GALÁPAGOS MANGROVE FINCH *CAMARHYNCHUS HELIOBATES*

RECOVERY PLAN

2010-2015

Photo: M. Dvorak

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CONTRIBUTORS TO THE PLAN

A draft of this plan was developed in November 2008, in Puerto Villamil, Galápagos, at the International Workshop on Management of Mangrove Finch *Camarhynchus heliobates* coordinated by Birgit Fessl, then Field Manager of the Mangrove Finch Project. The workshop was facilitated by Yolanda Matamoros (CBSG). Daniel Rivers and Vivian Salas from the Charles Darwin Foundation (CDF) helped throughout with logistical arrangements. By consensus, participants decided to approach the Mangrove Finch conservation problem in four major themes with groups covering each: 1) *in situ* conservation[1] 2) *ex situ* conservation[2] 3) a population viability analysis[3] and 4) the social and economic implications[4]. Preliminary outputs of each group were discussed in plenary sessions. Victor Carrion, the representative of the Galápagos National Park (GNP), is the Plan Coordinator (**PC**). A first version of the Recovery Plan (**RP**) was compiled by Birgit Fessl and revised by the Recovery Group Members (**RG**, * in list below) in July 2009. This second revised version is presented to CDF and GNP in April 2010.

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RECOMMENDED CITATION

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To provide new information to update this recovery plan, or correct any errors, email: glyn.young@durrell.org

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Workshop participants after successful brainstorming

ACRONYMS AND ABBREVIATIONS

Cartago – Bahía Cartago

CB – Caleta Black

CDF – Charles Darwin Foundation

Durrell – Durrell Wildlife Conservation Trust

GNP – Galápagos National Park

PTN – Playa Tortuga Negra

SUNY – State University of New York

EXECUTIVE SUMMARY

This plan responds to the perilous status of the Mangrove Finch *Camarhynchus heliobates*, one of the rarest birds in the world. The species is endemic to Galápagos and once occupied a number of mangrove sites on Isabela and Fernandina. The finch's area of occupancy, however, has declined severely throughout the last 100 years and the world population is now restricted to only two sites on the former island. Three small remnant populations that survive in two widely separated areas of coastal mangrove on the northwest and southeast coasts of Isabela hold a combined total of only around 100 birds. The Mangrove Finch is classified by IUCN as Critically Endangered. The principal threats are believed to come from predation of eggs and nestlings by introduced Black Rat *Rattus rattus* and loss of nestlings through parasitism by the larvae of the introduced bot fly *Philornis downsi*. Further sources of extinction risk are loss of genetic diversity due to the historical population decline and potential inbreeding, contact with introduced pathogens, climate change effects and major stochastic events such as land uplifts.

The Recovery Plan was developed at the International Workshop on Management of Mangrove Finch *Camarhynchus heliobates* held in Puerto Villamil, Galápagos in November 2008. Planning was designed to assist stakeholders to define, evaluate and plan their conservation role and activities. The process allows stakeholders to focus their resources on activities which can best achieve their goals.

The workshop used all available data and in particular data collected during the, at this time, two year project focusing on halting the decline of the species and restoring it to one or more of its former sites. The plan's vision is to increase the natural range of the species to at least two sites, helped by translocation and active management in the current population. With increased predator control, natural dispersal to the neighbouring Island of Fernandina is also expected and hopefully sites here will prove suitable for the finches.

Summary of actions

The Recovery plan highlights that the following actions are essential for the continuing survival of the Mangrove Finch and its restoration to areas of former occupancy:

1. Train personnel in all areas of plan;
2. Continue yearly monitoring;
3. Continue rat control at existing sites and develop programmes of control at proposed translocation sites;
4. Develop long term strategy for control of *Philornis downsi*;
5. Translocate birds to Bahía Cartago;
6. Increase awareness of Mangrove Finch in Puerto Villamil;
7. Secure necessary funding to ensure success of project.

1. BACKGROUND INFORMATION

Common name:	Mangrove Finch, Pinzón de Manglar
Scientific Name:	*Camarhynchus heliobates* / *Cactospiza heliobates*
Family / Order	*Emberizidae* / *Passeriformes*
Band size:	#1242-H Monel
Weight	17.2-20.8g
Measurements (mm): Wing Tarsus Bill dimensions: *Head-Beak*, *Feathers-Beak*, *Nostril-Beak,* *Height, Width, Gape*	 Average 71.4 (range 64-75) Average 24.2 (range 22.5-26.9) Average 31.5, 15.0, 10.0 Average 7.5, 6.2, 9.6

1.1 Taxonomic status

The Mangrove Finch is a member of the well-known group of Darwin's finches (subfamily Geospizinae), the most diverse group of endemic birds in Galápagos with 13 species living in this island group and one species, *Pinaroloxias inornata*, found only on Cocos Island about 600km to the north of the Galápagos Archipelago (Grant 1999). The Mangrove Finch was first collected by the Stanford University Expedition in 1898/99 and described by Snodgrass and Heller (1901). It was the last species of Darwin's finch named by science.

1.2 Distribution and abundance

1.2.1. Past and present distribution

Currently, finch populations only exist in the coastal mangles (<1km²) at Playa Tortuga Negra (PTN, 18ha) and Caleta Black (CB, 10ha) on the northwest coast of Isabela, separated by 1km of lava including three small mangrove stands of less than 4ha (in this Recovery Plan these are considered as one site), and at Bahía Cartago (Cartago) on the east coast at a distance of approximately 65km from the main population on west coast (**Fig. 1**) (Dvorak *et al.* 2004).

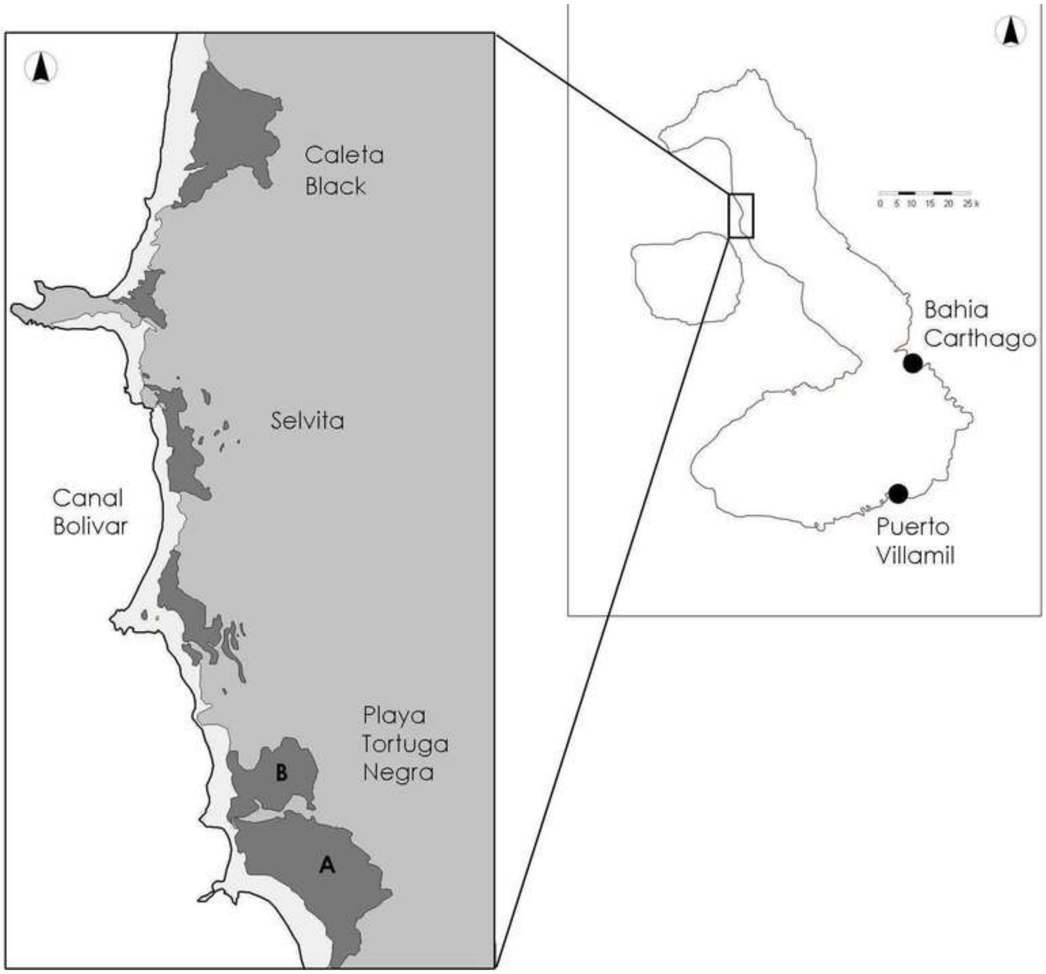


Fig. 1. Isabela Island with the inhabited coastal zone around Puerto Villamil and sites where Mangrove Finch currently occurs: Bahía Carthago in the south-east and Playa Tortuga Negra and Caleta Black in the north-west (from Fessl *et al.* 2010).

