Is the population of Floreana Mockingbird *Mimus trifasciatus* declining?

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El Cucuve de Floreana *Mimus trifasciatus* es una de las cuatro especies endémicas de cucuves en Galápagos, el cual está en Peligro Crítico según la lista roja de la UICN. Esta especie habita en los islotes Gardner-por-Floreana y Champion, ambos cerca de la isla Floreana. En los censos realizados entre 2003–08, el índice poblacional tuvo variaciones entre 85 a 225 y un promedio de 168 (± 55) individuos. La población de juveniles tuvo asociación positiva con la precipitación. En los dos islotes no se registraron especies de vertebrados introducidos 'agresivos' establecidos, las cuales fueron una de las posibles causas de la extinción del Cucuve de Floreana en el siglo XIX en la isla Floreana. A futuro, el cambio climático podrá alterar la frecuencia y fuerza de fenómenos naturales para las islas como el caso de El Niño, igualmente, podrá 'aportar' en el establecimiento de especies de vertebrados y invertebrados agresivos, afectando a poblaciones indígenas pequeñas, como es este caso en particular. También, la pérdida de la variabilidad genética en estas poblaciones tan pequeñas y su aislamiento es importante de considerar. Por lo tanto, conocer la dinámica poblacional y las amenazas frente a la variación climática ayudará, a su conservación a largo plazo, principalmente, al existir planes de reintroducir la especie a la isla Floreana en el futuro.

Floreana Mockingbird *Mimus trifasciatus* is one of four species of mockingbirds found in the Galápagos Islands. The first non-scientific record of this species on Floreana Island was made by David Porter in 1813[23]. Charles Darwin collected it when he visited the island in 1835 and reported that the species was 'common'. The last individual collected on Floreana was by Kingberd[27] in 1852, and the species was last seen there in 1868 by Simeon Habel[24]. It is believed to have become extinct on Floreana by 1880[26]. Fortunately, small remnant populations remain on the small islets of Champion and Gardner-by-Floreana (hereafter Gardner), both adjacent to Floreana. Due to the increasing threats posed by invasive species and pathogens, the small population size and restricted range, this species is considered one of the most threatened birds in the world and is currently listed as Critically Endangered[18].

Reasons for the extinction of Floreana Mockingbird on Floreana are uncertain, but it has been associated with predation by introduced Black Rats *Rattus rattus*, feral cats *Felis catus* and feral dogs *Canis familiaris*, the loss of cactus *Opuntia megasperma* (a nesting site for mockingbirds) due to grazing by introduced goats *Capra hircus*, and nest destruction by introduced House Mice *Mus musculus*[5,14,26]. Champion and Gardner lack introduced mammals[19,20] and maintain viable populations of *Opuntia megasperma*.

Prior to this study, Floreana Mockingbird population estimates for Champion ranged from 24–53 birds, with that on Gardner considered to be three to five times larger[6,12,14] (Table 1). This suggests a total population of <250 individuals. A population viability study for Champion suggested that mockingbirds there possess <50% chance of survival over the next 100 years (R. L. Curry unpubl.); no such analysis has been undertaken for Gardner[22].

Annual surveys of Floreana Mockingbird on both islets commenced in 2003 following a standardised protocol. Both islets are visited annually and all mockingbirds in accessible areas are counted. The islets are also surveyed for introduced species and other threats. Here we report population counts for Champion and Gardner in 2003–08 and discuss the current status of the mockingbird and potential threats to its survival.

Methods

Study sites.—The islets of Champion (90°23.100'W 01°14.240'S) and Gardner (90°17.700'W 01°19.969'S) lie north-east and east of Floreana (90°26.060'W 01°17.865'S), respectively. Champion has a total area of 9.4 ha and is just 700 m distant from Floreana. Gardner has a total area of 76.5 ha[2] and is separated from Floreana by 8 km[14]. The two islets are 14 km apart (Fig. 1).

