threats, the landbirds of San Cristóbal have fared much better than on the neighbouring islands Floreana or Santa Cruz. While two species went extinct very soon after human colonisation, the majority have adapted well to subsequent vegetation change and habitat loss. The endemic San Cristóbal Mockingbird *Mimus melanotis* is more widespread than previously thought and its population seems to be stable since the 1980s. We thus propose a change in IUCN classification from 'Endangered' to 'Near threatened'. We present evidence gained by interviewing locals which suggests that a small population of the Least Vermilion Flycatcher *Pyrocephalus dubius*, classified as 'Extinct' by BirdLife International, may have persisted until very recently. Although extensive searches in 2018 and 2019 were unsuccessful, the possibility remains that a few birds may have survived in remote parts of the island. Further searches that involve the general public and other interested parties are therefore deemed necessary.

Introduction

Birds on oceanic islands are especially vulnerable to the impacts of human colonisation and its consequences. Introduced animals, habitat loss and direct persecution are the main drivers of declines and extinctions (Steadman 1995, 2006, Blackburn *et al.* 2004, Szabo *et al.* 2012, Donald *et al.* 2013). As the ranges and populations of many island species are inevitably smaller than those of continental species, it is thus not surprising that 97 of 108 bird extinctions since 1800 have occurred on islands (Johnson and Stattersfield 1990). Large-scale bird species extinction has been documented for the Hawaiian Islands (73 species), while 36 species from the Mascarene Islands and New Zealand have been lost (Cheke and Hulme 2008, Walters 2016). These well-known examples of extinctions are just the tip of the iceberg and one may safely conclude that the bones of additional extinct species still await their discovery on Pacific islands (Steadman 2006).

Human colonisation of the Galápagos Islands only started about 180 years ago and was centered on the fertile highlands of four islands, leaving most of the arid lowlands unaffected. Although the density of the human population remained low until fairly recently, farming activities have led to the nearly complete destruction of native vegetation in the humid highlands of the four inhabited islands (Watson *et al.* 2010). This large-scale habitat loss and degradation, effects of invasive alien animals and plants (Mauchamp 1997, Phillips *et al.* 2012, Cisneros-Heredia 2018) as well as direct human persecution have led to significant population declines in endemic plants and animals and even to mass species extinctions, such as in the land snails of the genus *Bulimulus* (Coppois and Wells 1987).

Birds seemed to be less affected and until recently the conservation status of landbirds was considered to be favourable (but see Wiedenfeld and Jiménez-Uzcátegui 2008). Nevertheless, a significant amount of genetic diversity in Darwin's finches has disappeared over the last 100 years (Petren *et al.* 2010) and several populations or subspecies have experienced substantial declines or have become extinct on inhabited islands (Grant *et al.* 2005, Dvorak *et al.* 2012, 2017).

Geologically speaking, San Cristóbal is the oldest island of the archipelago, with a comparatively long history of human occupation and land use. First colonised in 1866, the forests of the transition and humid zones were almost completely replaced by plantations and pastures by the end of the 19th century (Hickman 1985). These forests harbored an especially high number of endemic bird taxa: beside the endemic San Cristóbal Mockingbird *Mimus melanotis*, there were unique subspecies of Woodpecker Finch *Camarhynchus pallidus striatipecta*, Small Tree-finch *Camarhynchus parvulus salvini* and Grey Warbler-finch *Certhidea fusca luteola*. The Least Vermilion Flycatcher *Pyrocephalus dubius* was recently raised to full species status (Carmi *et al.* 2016).

The bird fauna of San Cristóbal has never been assessed comprehensively and the conservation status of its landbirds remains largely unknown, apart from some information about the endemic mockingbird (Curry 1989). Following a short visit in April 1996, Vargas (1996) concluded that "populations have apparently been greatly reduced" and "some populations of birds may be on the verge of extinction". Aside from habitat conversion, the invasive parasitic fly *Philornis downsi*, introduced during the late 1960s, represents a new major threat for landbirds as it severely reduces their reproductive success (Fessl *et al.* 2018).

A quantitative survey of the landbirds of San Cristóbal and their habitats was thus a priority in order to clarify their current conservation status (Fessl *et al.* 2017). This paper presents the results of surveys conducted on San Cristóbal during the breeding seasons of 2010 and 2015 to 2019. Our specific aims were to clarify the status of endemic taxa and to compare the results with historical data collected by the Galápagos expedition of the California Academy of Sciences in 1905–1906 (Swarth 1931).

Methods

Study area

San Cristóbal (Figure 1) is the easternmost island of the Galápagos archipelago and, with an area of 556 km^2, is the fifth largest (Snell *et al.* 1996). With approx. 7,100 inhabitants, the island has the second largest human population, most of it located in the coastal town of Puerto Baquerizo Moreno, with about 500 people in smaller settlements and farms in the highlands (INEC 2015). The south-western part of the island consists of a humid highland area (84 km^2). The transition zone starts at around 80–100 m and ranges up to 500 m on the northern flank, which lies in the rain shadow. On its south-facing slopes the transition zone gradually changes into the humid zone from 250 m upwards. The humid zone covers the uplands up to the summit at 730 m.