Historically the Mangrove Finch had a wider distribution with records from five different locations on Isabela and one on Fernandina (Grant and Grant 1997, Dvorak *et al.* 2004). Some areas formerly occupied by the Mangrove Finch may have changed considerably (e.g. Bahía Urvina on Isabela Island and Punta Espinosa on Fernandina Island have been uplifted by volcanic activity) or could have always been a sink population (e.g. Fernandina), but hardly any historical information is available on Mangrove Finch abundance or habitat characteristics to understand the drivers of the population decline. Most knowledge about its former distribution comes from scientific expeditions and the main collection sites were north-western Isabela and eastern Fernandina. For example, the Hopkins-Stanford Expedition in

1899 took 26 birds from PTN and 12 birds from Fernandina (Snodgrass and Heller 1904) and the expedition of the California Academy of Science in 1905/06 another 25 birds from north-western Isabela with no records for Fernandina despite several visits (Gifford 1919), indicating that Mangrove Finches must have been relatively common at PTN during that time. Historically Mangrove Finches were also sighted at Cartago and birds were collected at this site in 1900, 1901, 1937, 1957 and 1971 (Snodgrass and Heller 1904, Bowman 1961, Collar *et al.* 1992, Grant and Grant 1997).

1.2.2 Current population estimate

In 2009, the world population of the Mangrove Finch was estimated to be around 100 birds (Fessl *et al.* 2010). The size of the populations at the two western sites (PTN, CB) was estimated between 2007-09 using territory mapping and distance sampling (**Table 1**). In early 2009, yearlings and adult birds (around five birds) were observed for the first time in the three mangrove stands adjacent to PTN and CB. In Cartago, 3-5 birds were found in 1998 with similar numbers in 2008 but only two birds in 2009. Song recordings revealed that the Cartago birds' song is clearly distinct from Mangrove Finches in the west (Dvorak *et al.* 2004, Brumm *et al.* submitted) which makes it highly unlikely that these individuals are vagrant members of the western population. One observation with photographic proof from Villamil is interesting in this respect. A bird that did not sing but resembles very much the Cartago birds (Fessl *et al.* submitted). However, follow-up searches were not successful. Two sightings come from the tourist site in Fernandina; both are considered as reliable (Fessl *et al.* submitted). The sighting from Punta Mangle is unconfirmed.

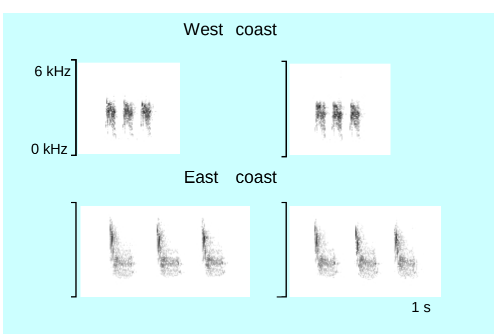


Fig. 2. Sonogram of a male from PTN (upper graph) and a male from Cartago (lower graph)

Table 1. Global population, distribution and trends (increasing, stable or decreasing) of the Mangrove Finch. The reliability of parameter estimates are coded using the quality codes (A = reliable, B = incomplete; C = poor; U = unknown) used in BirdLife International's World Bird Database.

Island	**Population (quality code)**	**# birds**	**Population trend (quality code)**	**Sporadic sightings**	**Notes**
Isabela	PTN (A)	51 (25-103)	Stable (A)		Counts in 2007, 2008, 2009
Isabela	CB (A)	49 (24-101)	Stable (A)		Counts in 2007, 2008, 2009
Isabela	Cartago (C)	2-5	Decreasing (A)		Searches in 1997,1998, 2008, 2009
Isabela	El Estero - Villamil			X (B)	By G. Merlen in March 2008
Fernandina	Punta Espinosa			X (A)	By guides in Nov 2008, 2009
Fernandina	Punta Mangle			X (C)	By G. Jimenez (2007)
Total	**Individuals**	**110**			

1.3 Populations as management unit

During the Recovery Plan Workshop, it was decided that the PTN and CB populations are very likely to be connected and therefore they should be considered as one evolutionary significant unit. Differences in song between the two sites exist but are negligible (BF, unpubl. data). We concluded that in case of an emergency, e.g. the necessity to initiate captive breeding, it would not be feasible to keep birds from these two sites separate. Birds at Cartago have a very different song and western birds react with less intensity to their playback type (Brumm *et al.* submitted), which indicates that they are separate populations. However, the population size at Cartago is now so small that in case of an emergency (necessitating captive breeding) it cannot reasonably be treated as a separate population.

1.4 Breeding biology

1.4.1. General breeding biology

Like all Darwin's Finches, Mangrove Finch breeds during the rainy season (late December to April). Breeding is continuous until the rain stops. Although one clutch is typically laid per breeding season, up to four clutches can be laid during strong *El Niño* events when conditions are good (HV, pers. comm.). Infrequently, some pairs may breed during the dry season (May to mid December) as young birds have been observed in September (BF, pers. obs.). Reproduction is poor or absent during the dry conditions of *La Niña* events.

A dome-shaped nest built in a Black Mangrove (left) and a White Mangrove high up in the canopy (right)

Mangrove Finches build dome-shaped nests in trees at 4-30m height (average: 13m), preferring the outermost branches of Black (*Avicennia germinans*) and White Mangroves (*Laguncularia racemosa*). Males build display nests and females finish the chosen nest (inner layer); only the female incubates eggs (usually for around 14 days) and the male feeds her occasionally. In the first days after hatching, the female sits on the chicks and the male feeds chicks and, sporadically, the female. Later, both parents feed the chicks. Chicks are ready to fledge when they are 12-14 days old. They stay with their parents for at least 2-4 weeks before becoming independent. It seems that some, if not all, young birds stay in their parents' territory until the next breeding season. After this period they are chased away and attempt to establish their own territory.

1.4.2 Nesting success

In 2006/2007, only five of the 44 monitored nests at PTN and CB were successful, producing only 10 fledglings in total. We identified several possible causes for this low breeding success (**Fig. 3**). Most nests were predated during incubation and in three cases eggs did not develop. Only ten nests made it to the nestling phase; five were either predated or succumbed to *Philornis downsi* parasitism indicated by very high numbers of *P. downsi* larvae in the abandoned nest. Nest success of Mangrove Finches increased markedly after rat control in PTN and CB (**Fig. 3**). This was largely due to a substantial decrease in the proportion of nests being predated during the incubation phase and a drop in the proportion of nests with eggs being abandoned. We found dead nestlings (seven nestlings in total) which appeared to have succumbed to *P. downsi* infection in 14% of nests with eggs or nestlings monitored in 2007/2008. Mean parasite number per nest was 40.8 (*stdev.*=15.3, *n*=15). Five more nests in this breeding season were thought to have been predated by rats during the feeding phase (Fessl *et al.* 2010).

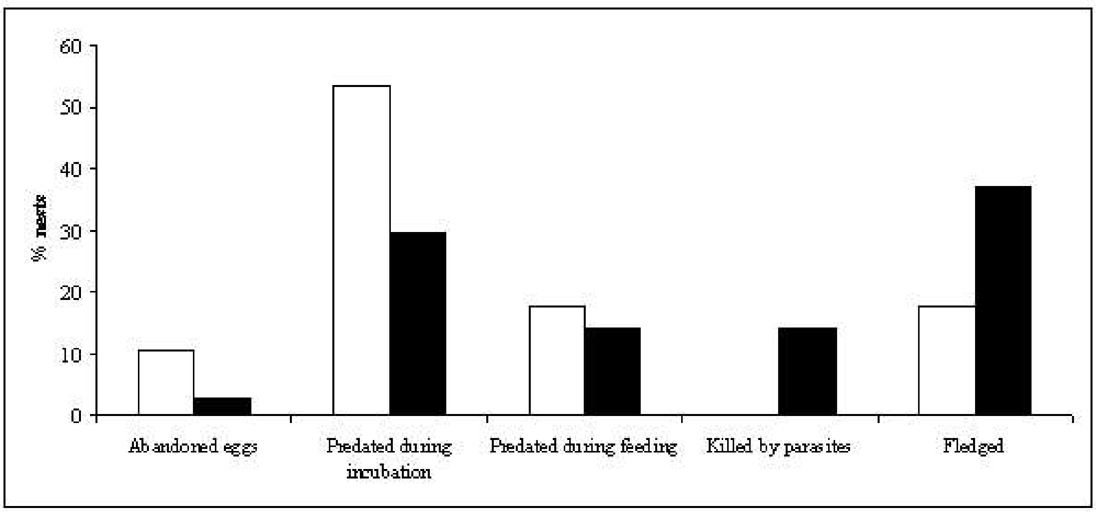


Fig. 3. Proportional outcome for nests with eggs or nestlings for the breeding seasons 2006/2007 (open bars) and 2007/ 2008 (black bars) (from Fessl *et al*, 2010).

1.5 Feeding ecology

The following data are sourced by an undergraduate thesis project conducted by A. Loaiza, Universidad Central del Ecuador (Loaiza 2009).

Mangrove Finches are restricted to mangrove stands of at least 1ha in area. They seem to prefer mangroves that are separated from the sea by banks of sand which prevent organic material being washed away, and, therefore, leaf litter and dead wood accumulates. We could observe a variety of feeding techniques changing for the humid (reproductive period) and the dry season. Insect larvae and spiders are the most important food sources observed (**Fig. 4**).