The islets differ in their structural characteristics. Gardner is a much steeper and more rugged islet than Champion, reaching an elevation of 210 m. It is a steep-sided tuff cone, surrounded by vertical cliffs of 50–100 m. A 100-m high plateau covers approximately the eastern third of the islet. Champion, in contrast, is much lower, reaching a max. of just 50 m. The centre of the island is dominated by a crater, but a plateau

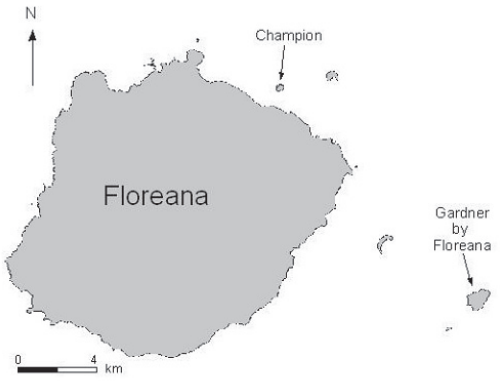

Figure 1. Location of Champion and Gardner islets in relation to Floreana Island.

surrounds this, which is most pronounced in the east and south. The less steep and less rugged aspect of the islet makes human access throughout much easier than to any part of Gardner.

Floristically the islets are very similar. The most abundant plant species on both islets are *Croton scouleri* and *Opuntia megasperma*, which provide nesting sites for mockingbirds[6].

Survey protocol.—Surveys were conducted annually in 2003–08 in the hot rainy season in mid May annually, except in 2006, when the survey was undertaken in mid June (due to logistical problems). Data were collected on distribution and abundance by age class on both islets. Adults were identified by their characteristic dark bill and fewer spots on the breast. Juveniles possess more breast spots and a yellowish base to the bill. Individuals lacking obvious adult or juvenile characteristics, and those too distant for age-class identification, were classified as indeterminate. Detectability did not differ between age-classes, and there are no apparent behavioural differences between them. The locations of all birds seen were recorded using a GPS.

The field work was undertaken according to the following protocol: *Champion Islet*.—Five observers were involved in the census, each following a separate transect. Two surveyed the north of the islet and two the southern portion. In both cases, one person surveyed the coast and the other the hillside. The fifth observer surveyed the interior of the central crater. All five observers started at point A (the landing site, with the exception of the observer in the crater) and ended at point B (sea lion beach) in the south-east of the islet (Fig. 2i). Field work was undertaken between 07h30 and 08h30. Duplicate counts were avoided by constant (radio) communication between the observers. Because of the small size of the islet, observers are never more than c.50 m apart and the entire island was surveyed. *Gardner Islet*.—Five observers again followed separate transects. Two surveyed the north-east of the island (over level ground), with one close to the edge and the other on the slope and flat part of the islet. Two additional observers surveyed the rim of the crater in opposite directions. The fifth observer covered the north-west slope of the crater. The first four observers made their way from point A to B, but the fifth observer began and ended at point A (Fig. 2ii). The survey was undertaken between 07h30 and 09h30. Due to the larger size of Gardner, compared to Champion, it was impossible to cover the entire islet during a two-hour period, so counts were corrected for the proportion of the island sampled. Survey area was estimated as the total area within 150 m of the GPS track for each transect. This buffer width was chosen because mockingbirds are curious and often approach observers if they pass within 75 m of the bird's original position. A 75-m buffer is also consistent with the species' home range (territory size is usually slightly <1 ha for Galápagos Mockingbird *Mimus parvulus* on Genovesa[7] and 0.9 ha for Floreana Mockingbird on Champion[6]). Assuming an even distribution, the population was estimated as (number of birds counted) / (proportion of island surveyed).

Presence / absence of introduced agents and species.—All observers were continuously alert for the presence of introduced vertebrates such as Smooth-billed Ani *Crotophaga ani*, Black Rats, Norway Rats *R. norvegicus*, House Mice, cats and goats[19]. In addition to direct observation, rat detection tubes[25] were placed on both islets overnight during the surveys. Abandoned mockingbird nests

Table 1. Estimated population of Floreana Mockingbird *Mimus trifasciatus* from various literature sources, prior to the present study.

Year	Champion	Gardner (estimated)	Total
1906[12,28]	24–26		
1966[15]			**150**
1973[14]			**150**
1979[13]	49	3–4 times more than Champion, >175*	**224**
1980[4]	49		
1983[4]	50	four times more than Champion	**250**
1984[4]	50	four times more than Champion	**250**
1980–91[14]	24–53	four times more than Champion, >154*	**193***
1995+	20–25		
1996+	44		

* Mean in these periods.

\+ Unpubl. data.

Table 2. Floreana Mockingbird *Mimus trifasciatus* population, counted on Champion and Gardner, and estimated population on Gardner by age.