The transition zone in the eastern part is dominated by the introduced common guava *Psidium guajava*, whereas the lower-lying southern and western part is dominated by native trees (mainly guayabillo *Psidium galapageium*). The lowlands and low-lying hills are characterised by extremely arid conditions and are covered by dry-zone vegetation, dominated by *Bursera graveolens*, *Croton scouleri*, *Piscidia carthagenensis* and *Cordea lutea* with very few cacti (*Opuntia megasperma*, *Jasminocereus thouarsii*). In the south-western dry zone, the manzanilla tree *Hippomane mancinella* expands into the transition zone up to 280 m. Bare lava fields occupy a total of 32 km^2. Apart from a very small area (1.3 km^2) around the crater lake El Junco, the entire humid zone and upper part of the transition zone are currently designated as agricultural zones

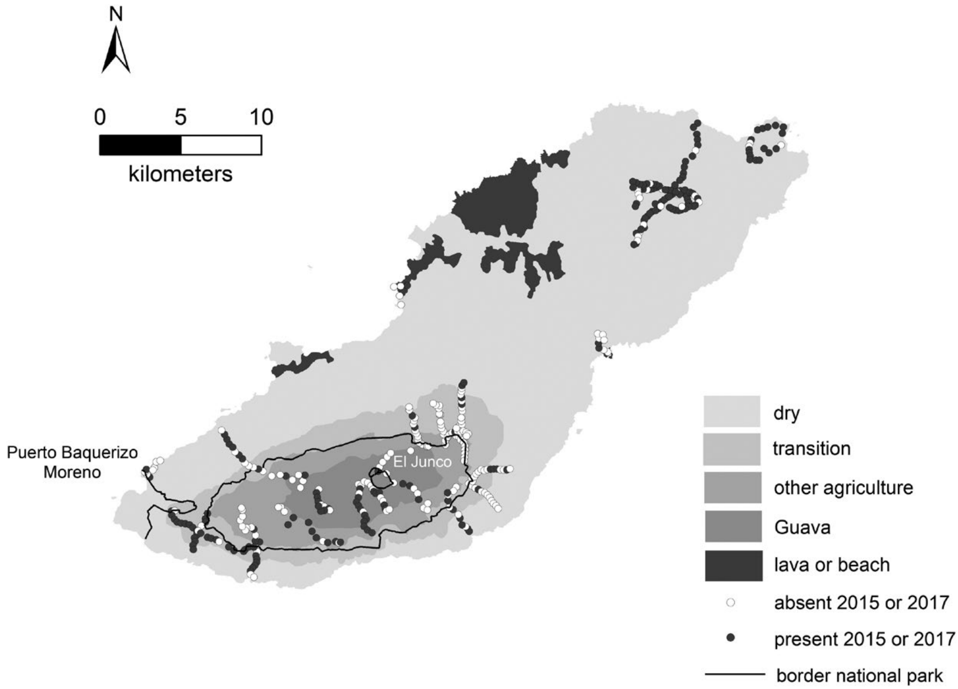

Figure 1. Distribution of survey points where San Cristóbal Mockingbirds were detected (black circles) or not detected (white circles) on San Cristóbal in either 2015 or 2017. Habitat types are represented in various shades of grey.

and private property. The lower reaches up to an altitude of about 300 m of the agricultural zone are heavily farmed (annual cultures, grassland, forest plantations, and pastures), while the higher elevations are largely covered by uniform stands of the introduced common guava, locally interspersed with pastures. Small areas have patches of the native miconia *Miconia robinsoniana.* All the remaining areas are dry and infertile and are part of the Galápagos National Park (see Figure 1).

For point sampling, we divided San Cristóbal into four broad habitat categories (Figure 1). The "Dry zone" (394.5 km^2) corresponds to the dry zone in the dataset of Huttel (1986). "Transition forest" (approx. 44.7 km^2) includes all parts of the transition zone not contained in the agricultural zone and therefore still in natural or near-natural state; while some areas in the north-east consist largely of alien species, namely old stands of common guava, blackberry *Rubus niveus* and lantana *Lantana camara*. "Farmland" is situated in the agricultural zone and is actively farmed today (49.3 km^2). The "Guava-pasture zone" (34.7 km^2) is the upper part of the agricultural zone, from 300 m up to the highest point at 730 m (including the area around El Junco, which is part of the National Park). The spatial delimitation of the guava-pasture zone includes the "very humid" zone as defined by Huttel (1986), which was modified according to data from our field surveys. Each location for point counts was assigned to one of these four habitat categories.

Bird counts

Bird counts of all landbird species present were conducted at 461 census points in January or February 2010, 2015 and 2017 during the period of highest song activity of most landbirds, corresponding to the breeding season in the Galápagos Archipelago (Table 1). Surveys were carried out in the mornings between 06h00 and 10h30 before conditions became too hot and song activity ceased. All counts were conducted along existing small roads and paths.