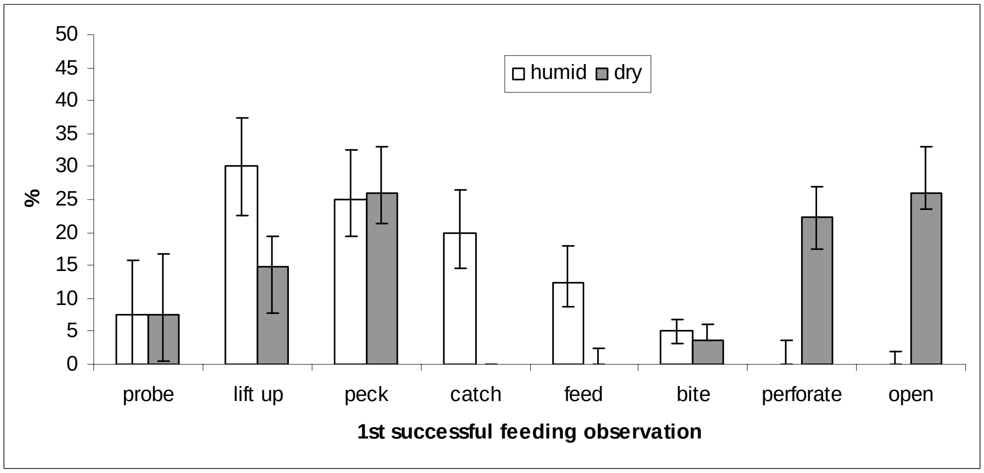


Fig. 4. Percentage of successful feeding techniques (1st observations only) for the dry and humid season. Observations were done in PTN and CB.

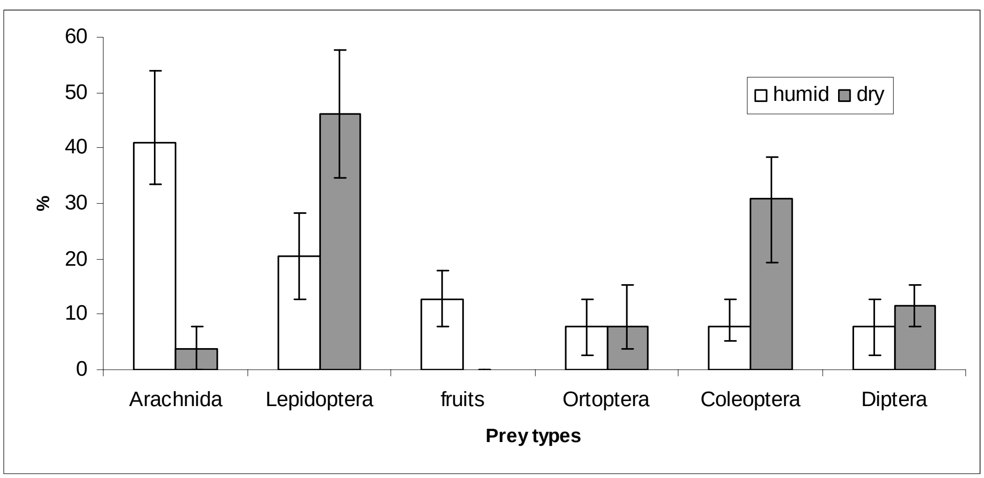


Fig. 5. Percentage of prey types observed (all observations) for the dry and humid season. Observations were done in PTN and CB.

Left: A. Loaiza and S. Gaona collecting leave litter with a Winkler trap.

Right: With the help of Berlese traps invertebrates are collected directly in alcohol packs.

Dead wood (standing and lying) and leaf litter are the preferred feeding habitat of this finch throughout the year (**Fig. 6**). Different parts of Red Mangrove (*Rhizophora mangle*) are especially important to finches in the dry season when they feed on Lepidoptera larvae developing in the buds and on the larvae of a small beetle (*Coccotrypes myzophorae*) that parasitizes fruits and aerial roots.

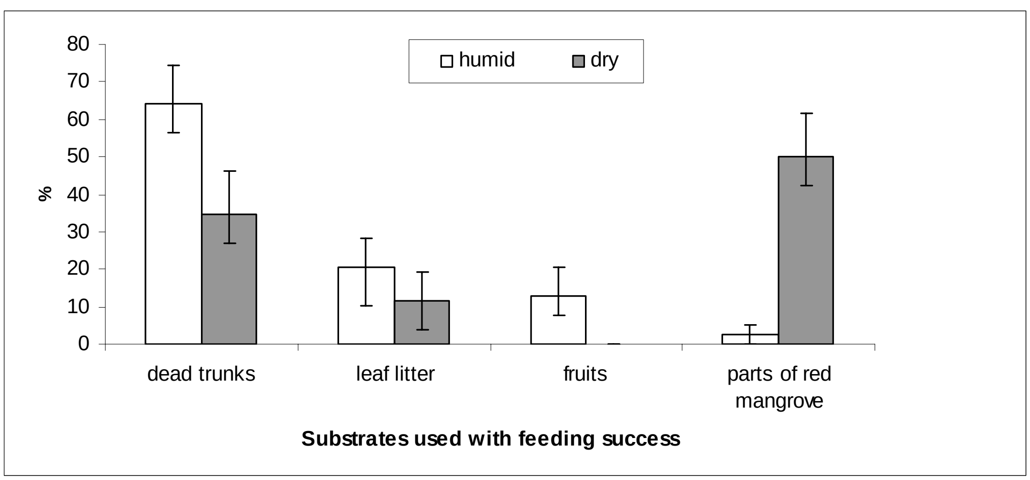
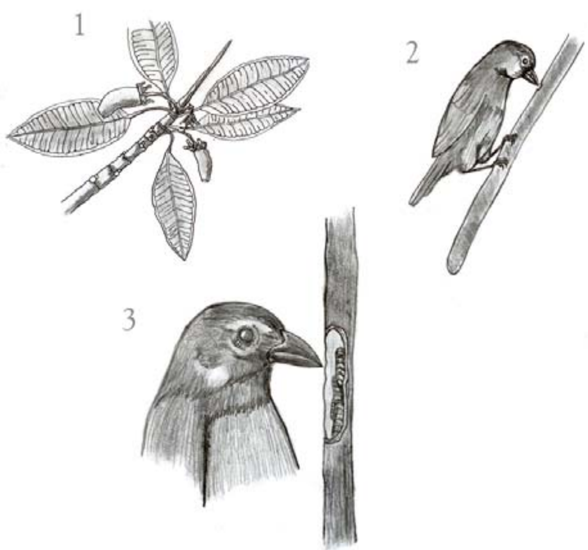


Fig. 6. Percentage of substrates used for feeding in the dry and humid season. Parts of Red Mangrove include aerial roots, fruits and buds of emerging leaves.

Upper left: Dead wood, **upper right**: leaf litter, **lower left**: Red Mangrove buds, **lower right**: *Tournefortia psylostacia*, one of the fruits consumed by the Mangrove Finch.



The finches use a special technique to "*perforate*" woody material to access larvae. *Perforate* is a combination of *probe*, *peck* and *remove*: they insert the upper mandible into scars in the wood caused by the beetle and remove small bits of vegetation until an opening big enough to introduce the whole beak and extract the larvae (drawing JL. Ruiz)

1.6 Habitat requirements for feeding and nesting

Red Mangrove is a preferred feeding substrate of the Mangrove Finch but they do not use this tree species for nesting as the branching is too open. Thus, pure Red Mangrove stands are not suitable for Mangrove Finches. The following results are extracted from the result of a habitat assessment for the breeding sites PTN and CB; the complete analysis can be found as **Annexe 1**.

Lagoon in the middle of PTN (photo G. Young)

Transect in PTN climbing over Red Mangrove (photo G. Young).

Table 2 shows the differences in vegetation characteristics between nest sites (N) and randomly chosen vegetation sites (L) within and between PTN and CB. For nesting, Mangrove Finches prefer Black Mangrove (*Avicennia germinans*) stands that are high and thick with more dead wood on the ground (**Annexe 1**).

Table 2. Results of two way ANOVAs comparing vegetation characteristics between 71 nest sites and 111 randomly chosen sites on one hand and CB and PTN on the other hand. P values are for *t* tests, no values mean effect is not significant.

	N-L	CB-PTN	X
Number of trees		>0.0001	
Max Height	0.002	0.000	
Sum dead trees and trunks			
Sum dead branches and twigs			
% stone on ground			
% deadwood on ground	0.023		
% litter on ground		0.001	0.026
% mud on ground	0.0012		
% moss on ground	0.000		
% Red Mangrove	0.000	0.002	
% White Mangrove			
% Black Mangrove	0.000	0.000	
Avg diameter (5 trees per site)	0.001	0.000	0.004
Canopy cover			

Because the Mangrove Finch prefers to forage in leaf litter and dead wood lying on the ground, mangroves that are separated from the sea (e.g. by a beach as PTN and CB) are more suitable than lagoon systems (as in Fernandina) from which dead wood and litter is washed into the sea or decomposes in lagoons. This difference might explain the much lower density of Mangrove Finches in the east coast of Isabela (most mangrove stands are not separated from the sea) and the disappearance of Mangrove Finch populations in Fernandina. In the Galápagos, only four mangrove species occur: Red, White, Black and Button Mangrove (*Conocarpus erectus*). In PTN, the first three species are prevalent (36%, 56% and 6.6% of trees respectively), whereas in CB we find only White and Red mangroves, in equal amounts. The sites in Cartago with Mangrove Finches consist mainly of Red and White with very few Black Mangrove trees. Button Mangroves could represent potentially suitable Mangrove Finch habitat, as these trees produce a lot of litter as well as dead wood and have branching that would make good nesting substrate for finches to build their nests. This species is widespread in southern Isabela, including the Ramsar site (Ecuador 6EC009 http://ramsar.wetlands.org/) in and close to Puerto Villamil.

Table 3 compares vegetation characteristics between the sites, separating PTN in PTN-A (main forest to the south) and PTN-B to the north, as in this area only few birds established territories and only one nest site was confirmed. Points from Villamil seem to be rather different though they have many features in common with either site. For example it is equally dense as CB, with comparable amounts of dead wood and considerable amounts of leaf litter. However, trees are especially low and tree species composition is very different, with Button Mangrove largely replacing Red and White mangroves. No data are available on the invertebrate community at this site. The suitability of this site is questionable, especially if vegetation height and percentage of Red Mangroves are more important than has been considered in the past.