Islet	Age	2003	2004	2005	2006	2007	2008
Champion	Adults	34	31	26	12	17	32
	Juveniles	14	4	1	4	16*	13*
	Not aged	4	7	1	4	5	1
	Total	52	42	28	20	38	46
Gardner	Adults	54	56	66	32	18	24
	Juveniles	3	3	14	5	36*	31*
	Not aged	17	16	9	7	4	2
	Total	74	75	89	44	58	57
Gardner estimated	Covered area (ha)	33.4	50.8	45.2	53.0	47.8	24.9
	Adults	126	86	114	47	29	75
	Juveniles	7	5	24	7	59	97
	Not aged	40	25	16	10	7	6
	Total	173	115	154	65	95	179
Total population		**225**	**157**	**182**	**85**	**133**	**225**

* In 2007 and 2008 the numbers of juveniles were larger than in previous years, because Floreana Mockingbird responds to rainfall by breeding.

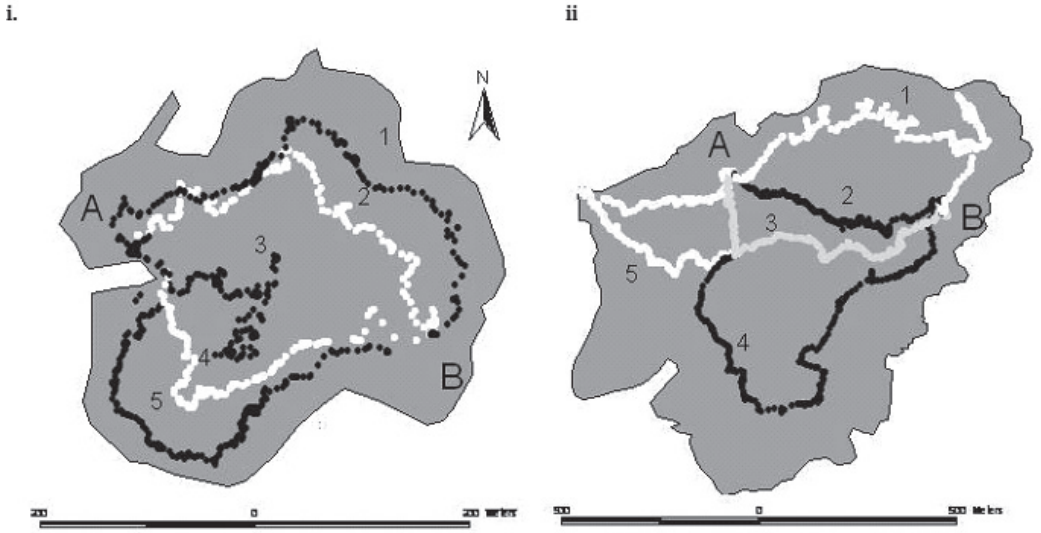

Figure 2. Champion Islet (i), Gardner Islet (ii). The five transects (1–5) on each islet during surveys in 2003–08. A: Start point. B: End point.

(without eggs or chicks and not in construction) were collected to determine the presence of the parasitic fly *Philornis downsi*, an introduced invasive species that has become a general problem throughout the Galápagos archipelago[11]. Puparia of the fly larvae can usually be detected in previously occupied nests for quite some time, possibly even years, after the nest is abandoned[29]. Observers also inspected mockingbirds for evidence of infection by avian pox (*Avipoxvirus* DNA). Symptoms of

active infection such as deformities or scabs on the legs or around the eyes and bill, or signs of past infection such as loss of digits or limbs[21] were readily apparent.

Results

Survey.—From 2003 to 2008, the index of the Floreana Mockingbird population on both islets varied from a low of 85 to a high of 225, with a mean 168 (± 55) individuals. These counts were consistent (Table 2) and indicated that the populations vary but with no decreasing trend. In relating the counts of the juvenile population (2003–08) with precipitation (polynomial regression) in the hot rainy season (January–May), a positive association emerged (n=6, r^2=0.88, p=0.041, level of confidence=95%).

On Champion, our census covered the entire islet each year. Numbers varied from 20 (2006) to 52 individuals (2003; Table 2), with a mean 38 (± 12) individuals. Relating the juvenile population with precipitation (polynomial regression) in the hot rainy season also suggested a positive association (but was not statistically significant) (n=6, r^2=0.23, p=0.673, lc=95%).

On Gardner, our survey did not cover the entire islet each year, so the total population of mockingbirds was estimated (see Table 2 for counted and estimated totals). The population estimate in 2008 (179) was the highest, whilst the lowest was 65 individuals (2006), with a mean 131 (± 46) individuals. Comparing our data of the juvenile population with precipitation (polynomial regression) in the hot rainy season again suggested a positive association (n=6, r^2=0.92, p=0.025, lc=95%).