Five-minute point counts with distance estimates were used for all quantitative surveys. We measured the distance between observers and birds with laser rangefinders (Nikon Laser 550 and 550a) or estimated it to the nearest 5 m on a scale between 0 and 20 m, and to the nearest 10 m beyond 20 m. If a bird was seen to take flight, the distance to the take-off point was estimated. Flying birds were omitted from the counts. At the start of each year's fieldwork, calibration sessions for song recognition and distance estimation were held by participants. For most species, only singing males were recorded, including duetting pairs for the Galápagos Flycatcher *Myiarchus magnirostris* and calling individuals of the San Cristóbal Mockingbird.

In November 2016, during a Galápagos giant tortoise *Chelonoidis chathamensis* census (organized by WT), 45 observers recorded San Cristóbal Mockingbirds and paid attention to the possible occurrence of Least Vermilion Flycatcher and Galápagos Dove *Zenaida galapagoensis*. The area covered is shown in Figure S1 in the online Supplementary material.

In July 2016 and January 2018, 54 people from San Cristóbal were interviewed about past and recent sightings of Least Vermilion Flycatchers (DA, BF, EN). Between 25 and 28 January 2018 and 22–26 January 2019, specific searches for the Least Vermilion Flycatcher were conducted in certain parts of the island, where sightings were reported recently or at sites that contain larger areas of suitable habitat. Playbacks of singing males were broadcast for at least two minutes at points, at intervals between 200 and 300 m along survey routes. In total, 392 points were visited during 18 person-days in both years (Figure S1).

Analysis

Population densities for nine bird species were estimated using the program *Distance v. 6.2* (Thomas *et al.* 2006). When there were at least 60–80 records, as recommended by Buckland *et al.* (2001), we calculated separate estimates for each of the four habitat categories. The main assumption of *Distance* is that all birds present at an observation point are detected. The program then calculates the number of birds present, but not detected, from the way in which their number varies with distance from the point. To determine the pattern in which detectability declines with distance, we used four separate combinations of key functions and expansions (Buckland *et al.* 2001). The distance data were then grouped into intervals to address the problem of heaping. Up to 10% of the most distant records were truncated to eliminate outliers. The distance bands used differed between species: 20-m intervals for species with loud, far-carrying songs (San Cristóbal Mockingbird, Woodpecker Finch) and 10-m intervals for species with songs of lower volume (all other species). Detection probabilities among zones, years and species were compared using the effective detection radius (EDR), which is the distance at which the probability of detecting an individual further away equals the probability of missing an individual within that

Table 1. Number of census points visited during the different survey periods in the four different vegetation zones.

Year	Period	Number of census points				Sum of census points	Surveyed by
		Dry zone	Transition zone	Farmland	Guava-pasture		
2010	January 21-26	14	5	50	30	99	MD, EN
2015	February 2-7	40	35	39	67	181	MD, EN, BF
2015	February 2-7	50	13			63*	JC, G. Samaniego, G. Robinson
2017	February 3-5	106	75			181	MD, EN, DA, BW, CS

*At these additional census points, only San Cristóbal Mockingbirds were counted.

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radius (Buckland *et al.* 2001). When individuals were approaching the observers (sometimes the case with San Cristóbal Mockingbird and Galápagos Flycatcher), the distances were corrected to the mean detection distance.

Mean densities and 95% CIs were calculated by bootstrapping with 1,000 iterations. The area of each of the four habitat categories was multiplied with calculated densities to obtain population size estimates for different zones. For all species except San Cristóbal Mockingbird and Galápagos Flycatcher, estimated population densities represent the densities of singing males. Despite a possible, but unknown proportion of unpaired males, the final population estimates were expressed as breeding pairs. Territories of the San Cristóbal Mockingbird were sometimes occupied by trios: among 62 territories at three study sites 21 (34%) held trios, while the rest had pairs (Curry 1989). We thus used a correction factor of 0.66 to obtain a more reliable estimate of breeding territories.

Population estimates for farmland and guava-pasture were based on data from 2015; estimates for dry and transition zones were based on combined data from 2015 and 2017. Occupancy rate was the percentage of points where a given species was counted. For the farmland and guava-pasture we had enough point counts (80 in 2010 and 107 in 2015) to test the influence of a year. For each species we analysed the effect of a year on the number of birds counted in the farmland and guava-pasture zones using a generalized linear model with a Poisson error distribution. In each model, year (2010 and 2015) and habitat (farmland, guava-pasture) were used as predictors. For statistical analyses, we used R 3.3.2. (R Core Team 2017).

Results

During point counts we detected 14 landbird species (Table 2). For nine species we obtained enough data to calculate breeding densities (Figure 2) and estimate population sizes (Table 3). Least Vermilion Flycatcher, Galápagos Rail *Laterallus spilonotus* and Galápagos Hawk *Buteo galapagoensis* were not recorded (Table 2).