Table 3. Characteristics of the mangroves of Puerto Villamil (Via) compared to mangroves in the north-west of Isabela. Values in bold characters indicate sites that do not differ from Puerto Villamil. Given are means and standard deviations of 87 observation points.

	CB	PTN-A	PTN-B	VIA	*Post Hoc* Tukey HSD
Leaf Litter (cm)	0,8	1,0	*2,3*	3,4	Via differs from CB & PTN
	1,5	1,4	1,5	4,0	
Number Trees	*22,8*	14,8	9,5	23,5	2 groups
	12,1	7,7	5,0	20,9	
Max Height	14,4	17,9	11,8	8,5	All different but PTNB and CB
	4,1	5,3	4,6	4,3	
Sum dead trees and trunks	*7,7*	8,1	*5,6*	4,2	Via from PTN
	4,1	5,1	2,8	3,3	
Sum dead branches and twigs	***7,9***	***8,5***	***8,8***	8,8	
	2,8	2,5	1,7	2,3	
% stone on ground	***1,9***	***1,2***	***2,1***	1,7	
	6,2	5,8	5,4	4,7	
% dead wood on ground	***11,2***	***12,8***	***9,6***	8,8	
	13,2	12,1	8,5	11,5	
% litter on ground	20,5	35,0	*60,4*	70,7	All different but Via and PTNB
	24,4	25,6	23,3	30,1	
% mud on ground	35,6	34,9	*15,3*	3,1	2 groups
	35,6	31,6	19,8	8,6	
% moss on ground	21,6	15,1	*2,2*	0,6	2 groups
	32,2	24,7	6,0	3,5	
% Red Mangrove	44,8	32,6	*17,5*	8,9	CB > others, Via differs PTN
	26,8	27,7	24,9	17,5	
% White Mangrove	54,7	48,6	80,4	6,8	All different but CB and PTNB
	26,3	29,2	23,9	15,1	
% Black Mangrove	*0,0*	17,9	*0,0*	6,0	PTN differs
	0,0	25,2	0,0	19,4	
% Button Mangrove	0,0	0,0	0,0	60,8	Via
	0,0	0,0	0,0	40,9	
Canopy Cover	***73,5***	***74,8***	56,2	74,4	PTNB different
	15,7	13,0	25,3	17,3	

In Dvorak *et al.* (2004) some basic information such as *canopy cover*, *leaf litter*, *dead wood* and *tree height*, is given for several historical sites, though information from Fernandina is missing.

1.7 IUCN Conservation Status

The Mangrove Finch was included in the second and third editions of the Red Data Book of endangered bird species owing to its very small range (potentially suitable habitat was estimated to be only about 500ha) and the suspected small population, estimated at 100-200 birds in 1974 (King 1981, Collar *et al.* 1992). Given the lack of recent information, it was classified as of "indeterminate" status, because "almost nothing is known about the current status and distribution of the bird or even its ecological requirements" (Collar *et al.* 1992). However, in the 1994 list of globally threatened bird species which used for the first time the new IUCN criteria, the Mangrove Finch was classified as Endangered (Collar *et al.* 1994) and it was uplisted to Critically Endangered in 2000 (Stattersfield and Capper 2000).

1.8 Causes of decline, risks and potential threats

The exact causes for the reduction of the Finch's range are unknown, but a variety of introduced animal species are known or suspected to negatively impact the Mangrove Finch (**Table 4**): Black Rats (*Rattus rattus*) are known to significantly reduce the breeding success of Mangrove Finches, largely by predating eggs (Fessl *et al.* 2010). A further significant threat stems from nestling mortality following parasitism by larvae of the botfly *Philornis downsi*: a fly first recorded in the islands in the 1960s and most likely introduced by humans (Causton *et al.* 2006). Parasitism by *P. downsi*, an obligate bird parasite (the adult fly is non-parasitic), was first identified in the Galápagos in 1997 (Fessl *et al.* 2001) and at Mangrove Finch sites on Isabela in 2000 (HV, pers. comm.). A mortality rate of 16-95 % due to parasitism has been recorded in other Darwin's Finches (Dudaniec et al. 2006, Fessl *et al.* 2006, Huber 2008). Mortality is negatively correlated with brood size (Fessl and Tebbich 2002, Dudaniec *et al.* 2006). The Mangrove Finch has a mean clutch size of only 2.1 (Fessl *et al.* 2010) and is, therefore, particularly vulnerable. Complete brood loss due to *Philornis* parasitism for the Mangrove Finch was between 10 and 15%, information on partial brood loss is incomplete (Fessl *et al.* 2010).

Adult fly *Philornis downsi*. Photo B. Landry, Natural History Museum, Geneva.

Nostril of same nestling (left), recently with *P. downsi* infected nostrils (middle) and once larvae have left nostril cavity to migrate to nest bottom and than suck blood as ectoparasites (right).

Cats (*Felis catus*), Smooth-billed Anis (*Crotophaga ani*), fire ants (*Solenopsis geminata*) and the wasp (*Polistes versicolor*) are also potential threats (Grant and Grant 1997, Dvorak *et al.* 2004) but, while their effect has not been studied yet, their likely impact is discussed below. The impact of introduced insect borne avian diseases such as avian pox or malaria is not yet clear but studies are currently underway (Deem *et al.* 2008). Extreme climate variability, climate change, volcanic activity (e.g. geological uplifting or sinking) and loss of genetic variation also represent potential threats (**Table 4**).

A comparative study of genetic diversity between current (specimens from PTN and CB from 1998-2008) and historical (specimens from different sites and islands; 1905-1906) Mangrove Finch populations suggests reduced genetic diversity in the current populations (Kenneth Petren, pers. comm.). This could lead to increased inbreeding and decreased ability to adapt to changes in the environment. On the other hand, there is some mixing up of the gene-pool through hybridisation with the Woodpecker Finch (*Camarhynchus pallidus*) (Kenneth Petren, pers. comm.).

Table 4. List of potential causes of population decline of the Mangrove Finch with extent of current knowledge, the level of impact the threat may pose, its priority for actions and feasibility of reducing threat levels.

Cause	Extent of knowledge	Importance of impact	Priority for action	Feasibility
Black Rats	Good	High	High	High
Philornis downsi	Good	High	High	Low
Diseases	Low	High	High	Medium
Habitat change	Medium	High	Low	Low
Smooth-billed Ani	Medium	Medium	High	High
Fire ants	Medium	Medium	Medium	High
Extreme climate variation	Good	Medium	Low	Low
Inbreeding	Good	Medium	Low	Low
Hybridisation	Good	Medium	Low	Low
Feral cats	Medium	Low	Medium	High

1.9 C*onservation efforts up to 2009 and suggestion for further management*

1.9.1 Invasive species control

1.9.1.1 Black Rat (*Rattus rattus*)

Hernan Vargas initiated experimental trials in 1997 to determine if Black Rats can cause declines in the populations through predation of eggs and nestlings at PTN (rats were controlled) and CB (no rat control). However, due to the confounding effects of especially wet *El Niño* and dry *La Niña* events, it was not possible to show a quantifiable effect of the rodent control on finch breeding success.

In May 2006, GNP initiated rat control applying 5g *Klerat*® wax cubes (1kg of the product contains 0.05g Brodifacoum) disseminated around the periphery of PTN and CB but this method proved to be unsuccessful. In 2007, we demonstrated the negative effects of rat predation on breeding success through nest monitoring and an artificial nest experiment (Fessl *et al.* 2010). Data on Mangrove Finch breeding success showed an increase in fledging success after rat control was initiated (Fessl *et al.* 2010). Since November 2007, permanent bait stations have been positioned every 50m in PTN (n = 129) and CB (n = 89) (**Fig. 7**). These grey PVC tubes (10.2cm diameter, 25cm high) with wide mesh approx. 8cm from the bottom and a lid to allow rats to access poisoned baits but prevent their removal. The poison is protected against rain; other animals cannot access it. Every three months, 20 to 30 *Klerat* cubes are placed in each bait station, with old *Klerat* cubes removed after a six month period (**Fig. 8**). Since March 2008, feeders are as well positioned in the small mangrove patches adjacent to PTN and CB. Rat monitoring (live-trapping) during the rat control programme showed a reduced number of rats following the deployment of bait and in relation to an experimental control site where no poison was deployed (Selvita; **Fig. 7**).

PVC tubes were fixed on branches that were accessible for rats but not flooded, filled with Klerat cubes and than closed with a lid.

Deployment of rat poison should be continued at least three to four times a year with the most important time being the start of breeding activity (December or January) and end of breeding season (April). Old or mouldy poison (especially after the rainy season) needs to be replaced.