Presence / absence of introduced species and infectious agents

Smooth-billed Ani.—Three individuals were observed on Gardner and seven on Champion in 2003. The species was not recorded in other years.

Other introduced vertebrates.—No signs of other exotic vertebrates were observed during the surveys. Rat detection tubes placed on the islets during the surveys in 2003–08 were all negative.

Philornis downsi.—Evidence of this invertebrate was detected in four (20%) of 20 old nests on Gardner in 2003, and in one (20%) of five old nests on Champion in 2007.

Avian pox.—No birds were observed with deformities or scabs on the legs or around the eyes and bill, or with missing digits or limbs, during any of the surveys. However, in 1984 on Champion Floreana Mockingbirds were reported with lesions on the legs[4], which might have indicated the presence of avian pox in that year.

Discussion

Two questions are timely: is the population of the Floreana Mockingbird on the islets of Gardner and Champion declining, and do our research results give insights into possible causes of the mockingbird's extinction on Floreana Island?

Extreme aridity was noted on the islets in those years (2004–07) of low mockingbird abundance for which Charles Darwin Foundation rainfall records reveal below-average levels of precipitation[3] (data taken from Santa Cruz meteorological station—no data are available from Floreana or its nearby islets). This suggests that rainfall may have an important role in regulating the mockingbird population. Curry & Grant[7,9] mentioned that fluctuations in rainfall affected the population of Galápagos Mockingbird on Genovesa over 11 years of study, and this may also be the case for the Floreana Mockingbird (Fig. 4). Our data from 2003–08 suggest that the numbers of juvenile Floreana Mockingbirds may directly depend on the quantity of precipitation. Adults appear 'active' and breed immediately following the rains.

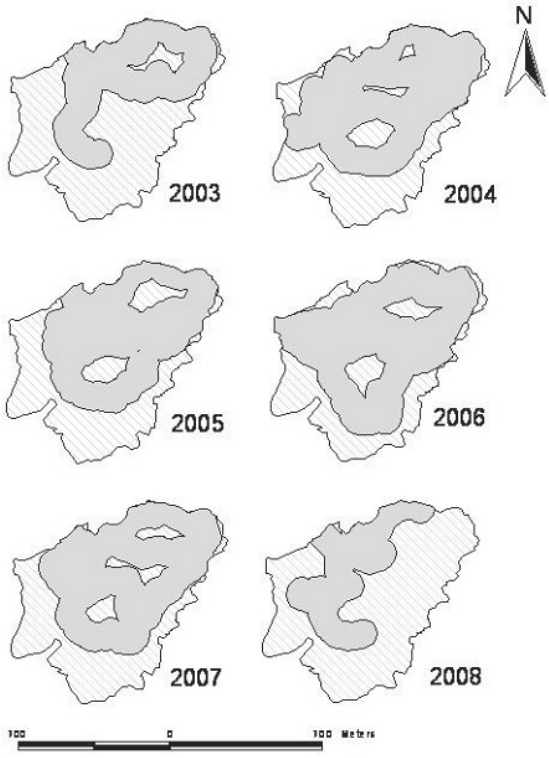

Figure 3. Gardner Islet with estimated areas covered by surveys in 2003–08 (buffer zone: 75 m each side of the observer). The difference in coverage in the surveys is because the vegetation differed annually, and is dependent on rainfall. The surveys were conducted over a two-hour period (see text).

However, in the long term, the population status depends on offspring production as well as survival through the adult stage. Our analysis of the number of adults as related to rainfall did not reveal any association, unlike the case for juveniles. However, what might happen during a longer drought? It is possible that in 1860–1954, during the cooler and drier conditions of the Little Ice Age[10], the Floreana Mockingbird population was negatively affected by the dry climate, since the last record of this species on Floreana Island was in 1880[26]. But if so, why were other passerines such as Darwin's finches not affected? It seems possible that the combined effects of the long drought, introduced predatory species[5,14,16] and habitat loss could have caused the extinction of the mockingbird population on Floreana Island.