Table 2. Total number of bird observations, average observations/point and percentage of all birds counted in 2010, 2015 and 2017, starting with the most frequent bird species. For comparison, the number of specimens collected (and the percentage of all birds collected) during the expedition of the California Academy of Science in 1905-1906 is given. E = endemic, N = native and I = introduced.

Species	2010, 2015, 2017			1905-1906	
	Number of observations	Observ./point	%	N	%
Small Ground-finch E *Geospiza fuliginosa*	1148	1.98	22.98	155	19.35
Yellow Warbler N *Setophaga petechial*	1145	1.98	22.92	71	8.86
Grey Warbler-finch E *Certhidea fusca*	761	1.31	15.24	51	6.37
Small Tree-finch E *Camarhynchus parvulus*	683	1.18	13.67	116	14.48
San Cristobal Mockingbird E *Mimus melanotis*	320	0.55	6.41	133	16.60
Woodpecker Finch E *Camarhynchus pallidus*	270	0.47	5.41	10	1.25
Medium Ground-finch E *Geospiza fortis*	268	0.46	5.37	94	11.74
Galápagos Flycatcher E *Myiarchus magnirostris*	177	0.31	3.54	27	3.37
Smooth-billed Ani I *Crotophaga ani*	133	0.23	2.66	Absent	
Vegetarian Finch E *Platyspiza crassirostris*	47	0.08	0.94	26	3.25
Dark-billed Cuckoo N *Coccyzus melacoryphus*	23	0.04	0.46	15	1.87
Paint-billed Crake N *Neocrex erythrops*	11	0.02	0.22	Absent	
Common Cactus-finch E *Geospiza scandens*	9	0.02	0.18	6	0.75
Galápagos Dove E *Zenaida galapagoensis*	Single observations			3	0.37
Least Vermilion Flycatcher E *Pyrocephalus dubius*	Absent			94	11.74
Galápagos Rail E *Laterallus spilonotus*	Absent*			Absent	
Galápagos Hawk E *Buteo galapagoensis*	Absent			1	

*One typical vocal response to playback calls in 1987 by D. Rosenberg (pers. comm).

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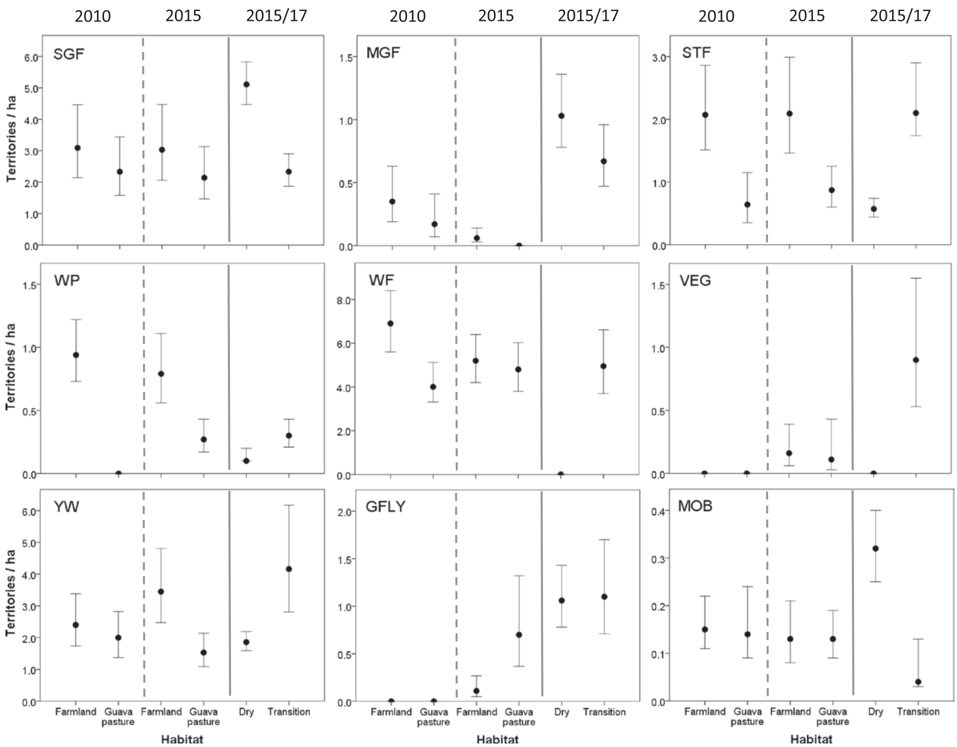

Figure 2. Density estimates (singing males = territories/ha) for nine bird species and four ecological zones on San Cristóbal determined using the program Distance 6.2. For each species and zone, average density values ± 95% confidence intervals are provided. The humid farmland zone and guava pasture were counted both in 2010 and 2015, while combined values from counts in 2015 and 2017 are given for the dry zone and the transition zone. Exceptions are the Woodpecker Finch and the Vegetarian Finch, for which data is only available from 2017 for the dry zone and from 2015 for the transition zone. Species abbreviations: Small Ground-finch = SGF, Medium Ground-finch = MGF, Small Tree-finch = STF, Woodpecker Finch = WP, Grey Warbler-finch = WF, Vegetarian Finch = VEG, Yellow Warbler = YW, Galápagos Flycatcher = GFLY, San Cristóbal Mockingbird = MOB.