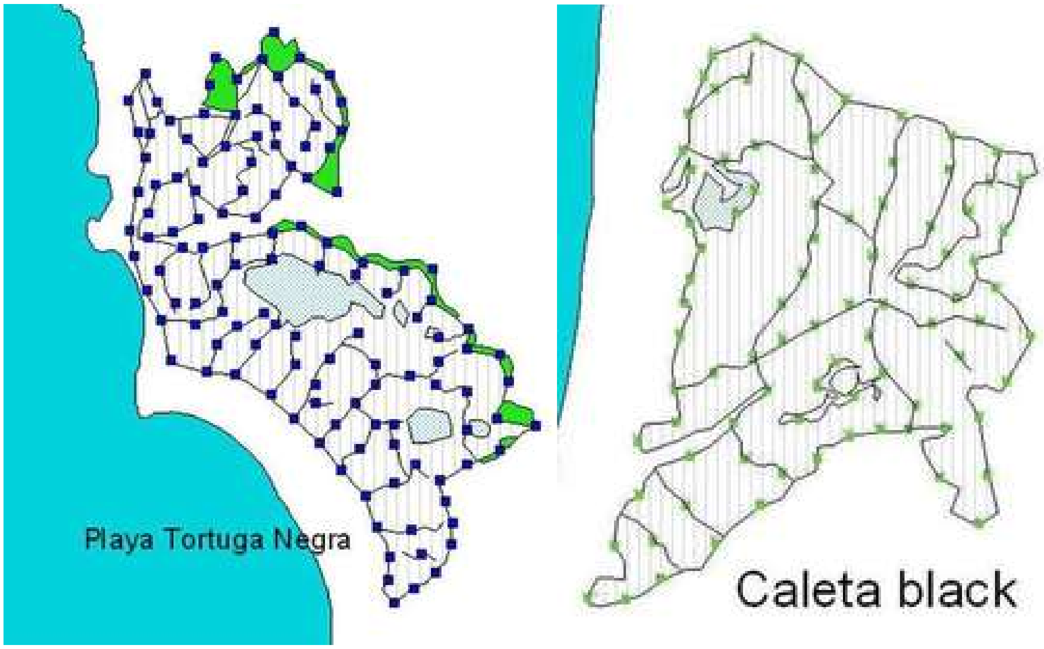


Fig. 7. Placement of permanent rat bait stations in the two main breeding sites: Playa Tortuga Negra and Caleta Black.

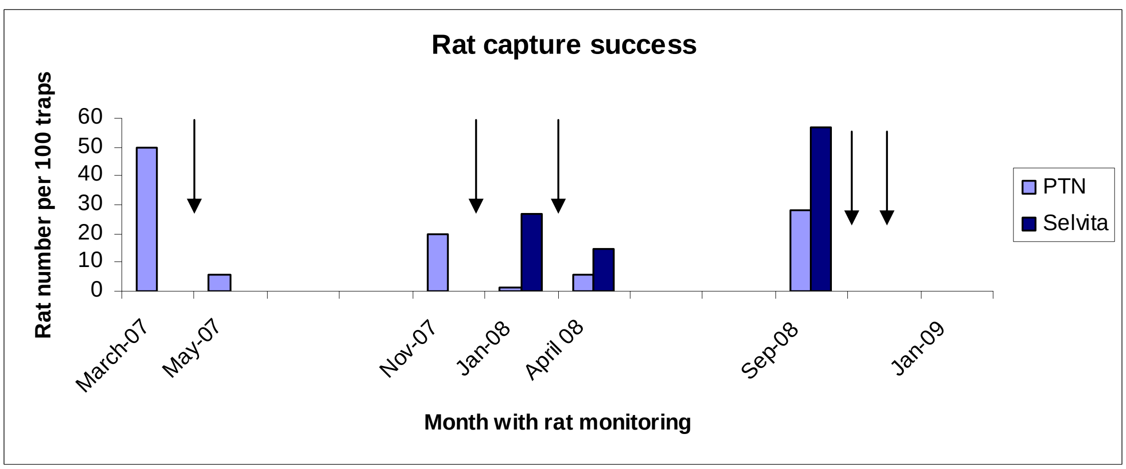


Fig. 8. Number of rats caught/100 traps (three trap-nights) for different months for the sites PTN and Selvita (adjacent mangrove stand of 3.8ha). Rat monitoring in Selvita was started in January 2008. Black arrows indicate when rat poisoning with Klerat (form March 2008 onwards for both sites) took place. Permanent feeding stations were put out in PTN in November 2007 and in Selvita in March 2008.

1.9.1.2 Feral Cat (*Felis catus*)

Feral cats are common at breeding sites and are potential predators of inexperienced juveniles as well as of adults, as Mangrove Finches spend much feeding time on the ground. This is a potential problem especially in the adjacent small mangrove patches, as birds are more often seen at the edges. Between 2006-09, we regularly saw feral cats close to PTN and CB. In the early morning, fresh tracks can be seen close to the sea where cats seem to forage for small fish and crabs. Tracks were frequently seen on the beach side of both sites and some cat faeces were seen at the lava side. During our field trips, only three cats were killed; 10-80 poison baits were applied in September 2007 and twice in 2008 and 2009 by GNP. Biannual cat control in the area is part of the GNP management plan but more intense campaigns could be planned during breeding activity of finches.

Feral cat walking close to the shoreline at PTN. Great Blue Heron (*Ardea herodias*) in foreground (photo E. Sandoval).

1.9.1.3 Smooth-billed Ani (*Crotophaga ani*)

Smooth-billed Ani were introduced in the 1960s to Santa Cruz Island (Rosenberg *et al*. 1990) and are now widespread over the archipelago. They are known to be predators of invertebrates and small vertebrates (Rosenberg *et al*. 1990) and are very territorial birds (Quinn and Startek-foote 2000) which may disturb Mangrove Finch breeding activity and thus represent an extra possible threat. They can be encountered in PTN and CB in small groups of 3-8 individuals and they have been regularly shot since 1997. However, an analysis of stomach contents indicated that in PTN and CB grasshoppers (*Schistocerca* sp) and crickets were their main food items and no evidence of predation of eggs or chicks was found (HV, pers. comm.). As a precautionary principle, the Smooth-billed Ani population should regularly be reduced, especially during the breeding season.

1.9.1.4 Fire ant (*Solenopsis geminata*)

In 1997-1998, inventories of insects and plants were conducted at PTN and CB and aimed at determining the diversity of plant and animal food available for the Mangrove Finch and the occurrence of introduced species. During the survey the invasive fire ant was found. This species is known to reduce populations of native butterfly eggs and larvae and displace native ant populations. The fire ants' distribution was found to be small (0.25ha) and restricted to the locality used as a campsite for illegal fishing activities at PTN (-0.24 S, -91.39 W). In March 1998, CDF attempted an eradication programme and a survey in June 1998 found no fire ants. GNP repeated the ant control in October 2004 and in January 2007, and no fire ants were found during follow-up monitoring in PTN (-0.24 S, -91.38 W) and at another campsite at mangrove patches close to CB (-0.22 S, -91.39 W) (Herrera, CDF, pers. comm.). In November 2009, the GNP again did ant control in the area (with *Sigue Pro*). Further monitoring of fire ants in PTN and CB should be conducted to conclude if future control is necessary, especially after *El Niño* events. In case of a translocation, recipient sites should be monitored as well.

1.9.1.4 Paper wasp (*Polistes versicolor*)

Little is known about the possible impacts of the paper wasp on the native invertebrate community. So far, only one nest has been observed inside the mangrove area (15m from edge) and wasps are only randomly encountered in the forest. However, as a precaution, wasp nests located in the surrounding *Scutia* vegetation should be destroyed during the Mangrove Finch breeding season (January to April).

1.9.1.5 Parasitic diptera *Philornis downsi*

Currently, no control or management is possible for this blood sucking parasite. A two year project led by CDF gave some more insights into fly life cycle characteristics (Lincango and Causton 2008a, 2008b); however, some important parts are still not understood, especially how flies find partners, copulation and host nest detection. Currently, a project by SUNY in collaboration with CDF and GNP aims to develop pheromone traps for *Philornis* control in breeding sites. This could be a very useful localised solution to the problem.

1.9.2 Preventing disturbance by birdwatchers at Playa Tortuga Negra

In 1998, after noticing that some of the naturalist guides were using playbacks to attract Mangrove Finches, GNP closed PTN to tourists and banned playback, in case this activity disturbed breeding activity. PTN is now a limited visitor site under special permission. The captain of a boat has to approach the GNP to get permission with justification that the group of tourists is special. Playback is still prohibited.

1.10 Population viability analysis

The complete results from the PVA can be found in **Annexe 2**.
A population viability analysis (PVA) for the Mangrove Finch was conducted using VORTEX 9.92 (Miller and Lacy 2005). The data needed for the PVA were obtained from the current field study conducted by Birgit Fessl and from previously published research articles of this and other related species (Grant and Grant 1992, 1997, Dvorak *et al.* 2004). Environmental variation (EV) was calculated from the field studies of BF and from expert opinion. VORTEX models the effects of deterministic and stochastic process (demographic, environmental and genetic) over populations. Allowing the programme to generate random values for an event within certain limits VORTEX can predict: 1) the extinction risk at specified intervals (e.g. every 10 years during a 100 year simulation), 2) population's stochastic growth rate, 3) median time to extinction, 4) mean time to extinction of those simulated populations that became extinct and 5) mean size of, and genetic variation within, extant populations. VORTEX is not intended to give absolute answers; it projects stochastically the interactions of many input parameters and takes into account random processes involved in nature. Interpretation of the output thus depends upon expert knowledge of species biology and the environmental conditions that are affecting it.

The baseline model represents the actual status of the Mangrove Finch populations (**Table 5**, **Fig. 9** juvenile mortality 84%). The purpose of this model is to have a reference to develop different scenarios of the effects of the threats and possible management strategies to have better decision criteria at the time of implementing actions that guarantee the long term viability of the species.