When the islets were evaluated separately, we see that the Champion population has fluctuated widely (Table 2, Fig. 4). Data obtained by Curry[4] and Grant *et al*.[14] (Table 1) reveal that the population fluctuated between 24 and 53 individuals (1980–91), although it has been even lower, e.g. the report by Gifford[12] in 1906 of apparently just 10–12 individuals: 'I think that two more days of hunting on Champion would have made the species extinct there'. However, if we consider the 14 birds collected by the California Academy of Sciences (CAS)[28] at that time, the population would have been 24–26 individuals. Our results, showing a 20–52 individual fluctuation in Champion in the period 2003–08 accord with those of Curry[4] (1984) and the CAS (1905–06). So, although the mockingbird population is small, it has managed to survive despite its isolation for c.120–130 years.

On Gardner the population has also been fluctuating, but the range is wider and fluctuations seem better correlated to precipitation. The population has fluctuated between 65 and 179 individuals (2003–08; Table 2, Fig. 4). Recent estimates are more accurate than previous totals and provide a more solid appraisal of what happens to the population on the islet during extended dry conditions such as during La Niña periods. If the climate changes in the future, El Niño and La Niña could be stronger and more frequent. Given such a scenario, the Floreana Mockingbird population might not have time to recover. And, if introduced species or agents exacerbate these problems, the mockingbird population could decline towards extinction.

We must also consider inbreeding as a result of a genetic bottleneck. The loss of genetic diversity

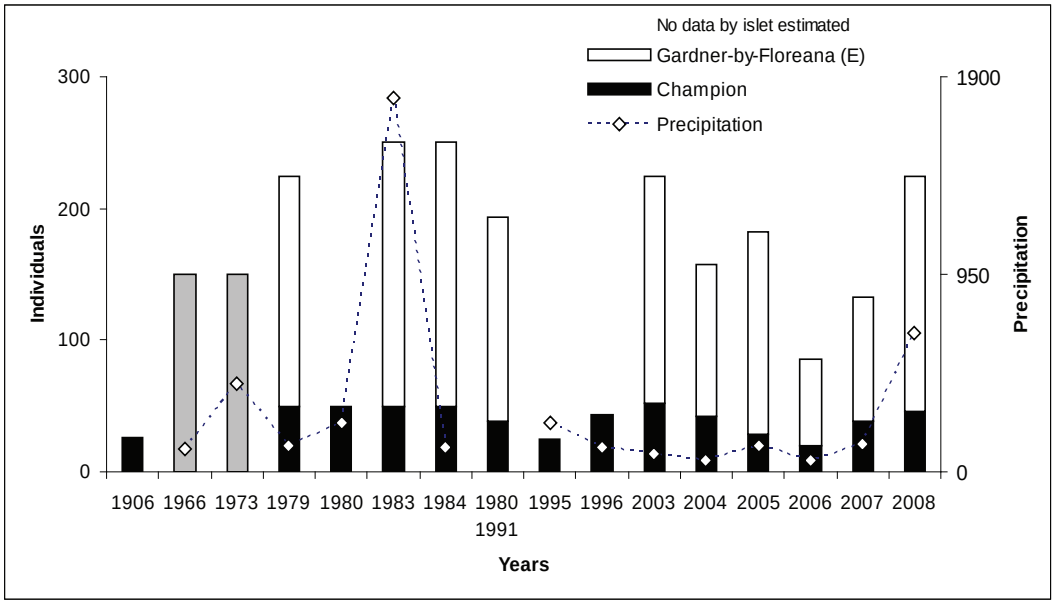

Figure 4. Estimated population of Floreana Mockingbird *Mimus trifasciatus* on both islets in relation to annual rainfall (mm) in January–May recorded at the Charles Darwin Found meteorological station on Santa Cruz[3]. Data taken from Gifford[12], Swarth[28], Harris[15], Grant[13], Curry[4], Steadman 1995 (unpubl.), Grant *et al.*[14], Vargas 1996 (unpubl.), and this study in 2003–08.
* 1906: mean in this year.
** 1980–91: mean in this period.

in the population[14,17] during its c.130 years of isolation has possibly caused inbreeding depression; unfortunately this is irreversible.

To conserve the Floreana Mockingbird, the Charles Darwin Foundation and Galápagos National Park Service recently initiated the Floreana Project, a long-term programme which will seek to restore the island's ecosystem, eradicate introduced / invasive species, and eventually re-introduce native and endemic species, among them Floreana Mockingbird (from both islets to Floreana Island). Meanwhile, measures to protect the populations on the offshore islets are still required. This will include continuing to ban tourists from visiting and to limiting camping by scientists to short stays. In the long term, there must also be continued monitoring to ensure control or eradication of any introduced species.

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