Threatened species

Three breeding birds of San Cristóbal are included in one of the Red List threatened categories (IUCN 2012). The Least Vermilion Flycatcher is classified as 'Extinct' and was not found during our surveys, nor during giant tortoise monitoring or specific searches (see Figure 1 and Figure S1). Interviews with residents showed that most people under the age of 25 did not even know about its occurrence in San Cristóbal, while 27 people older than 40 could name specific sites. This eye-catching bird was apparently still widespread in the 1970s and observed from the coast up to the highlands, including villages. In the 1980s reports became less frequent; one interviewee mentioned a significant decrease after the El Niño event of 1982/83. During the 1990s and up to around 2010, the number of reports further declined, suggesting that the species became very rare during these decades (Table S1). Surprisingly, in 2016 a reliable report from a farm became known and was confirmed during interviews in January 2018. However, during our specific searches in January 2018 and 2019 we failed to locate any surviving individuals.

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Table 3. Lower and upper values for confidence intervals of population estimates (number of territories) for nine species on San Cristóbal Island, with estimates to the nearest thousand. Estimates for farmland and guava-pasture were calculated with densities from 2015; for the dry zone and transition zone the combined values of 2015/2017 were used.

Species	Number of territories (lower and upper C.I.)
Small Ground-finch	200,000–276,000
Medium Ground-finch	34,000–61,000
Small Tree-finch	33,000–58,000
Woodpecker Finch	8,300–16,800
Grey Warbler-finch	51,000–82,000
Vegetarian Finch	3,000–9,000
Yellow Warbler	92,000–146,000
Galápagos Flycatcher	36,000–69,000
San Cristóbal Mockingbird	10,000–19,000

The San Cristóbal Mockingbird, currently classified as 'Endangered', was recorded on almost half of the census points (46.7%) in all vegetation zones. Highest occupancy rates and densities were found in the dry zone (43–78%; 0.32 territories/ha). Mockingbirds were widespread in farmland (42–47% occupancy) and open uplands with native *Miconia* and introduced guava (43–46% occupancy), albeit with lower densities (Figure 2). The total breeding population is estimated at 10,000–19,000 breeding territories (Table 3).

The population strongholds of the Woodpecker Finch, classified as 'Vulnerable' since 2015, were in the humid zone with occupancy rates of 40 to 88% and breeding densities of 0.3 to 0.9 pairs/ha (Figure 2). The species was sparsely distributed in the arid part of the island with occupancy rates of only 2.5% in 2015 and 14.2% in 2017. Breeding densities were 10 times lower than in the wet highlands. The total breeding population is estimated at 8,000–17,000 breeding pairs (Table 3).

Non-threatened species

The two most common bird species on San Cristóbal were Small Ground-finch *Geospiza fuliginosa* and Yellow Warbler *Setophaga petechia*, both widespread with mean occupancy rates of > 75% and > 90% respectively. Because of its wide distribution in the dry zone, the Small Ground-finch was by far the most common breeding bird (Table 3), with densities of 1.8–3.1 pairs/ha in the highlands and up to 5.1 pairs/ha in the dry zone (Figure 2).

The Yellow Warbler had its highest densities in the transition zone (4.16 pairs/ha) and in farmland (2.40 in 2010, 3.45 in 2015) and much lower densities in the dry (1.86) and guava-pasture zone (1.97 in 2010 and 1.53 in 2015). The total breeding population was estimated at over 100,000 pairs (Table 3).

The equally widely distributed Small Tree-finch (occupancy rate > 60% in all three years, all habitats combined) reached its highest population densities in the transition zone (2.1 pairs/ha in 2015/17) and in farmland (2.1 pairs/ha in both 2010 and 2015). It was less common in the dry zone (0.44 pairs/ha in 2015/17) and in the guava-pasture area (0.6.–0.9 in 2010 and 2015). The total breeding population was estimated at 33,000–58,000 pairs. Grey Warbler-finches were largely absent from the dry zone and common above 100 m, with densities ranging between 4.0 and 6.9 pairs/ha. The total breeding population was estimated at 50,000-80,000 pairs (Table 3).

Medium Ground-finches *Geospiza fortis* were more locally distributed than their smaller cousin, with occupancy rates of 64.3% (2010), 35% (2015) and 63.2% (2017) in the dry zone and an overall density of 1.03 pairs/ ha. Occupancy rates in the different parts of the transition zone varied greatly with 82.4% in 2015, but only 28% in 2017 and overall density was lower (0.67 pairs/ha). The species was sparsely distributed in areas of higher altitude, with occupancy rates generally below 30% and densities under 0.3 pairs/ ha (Figure 2). The total breeding population was estimated at 34,000–61,000 pairs.