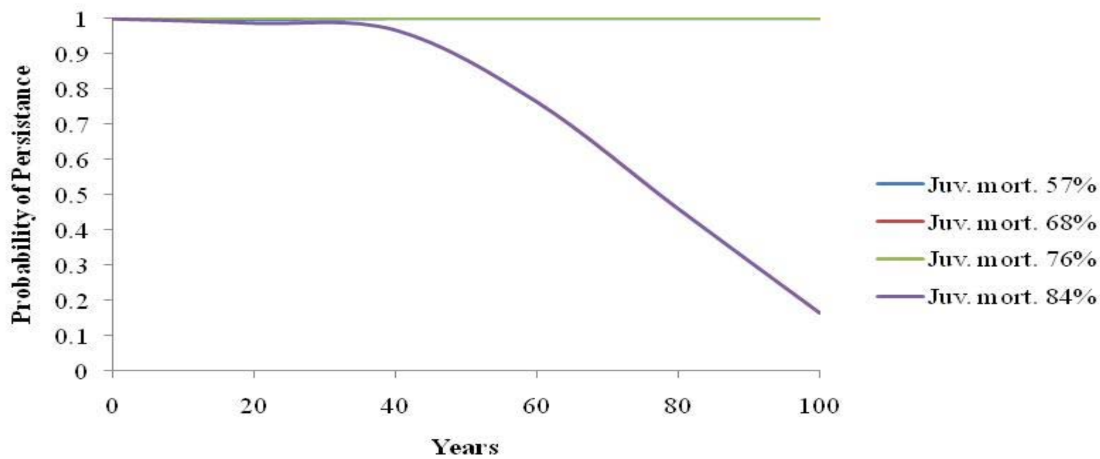
1.10.1 Management strategies tested

- Lowering juvenile mortality by varying amounts through the implementation of predator control actions (**Table 5, Fig. 9**)
- Extracting eggs from PTN population to establish a captive population to supplement other populations.
- Extracting adults from PTN population to establish a captive population to supplement other populations
- Translocating adult birds from a captive population to Cartago

1.10.2 Risk assessment tested

- Habitat change
- Disease epidemic
- An increase in *El Niño* and *La Niña* events

A.



B.

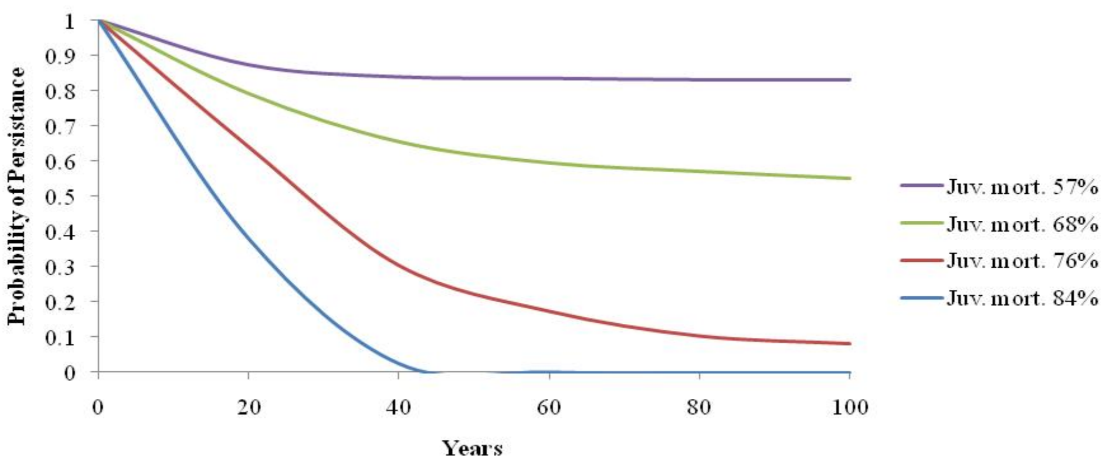


Fig. 9. Probability of persistence of the Mangrove Finch populations over a period of 100 years, when lowering juvenile mortality by implementing predator and parasite control actions is implemented. Juvenile mortality: Juv. mort. A) PTN-CB, B) Cartago.

Table 5. Mangrove Finch baseline model with 84% juvenile mortality and management actions resulting in lower juvenile mortality: 76% after basic rat control, 68% after major rat control, 57% after major rat control and *Philornis* control. Results are from projections in 100 years. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: N-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE. Values are given for the united population of PTN and CB with a carrying capacity of 112, for the population of Cartago with a carrying capacity of 135 and for the Metapopulation.

Juv. Mort.	Population	stoc-r	PE	N-extant	GD	MedianTE	MeanTE
	PTN-CB	-0.034	0.836	15	0.701	78	72
84%	Cartago	-0.056	1.000	0	0.000	17	19
	Metapopulation	-0.036	0.836	15	0.701	78	72
	PTN-CB	0.058	0.000	102	0.839	--	--
76%	Cartago	-0.019	0.918	69	0.675	28	30
	Metapopulation	0.054	0.000	107	0.843	--	--
	PTN-CB	0.119	0.000	109	0.833	--	--
68%	Cartago	0.052	0.448	124	0.706	--	28
	Metapopulation	0.108	0.000	177	0.860	0	0
	PTN-CB	0.188	0.000	111	0.817	--	--
57%	Cartago	0.132	0.168	132	0.711	--	17
	Metapopulation	0.172	0.000	220	0.866	--	--

1.11 Captive breeding trials 2008-2009

Any potential captive-breeding project or planned temporary holding of birds during translocation is best enhanced by a thorough understanding of the species' requirements in confined conditions. These include settling in, establishment of optimal housing needs, social structure in enclosed spaces and dietary requirements. Furthermore, in order to then propagate the species, information is needed on the optimal conditions required to allow pairs to be established, to nest and to rear young, and to successfully integrate their young into the population. If numbers need to be increased rapidly, protocols for artificial rearing are also necessary.

Darwin's Finches have rarely been kept in captivity and basic details of husbandry techniques only exist for *Geospiza* (four species: Orr (1945) based on birds held outside of Galápagos).

None of these captive populations survived. Woodpecker Finches were held in aviaries at CDF during behavioural studies in 1995-1998 (Tebbich *et al.* 2001); however, these reports include few details of husbandry issues. More Woodpecker Finches were kept in the existing aviaries at CDF in 2007-2008 and unpublished notes were produced internally by project personnel.

Scientific infrastructure in Galápagos is, at present, concentrated on Santa Cruz, and it was decided to carry out trials on this island, rather than on Isabela. As Mangrove Finches cannot be moved from Isabela (and anyway should not be used for trials), it was decided that the closely related Woodpecker Finch could be used as a surrogate to establish best husbandry practices. A new range of purpose-built aviaries was constructed at CDF in January 2008 and ten Woodpecker Finches from the behavioural research project were transferred in March. The finches chosen were all from the wet zone in Santa Cruz and had been captured in the vicinity of Los Gemelos. Difficulty in sexing the Woodpecker Finches during the early phase of the trials meant that breeding was not possible and in order to establish protocols for hand-rearing six Medium Ground-finch (*Geospiza fortis*) eggs were collected and one successfully hand-reared (Good *et al.* 2009)

The aviaries were staffed by personnel from CDF with technical assistance from Durrell who placed staff at the aviaries for nine months. Basic husbandry protocols including diets and medical requirements were produced and published in 2008 and updated in 2009 (Good *et al.* 2009) and this is available for download at http://darwin.defra.gov.uk/project/15005/. A more general guideline for avian captive care exists in Spanish and English, and is available in the CDF library (Deem *et al.* 2009b, 2009a).

The finches adapted well to captivity and daily maintenance was straight forward and easy suggesting that Mangrove Finch would not prove too difficult. However, there were some very serious problems encountered and these are detailed below. The finches were held in the aviaries until mid-2009 when they were released back into the wild. Released Woodpecker Finches, ringed and fitted with radio transmitters, had returned to point of capture in less than one week (Report to the NPS, **Annexe 3**).

1.11.1 Results of husbandry trials

The finches were relatively easy to manage after birds had been settled into confinement and taught to feed on artificial diets (Good *et al*. 2009). The trials highlighted several concerns for any future breeding programme for Mangrove Finch:

1.11.1.1 Sexing the birds

Woodpecker (and Mangrove) Finch is monomorphic and sexing of the captive birds proved difficult. On song (only male Darwin's Finches sing), nine males and one female were identified but blood (DNA) sexing threw doubts on this. However, as the finches continued to sing these results in turn were doubted and, therefore, pairs were only made up for small periods to avoid potential fighting. Since problems in sexing methodology based on DNA are not resolved for this species, identification of singing birds would still be the best method.

1.11.1.2 Avian pox

All the captive Woodpecker Finches contracted avian pox with lesions principally on their legs. All birds were monitored closely throughout their time in the aviaries and responded well to treatment (Good *et al*. 2009). Avian pox is present at very low levels in montane areas but is widespread in the coastal regions. The Woodpecker Finches in the trial had probably not encountered the disease until they were captured and moved to CDF. Infected birds, notably Galápagos Mockingbird (*Mimus parvulus*), were common in the vicinity of the aviaries in 2008/2009 and it was considered that the captive finches were infected in the older aviaries as mosquito proofing here was very poor.

Two Woodpecker Finches in captivity with pox on leg and toe. Both birds recovered completely after several months.

The new aviaries had good mesh proofing throughout but this had to be replaced quite quickly as the material used initially was of poor quality and corroded in the salty air. Any damage to the mesh, or a service door left open, could immediately allow pox carrying mosquitoes into the aviaries and vigilance must be maintained at all times during any breeding programme. Finches that contract pox and survive are not likely to be re-infected; however, birds from pox-free areas are at risk and may be stressed during treatment. Avian pox is currently unknown in Mangrove Finch and, therefore, avoidance of this disease is of major importance if birds are taken into captivity away from their existing sites, even if only temporarily.