The Galápagos Flycatcher was widespread in the dry and transition zone with occupancy rates of 50–57% and estimated densities of around 1 pair/ha, except for the north-eastern transition zone that had lower occupancy rates (22%). The occupancy rate in the highland area was < 15%, with densities of 0.11 to 0.7 pairs/ ha (Figure 2). The total breeding population was estimated at 36,000–69,000 pairs.

The Vegetarian Finch *Platyspiza crassirostris* was locally distributed and largely confined to the south-western parts of the transition zone and lower parts of the farmland, where it occurred at high densities of up to 0.9 singing males/ha. Its population was estimated at around 6,000 pairs (Table 3). Finally, the introduced Smooth-billed Ani *Crotophaga ani* was mainly found in the agricultural and urban zones (including adjacent areas of the dry and transition zone) but was largely absent (only one record during the point counts) in the dry zone of the central and eastern part. Average group size was 3.6 birds ($n = 26$) with maximum of eight birds.

Four breeding species were encountered in very low densities. Eight Galápagos Doves were observed in the dry zone in the eastern part of the island, seven of those during the giant tortoise census. In interviews, several people confirmed that the dove can readily be seen at farms, which we were unable to confirm.

For the Common Cactus-finch *Geospiza scandens*, we recorded only one in 2010, none in 2015, two in 2016 during the giant tortoise census and eight at one site, Jardín de Opuntia, in 2017.

The Paint-billed Crake *Neocrex erythrops* was recorded from 10 of 461 counting points, with three additional sightings from overgrown pastures in the humid zone above 400 m. There was also a record of two single individuals lower down in farmland, at around 130 m.

Another rare and local species was the Dark-billed Cuckoo *Coccyzus melacoryphus*, with 22 individuals recorded (1 in 2010, 9 in 2015 and 12 in 2017) in all four habitat types.

Comparison of counts in 2010 and 2015

None of the seven species showed a significant decrease in their numbers in both farmland and guava-pasture (Table 4).

Discussion

Population changes and extinctions

Despite the near total loss of natural highland vegetation and in contrast to the bleak picture drawn by Vargas (1996), the landbirds of San Cristóbal fared much better than anticipated over the last 100 years. Since we did not find significant differences in bird numbers in 2015 compared to 2010, our surveys indicate stable populations for all seven analysable species, at least in the highlands (Table 4).

Nevertheless, three species were lost during the 19th century and one disappeared in the 20th century (Table 2). The Galápagos Hawk was extirpated soon after human colonisation; the last specimen was collected in 1905 (Swarth 1931). Both Large Ground-finch *Geospiza magnirostris* and Sharp-beaked Ground-finch *Geospiza difficilis* were collected in 1835 by members of the Beagle Expedition (Sulloway 1982), but not found subsequently. There is only a single recent record of a calling Galápagos Rail from January 1987 (Rosenberg 1990).

In general, species that were already rare at the beginning of the 20th century are still rare nowadays, and species common at the beginning of the 20th century are still common today (Swarth 1931). Thus, while some species declined or went extinct very soon following human colonisation, the majority have adapted well to subsequent vegetation change and habitat loss.

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Table 4. Comparison of bird counts in the guava-pasture and farmland zone in 2010 and 2015. Number of observations, number of points with records of the species, encounter rate (percentage of points with records), and number of singing or calling birds per point in 2010 (80 points) and 2015 (106 points). When sample sizes were sufficient, we tested for possible differences in the number of birds observed per point between years. Therefore, we first calculated GLMs where the numbers of observations per point are predicted by habitat or by habitat and year. We then used a log-likelihood tests to check whether a model with year and habitat explained more deviation than models with habitat as the only predictor. *P* -values < 0.05 indicate a significant difference in the number of observations between years.

	Number of observations		Points with records		Encounter rate		Observations per point		
Species	2010	2015	2010	2015	2010	2015	2010	2015	**P**
Small Ground-finch	161	178	71	78	88.8	73.6	2.01	1.68	0.51
Medium Ground-finch	21	6	19	6	23.8	5.7	0.26	0.06	#
Small Tree-finch	127	157	56	72	70.0	67.9	1.59	1.48	0.82
Woodpecker Finch	64	100	52	72	65.0	67.9	0.80	0.94	0.20
Grey Warbler-finch	216	248	75	94	93.8	88.7	2.70	2.34	0.80
Vegetarian Finch	3	13	3	8	3.8	7.5	0.04	0.12	#
Yellow Warbler	158	238	72	97	90.0	91.5	1.98	2.25	0.32
San Cristóbal Mockingbird	34	49	31	43	38.8	40.6	0.43	0.46	0.37
Dark-billed Cuckoo	0	4	0	4	0.0	3.8	0.00	0.04	#
Smooth-billed Ani	31	42	31	38	38.8	35.8	0.39	0.40	0.77
Paint-billed Crake	0	4	0	4	0.0	3.8	0.00	0.04	#

Numbers too small for calculation

The endemic Least Vermilion Flycatcher

The Least Vermilion Flycatcher is a notable exception to this picture. It was collected in large numbers (94 specimens) in 1905 and 1906 (Swarth 1931) and described as "quite common" by Gifford (1919), it was still common in 1929 (Fisher and Wetmore 1931) but described as very rare by the early 1980s (Steadman and Zousmer 1988). In 1996, Hernan Vargas could not find the species during a one-week visit and only mentions a single record by local naturalist J. Gordillo from 1987 (Vargas 1996).

Based on this information, BirdLife International (2017) categorised the species as 'Extinct' with the last records dating to the 1980s. However, the numerous reports by inhabitants of San Cristóbal since that time (Table S1) strongly suggest that the species was not extinct but survived at least until very recently: In a very short period of time (2 weeks), our interviews of local people revealed at least 25 sightings from 1976 to 2016 (Table S1, Figure S1). Although no photographic evidence exists, the conspicuous bright red plumage of the males, the absence of other bright red birds in Galápagos and its popularity among local people make these records very plausible. While it is possible that the reports include vagrant Little Vermilion Flycatchers *Pyrocephalus nanus* from other islands, these reports cover a large area in the south of San Cristobal (see Figure S1) which makes it unlikely that they concern single stragglers from other islands. On the negative side, during our point counts from 2010 to 2017, January 2018 and 2019 we visited a large portion of the former range and most of the sites that had reports of recent observations. We conclude that our failure to discover any remaining birds is almost certainly due to absence of a larger population. We believe that at best some remnant single individuals or pairs still remain, but think it is more plausible that the species went extinct very recently, most likely during the last 10 years. Butchart *et al.* (2006) define 'Possibly Extinct Species' as "those that are, on the balance of evidence, likely to be extinct, but for which there is a small chance that they may be extant and thus should not be listed as Extinct until adequate surveys have failed to find the species and local or unconfirmed reports have been discounted". The Least Vermilion Flycatcher (partly) fulfills only two out of four types of evidence for extinction, but three out of four types of evidence against extinction. We therefore conclude that the species should, for the time being, be classified as 'Critically Endangered', but consider the additional qualifier of 'Possibly Extinct' as appropriate.

The endemic San Cristóbal Mockingbird

Curry (1989) reported an average population density of 0.6 birds/ha and later estimated a declining population of 8,000 individuals (BirdLife International 2016). Based on this information, the species was assigned the status 'Endangered' in 2006. Our surveys resulted in similar density estimates, with partly higher numbers for the dry zone habitat and lower numbers in guava-pasture (Figure 2). However, while Curry (in BirdLife International 2016) concluded that only around 25% of the island was occupied by the species, we found the mockingbird in all four habitat types (Figure 1), including scrub woodland and cactus scrub, which were noted as unoccupied by Curry (1989). Hence, our total population estimate of at least 10,000 territories is four times higher than the number cited by BirdLife International (2016). Considering its still wide distribution and relatively high densities, we find no indication for a population decline. We propose to re-classify the San Cristóbal Mockingbird as 'Near Threatened', since none of the criteria A-E for threatened status apply (IUCN 2012).

Rare species

Our records of the Paint-billed Crake are the first confirmed observations on San Cristóbal, but this is a very secretive species and therefore was most probably overlooked before. The Galápagos Dove, with eight individuals found in the dry zone, was already rare 110 years ago, when only three specimens were collected by the Academy expedition (Swarth 1931). Dark-billed Cuckoo was rarely recorded during our study, but it is a regular breeding bird on San Cristóbal and was already collected in small numbers in 1905–1906 (Swarth 1931). Its real abundance is very difficult to assess, as song activity varies greatly among years (MD and BF, pers. obs.). The Common Cactus-finch depends largely on the presence of cacti (mainly *Opuntia* sp.), which are very rare and local on the island, probably due to destruction by introduced mammals in the 19th century (Phillips *et al.* 2012). We only found the species at three sites: Jardín de Opuntias in the south-east and two places at La Galapaguera Natural in the eastern part. Its rarity does not seem to be a recent development, as the Academy Expedition collected only six birds in 1905–1906 (Table 2).

Threats and population changes compared to other inhabited Galápagos Islands

Habitat alteration

The original humid forest vegetation has largely been replaced by cultivation on all inhabited Galápagos Islands (Watson *et al.* 2010, Mauchamp and Atkinson 2010). The consequences of this severe habitat loss have been quite varied on the different islands. While Floreana has lost no less than 10 of 22 originally occurring species (Dvorak *et al.* 2017), the other three islands have largely retained their original avifauna (Dvorak *et al.* 2012, this study). The degree of preservation of the original humid forest (measured as the percentage of remaining *Scalesia* forest, prime habitat for insectivorous birds) was lowest in San Cristóbal and Isabela (on both islands practically zero), highest in Floreana and intermediate on Santa Cruz (Mauchamp and Atkinson 2010). Therefore, today, the presence or absence of natural forest habitat does not appear to affect the extinction risk or even the densities of insectivorous birds. However, the situation may have been different historically, as at least one species (Sharp-beaked Ground-finch) was described as a habitat specialist that is confined to a special type of highland forest (Schluter and Grant 1984); it likely disappeared from Santa Cruz and San Cristóbal soon after settlers started clearing this type of vegetation in the second half of the 19th century.