1.11.1.3 Electricity supply

The birds in the aviaries do not need electricity as it is unlikely that they will ever need heat or extra light. However, the water supply requires a pump so regular power cuts can lead to water shortages. The most critical use of electricity is during incubation and hand-rearing when incubators and brooders need a reliable supply. Hand-rearing trials in 2009 were undoubtedly affected by regular and often lengthy power cuts in Puerto Ayora. Portable petrol generators should be acquired specifically for any captive project, wherever work will be undertaken, and incubators/brooders should be capable of running from car batteries charged from the generator.

1.11.1.4 Technical support

Survival of birds in captivity relies on the skill of personnel responsible for them. Skilled personnel can be the difference between success and failure; however, these are skills that are not easily acquired and often come from a natural aptitude for looking after birds. With no caged birds and almost no history of any captive birds in Galápagos there will always be very few people with required levels of skill available locally and technicians from outside will always be needed during crucial times. The need for imported skills will add to any project's budget.

1.11.2 Conclusions on captive breeding

Necessary requirements to ensure success of captive breeding will be logistically difficult and very expensive. Any Mangrove Finch project will have to be undertaken on Isabela where there will be further difficulties and costs incurred. To this end, captive management, either holding birds temporarily, or establishing a breeding population is only recommended in an emergency.

1.12 Translocation

1.12.1 Determining composition of translocated birds and transport

In case of a translocation different population compositions are possible. Birds may be:

- Randomly captured at source site and will probably include some adult birds
- Selectively captured through existing monitoring and ringing programme
- Taken as fledged juveniles either in year of fledging or subsequent year while still identifiable as juveniles
- Taken from the nest and head-started i.e. hand-reared to fledging.

Exact make up of birds for translocation/release will be established through literature review and discussion with managers of similar projects with passerines elsewhere in the world. Determining factors will probably be 1) ease of capture and transportation, 2) suitability for temporary holding and release in groups, 3) likelihood of settling at new, unknown, site or possibility of attempting to return to natal (source) site.

The best practice would be to take birds approximately one year old, as they have survived the most critical period but are not active breeders yet and do not have territories (females might start in year one, males not before year two). Young birds can be identified through clear beak colour. If adults are taken, it must be made sure, that they do not have active nests. Taking birds at the beginning of the breeding season is not advisable due to unexplained cases of mortality in captivity in two related species during this phase. Stress, related to hormonal changes at beginning of breeding is as possible explanation for this (Deem *et al.*, unpublished data).

1.12.2 Possible translocation sites

1.12.2.1.Sites on Fernandina

Table 6 gives an estimate for the suitability of possible re-introduction sites (**Fig. 10**), though hard data are in most cases missing. Fernandina Island seems to be a good option for translocation as Black Rats are absent. However, we believe that birds could disperse without intervention from Isabela, particularly from PTN to *Punta Espinoza* on Fernandina (7km apart) and colonize this site, if suitable. Several sightings of Mangrove Finches at the visitor site *Punta Espinosa* in 2008 and 2009 indicate that this is already happening. From *Punta Espinosa*, Mangrove Finches could move southwards to *Punta Mangle* thorough patches of small mangrove patches along the eastern cost of the island.

1.12.2.1. Sites on Isabela

Bahía Urvina and *Punta Moreno* are potential suitable sites (**Fig. 10**); however, more detailed information on habitat quality is needed before making a decision.

The mangrove sites around *Bahía Elizabeth* are not suitable partly due to species composition (Red Mangrove is most abundant) and partly due to forest size and accessibility.

The habitat at the *Ramsar site* close to Puerto Villamil seems suitable and would be very attractive because the accessibility of this site would make follow-up monitoring feasible and relatively cheap. However, vegetation height was very low and Red Mangroves are almost absent; features that might be important for the finches. In addition, this site is not regularly flooded, thus the invertebrate community might be different or insufficient for the Mangrove Finch; invertebrate collection is needed to clarify this point. Perhaps most importantly, this site is not ready yet for such an action as it holds many other problems including introduced predators and diseases.

We would like to point out the importance of the restoration of the Ramsar site as a necessary step before Mangrove Finches could be re-established at this otherwise suitable place. Galápagos only holds few wetlands which make this rare habitat type especially valuable. An action plan for the site exists addressing all problems from alien species control, education, sustainable fishery and increased tourism with especially skilled guides. The plan also assesses the economic benefits for locals through tourism, invasive species management, controlled fishery and job opportunities. Single actions could be taken directly from this document. However, funding for the Ramsar site restoration is currently unavailable.

Bahía Davis is too small to be considered as re-introduction site.

Cartago may be most obvious site for establishment of 'new' population as 1) it is an historical site of Mangrove Finches, 2) there have been individuals present over the last 10 years, 3) some information on vegetation structure already exists, 4) it is the most extensive mangrove area known in the Galápagos thus there is a good chance that birds would find suitable habitat requirements. However, information on habitat quality, invertebrate community and prevalence of Black Rats is incomplete or missing.

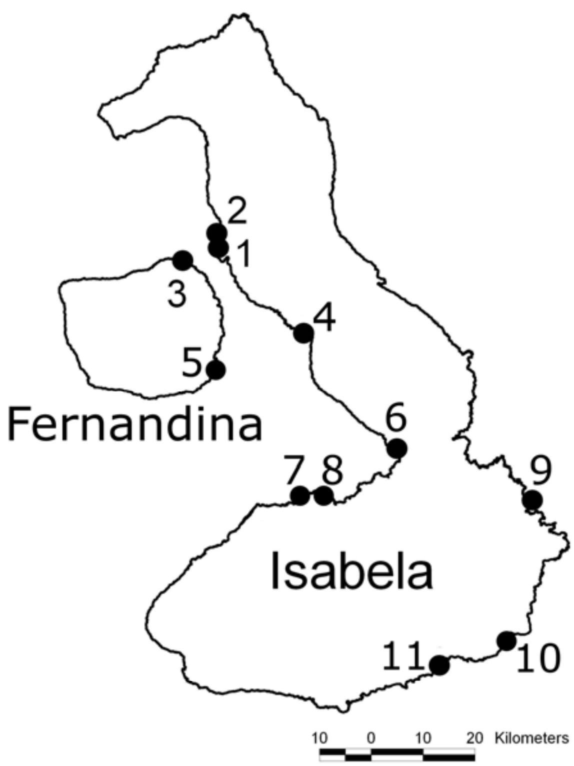


Fig. 10. Current and historical sites of Mangrove Finch distribution. 1 – Playa Tortuga Negra, 2 – Caleta Black, 3 – Punta Espinosa, 4 – Bahía Urvina, 5 – Punta Mangle, 6 – Bahía Elizabeth, 7 – West of Bahía Elizabeth I, 8 – West of Bahía Elizabeth II, 9 – Bahía Cartago, 10 – Bahía Davis, 11 – West of Puerto Villamil

Table 6. Historical sites of the Mangrove Finch and other extended mangrove areas and their suitability as translocation site based on current knowledge (see **Fig. 10**). We used the quality codes (A = reliable, B = incomplete; C = poor; U = unknown) used in BirdLife International's World Bird Database. @ Information in Annexe 1, # Information in Dvorak *et al*. 2004.

Site	Suitability assessment	Size (ha)	Habitat quality	Possible impact by black rats	Risk of diseases	Feasibility of logistic
Punta Espinosa, Fernandina	Good		Medium C	None A	Medium U	Good
Punta Mangle, Fernandina	Good		Medium C	None A	Low U	Medium
Cartago	Good	314	Good B#	Medium B	Low U	Medium
Bahía Urvina	Medium	140	Medium B#	Medium B	Low U	Medium
Bahía Elizabeth	Low	16	Low B#	Medium U	Low U	Medium
West I of Bahía Elizabeth	Low	25	Medium B#	Medium U	Low U	Medium
West II of Bahía Elizabeth	Low	?	U (unable to land)	Medium U	Low U	Low
West of Villamil	Low		Good B @	High U	High A	Good
Bahía Davis	Low	8	Good B#	Medium U	Low U	Medium

1.12.3 Good and bad points for captive breeding versus translocation

In the following box we underline the strong and weak points of each approach for the reinforcement and/or restoration of populations.

	Captive breeding	Translocation
+	Increase numbers of birds for release	Birds are not affected by captivity and are, therefore, possibly best suited for release into wild
+	Control pedigree of released birds	Reduces time and work and thus costs
+	Reduce impact on the wild population following removal of breeding birds	No need for permanent aviary space and skilled personnel
+	Establish a safety-net population if source populations become unviable	
+	Train birds for monitoring	
+	Maintain founder birds in a secure situation	
+	Collect birds from throughout the source population	
-	New, purpose-built, aviaries must be constructed and currently the only really suitable site is at Puerto Villamil which is distant from both source and potential release sites	Consecutive translocations might impact source population especially during dry years or in case of catastrophic events
-	Disease risks from insect vectors of avian pox and malaria are high at a Villamil site and may, potentially, threaten all captive birds.	No check for diseases prior to translocation
-	Captive-breeding facility would have to be permanently staffed by trained personnel involving high costs	Birds cannot be sexed in the field and thus the composition of new population can only be established post-translocation.
-	It is possible that source animals will not breed	Pedigree cannot be controlled for

1.13 Stakeholder analysis

The main and only stakeholder in this species is GNP as these birds only occur in the National Park area. A stakeholder analysis might, however, become necessary if the Mangrove Finch is moved back to the Puerto Villamil area. Cartago is a fishing zone and it is unlikely that this status will be changed; thus there could be always indirect impacts of this activity such as the introduction of pests like fire-ant (as has happened at PTN). Mangrove Finches are fully legally protected under the Special Law for the Galápagos Province, general environmental legislation from Ecuador, and regulations from the Galápagos National Park.