Introduced predators

San Cristóbal has introduced Smooth-billed Ani, dogs *Canis lupus familiaris*, cats *Felis silvestris catus*, House Mouse *Mus musculus*, Black Rats *Rattus rattus* and Norway Rats *Rattus norvegicus* (Phillips *et al.* 2012), all of them potential predators of birds and theirs nests. The almost complete disappearance of the Galápagos Dove on all inhabited Galápagos Islands (Dvorak *et al.* 2017, Fessl *et al.* 2017) is commonly ascribed to the presence of feral cats (Harris 1973, Konecny 1987) and this certainly also applies to San Cristóbal. The other possibly impacted species is the Vermilion Flycatcher, whose nest sites can be very exposed (pers. obs.) and hence are particularly prone to predation. Introduced mammals (rats and cats in particular) are believed to be the main factor behind the disappearance of the mainly ground-dwelling Floreana Mockingbird *Mimus trifasciatus* on Floreana (Curry 1986, Steadman 1986), but their negative effect on the population of the San Cristóbal Mockingbird seems to be limited.

Introduced parasites and diseases

Nowadays, the invasive parasitic fly *Philornis downsi* represents the main risk factor for small landbirds on Galápagos (Fessl *et al.* 2018), as it can severely impact their breeding success (e.g. Koop *et al.* 2011, Cimadom *et al.* 2014). *Philornis downsi* occurs on San Cristóbal, but little is known about its abundance and impact (Fessl *et al.* 2018). In conjunction with other possible, but unknown factors (nest predation, avian pox, pesticides, habitat change etc.), *Philornis* may be the main driver of the almost complete disappearance of the Least Vermilion Flycatcher. *Philornis* might have been the factor that tipped the balance, resulting in the loss of the Grey Warbler-finch and Little Vermilion Flycatcher in Floreana (Grant *et al.* 2005, Bulgarella *et al.* 2018). It is the main factor responsible for the decline of six landbird species in Santa Cruz (Dvorak *et al.* 2012).

Conservation actions and management – expected future changes

Some habitat restoration is in progress on San Cristóbal; e.g. the area around El Junco was successfully restored with *Miconia* (Bush *et al.* 2014). A small reforestation project with the endemic *Scalesia pendunculata* has started in a private reserve (San Cristóbal Biological Reserve Jatun Sacha), but only a large-scale restoration programme, similar to that planned in Santa Cruz (Wilkinson *et al.* 2005) would be beneficial to landbirds (Dvorak *et al.* 2012, 2017). In southern Isabela, where *Scalesia* forest has been destroyed (Mauchamp and Atkinson 2010), large areas are dominated by uniform stands of guava and pasture, which seem less suitable for many bird species, including the Little Vermilion Flycatchers (Charles Darwin Foundation, BF unpubl. data).

The Galápagos National Park Directorate puts continuous effort into the control and possible eradication of introduced vertebrates. So far, the Rock Pigeon *Columba livia*, a known potential disease transmitter (Padilla *et al.* 2004), was eradicated from Galápagos in 2006 (Phillips *et al.* 2012). Donkey *Equus asinus*, goat *Capra hircus* and cattle *Bos taurus* numbers were reduced in San Cristóbal in the last 10 years, with unknown numbers remaining (Phillips *et al.* 2012). Dog and cat sterilisation programs are operating. Control of feral cats is only done on specific sites and needs to be amplified and combined with rodent control. We especially recommend surveys and control of the Norway rat in the farmland zone to reduce its further spread to more natural vegetation.

Baseline studies on the impact of *Philornis* in San Cristóbal are in progress (Carrión-Avilés 2015, S. Knutie pers. comm.). A multi-institutional group is working intensively to find ways to reduce *Philornis* infestation (Causton *et al.* 2013). Large-scale methods are still missing, but a method to inject insecticide into bird nests has been developed by Cimadom *et al.* (2014) and can be used to protect the nests of species of highest conservation concern or selected sites, as is currently done for the critically endangered Mangrove Finch *Camarhynchus heliobates* (F. Cunninghame pers. comm.) or the Little Vermilion Flycatcher in Santa Cruz (D. Mosquera *et al.* unpubl. data). Active and passive surveillance data for the presence of several diseases and their vectors, either already detected in Galápagos or classified to be of potentially high risk, need to be amplified (see (Huyvaert 2018, Padilla *et al.* 2018, Parker *et al.* 2018).

While the above-mentioned measures should be implemented to reach the medium-term goal to preserve the avifauna of San Cristóbal, immediate action is crucial to confirm whether a breeding population of Least Vermilion Flycatcher is still present and, if so, to implement measures to prevent its extinction.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S0959270919000285

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