2. ACTION PROGRAMME

2.1 Vision, aim, and objectives of the Recovery Plan

The objectives were discussed and prioritised during the workshop; and are listed in order of priority. Objective 0 (zero) is essential to ensure that the other objectives are met and the aim can be reached. This plan has a five years time frame.

Vision, aim and objectives and their justification and indicators.

VISION: The plan's vision is to increase population size by 25% and increase the natural range of the species to at least two more sites assisted by active management of the current extant populations and translocation of individuals. With increased predator/parasite control, natural dispersal to neighbouring Island Fernandina and to other sites of Isabela is expected and hopefully these sites will prove suitable for the finches. We also predict that Mangrove Finches could naturally colonize mangrove areas around Puerto Villamil and will become the pride of local human population. In consensus with local stakeholders, this Ramsar site will be restored for the benefit of the Mangrove Finch and associated biodiversity.
Description and justification: The main site of the remaining Mangrove Finch population will reach its carrying capacity probably after a 25% increase. However, there is space nearby, on Fernandina Island, which historically was occupied by the Mangrove Finch, very probably through dispersal from Playa Tortuga Negra and Caleta Black. Other close dispersal sites on Isabela Island are difficult to access and predators control is thus unsustainable there. A translocation to a site for which predator control is possible is thus envisioned. From these translocation sites, birds may than disperse as well and finally reach the mangrove area around Puerto Villamil. However, to make it a suitable habitat for the Mangrove Finch, an intense restoration is necessary.
Indicators: The population increases in size from 2009 levels by end of the plan and a first translocation was successfully conducted. GNP was approached for the possibility of restoration of the Ramsar area.
AIM: A measurable increase in the range of the Mangrove Finch populations within the time frame of the plan.
Description and justification: To successfully increase the range of the species, the current

population needs to grow. This is only possible with an efficient predator control system. Excess birds may disperse or need to be translocated.
Indicators: Population census give higher estimates and/or birds are regularly seen at other sites. Translocated birds settled and with reproductive activity (e.g. song, nest building).
OBJECTIVE 0: Ensure the human capacity needed to implement the Recovery Plan over the long term is developed
Description and justification: The most effective plan needs money and people to do the work. At the moment, funding and personal is only secure for year 1 and 2; thus a follow up solutions is needed. GNP personal should be trained where necessary (especially for census work) and should be able to manage the entire project with only minor assistance. This can be achieved more easily if the GNP includes main parts of this plan in its yearly management plan.
Indicators: GNP takes over all rat and predator control activities under an agreed schedule. GNP and CDF personal trained in census techniques. New proposal to secure further translocation activities sent.
OBJECTIVE 1: Increase the population size in PTN and CB by approximately 25% in the next five years which is equal to the estimated carrying capacity (PTN: 74 birds, CB: 40 birds) of these sites
Description and justification: An increase in the current populations is necessary to conduct a translocation without putting the Mangrove Finch at risk. The rat control is the most important tool for assuring a population increase though other potential threats need to be checked and followed (e.g. parasitism by *Philornis downsi*). Research about genetic diversity/ bottleneck/ hybridisation needs to be completed.
Indicators: Yearly census at both sites show slight increase in numbers. Regular sightings in the small mangrove patches between PTN and CB and / or in Fernandina Island indicate that birds look for new breeding areas. Yearly rat trapping numbers shows that rat control is efficient.
OBJECTIVE 2: Increase the number of self sustaining populations to at least two.
Description and justification: It seems that the current rat management is functional and with this the population at PTN and CB might stabilize. However, the two sites are close together and thus equally exposed to danger, for example a new emerging disease, volcanic activity and related geographical uplifts. Thus, it is considered as crucial to build up a second, independent population.
Indicators: A site is chosen and suitability tested (food availability, habitat characteristics). The park agrees to this site and protocols are developed for establishing a new population including

possibilities for translocation and captive breeding. If decided for translocation, a first translocation of a maximum of 10 birds should be conducted and birds monitored.
OBJECTIVE 3: Determine the social and economic benefits of using the Mangrove Finch as a flagship species for sustainable conservation and site restoration.
Description and justification: Even though the Mangrove Finch is at the moment restricted to uninhabited and inaccessible areas, there is potential to bring it back to the Ramsar site by Puerto Villamil. This village is in steady growth and there are emerging conflicts between the GNP authorities and the local population. Bringing the Mangrove Finch to this area would need the full support of local stakeholders for a complete restoration of the habitat but it success could be a possible prime example for conservation based on community work. Pride campaign in Puerto Villamil to increase awareness and promote "pride" among community for the Ramsar site and the Mangrove Finch.
Indicators: Awareness raising campaign in Puerto Villamil started. Communication with local stakeholders and park to see their interest in restoration of site. Possibilities for long term financial support assessed (led by GNP).

2.2 Projects and Activities

The *projects* and their *activities* in **Table 7** detail the before stated objectives. An objective is achieved if all the activities are completed.

Priority is the importance of project activities for achieving the overall aim of the Plan (critical, high, moderate, low).

Costs are estimated as the overall costs during the Plan's period set in thousands of US Dollars.

Timescale indicates the period during which an activity will be conducted

Indicators demonstrating that the project has been successfully carried out are given.

Risks and opportunities possibly affecting the project achievement are specified.

Table 7. Projects and activities

	Activities	Priority	Agencies responsible	Costs (US $ k)	Time scale	Indicators	Risks and opportunities
0.1	Train personnel in all areas of project	**High**	CDF, Durrell,		2010-2013	At least two permanent staff from CDF and GNP trained (for different activities there could be different people)	Enhance local capacity for research and conservation High turn over rate in personnel
0.2	Assure money for further monitoring or follow up translocations for year 3-5	**High**	CDF, Durrell, GNP		2010	Proposal written and submitted Fundraising personal at CDF and Durrell approached and fund raising strategy developed	Fostering collaborations GNP can guarantee to undertake invasive species control for at least two years. Rat control is part of the GNP annual operation plan and thus will be continued.
1.1	Evaluate outcome of management effort to be able to act promptly if the population is decreasing	**Critical**	CDF		2010-2015	Population estimate	
1.1.1	Yearly monitoring (point counts, eventually territory mapping) in PTN and CB to evaluate outcome of management effort and to be able to act promptly if the population is decreasing	**Critical**	CDF, Durrell	11 k	2010-2015	Yearly or Bi-annual population estimate Report on nesting activity or young birds n field reports	Extreme weather conditions so that birds do not sing and thus cannot be counted in a comparable way. Oscillating population: what is the lower “normal” limit?

1.1.2	Yearly monitoring of adjacent mangrove patches and enhanced communication with tourist guides to confirm presence of Mangrove Finches in Fernandina Island (e.g. web-data-base)	**Moderate**	CDF		2010-2015	Field reports	Casual sightings will not allow estimation of complete numbers and the conclusion that birds are dispersing because population is growing might be misleading. Additional transects might be needed. Including tourist guides help the project to promote its ideas and give potential for further funding.
1.2	Low predation pressure of Black Rats	**Critical**	GNP		2010-2015	Rat monitoring data	
1.2.1	Continued rat control in PTN, CB and adjacent mangrove patches (permanent rat poison stations)	**Critical**	GNP	18 k	2010-2015	At least once per year at the same time of year (before, during or after breeding) monitoring of rat density using protocol established under Mangrove Finch Project. Three or four trips per year to site for distribution and eventually replacement of poison in all feeding stations.	This type of rat control done with a fixed schedule (three to four times a year) and responsible handling (removal of old or mouldy poison) can be used as a model for rat control in other islands where rat eradication is not yet possible. Political instability in the direction of the GNP. Improper execution through untrained or unmotivated personnel.
1.2.2	Rat control in release site using protocol established under Mangrove Finch: permanent rat feeders approx. 30-50m apart, 4 times refilling per year	**Critical**	GNP	21 k	2011-2015	Evidence of low rat numbers from monitoring	Needs to become part of the yearly management plan of the GNP and importance accepted. Political instability in the direction of the GNPS

1.3	Reduced mortality due to parasitism by *Philornis downsi*	**Critical**	SUNY, CDF, GNP		2010-2015	Increased numbers of juveniles surviving after each breeding season	Requires lots of effort to detect juveniles as they usually do not respond to playback calls used to census population
1.3.1	Increase knowledge of biology of *Philornis downsi*	**High**	SUNY, CDF	10 k	2010-2012	Publications and reports	Fostering collaborations The already existing Google group *Philornis* could be used as a platform for information and idea exchange
1.3.2	Develop pheromone traps and test in the field	**Critical**	SUNY, CDF, GNP	25 k	2010-2012	Test in the field executed (initially in Santa Cruz) Protocol for control of *Philornis* established	Pheromone traps might be a great short term solutions but the development of functional traps might need many years or fail.
1.3.3	Develop a long term strategy for *Philornis* control	**High**	CDF, SUNY, GNP	5 k	2010-2014	Report Collaborators identified and proposal written	There might be no workable alternative for intense *Philornis* control or eradication Provides knowledge to also protect other species of endangered finch species in the future.
1.4	Low population densities of other potential predators and competitors	**Moderate**	CDF, GNP, Durrell		2010-2015		
1.4.1	Establish a simple protocol for evaluating abundance of cats and Smooth-billed Ani	**Critical**	CDF, Durrell		2010	Protocol developed and tested	A simple but effective protocol for quantifying abundance of this two introduced species might profit to other projects in Galápagos. Arrival of new alien species
1.4.2	Smooth-billed Ani control	**Low**	GNP	4 k	2010-2015	Report: Lower numbers in study sites compared to baseline (1997-2009)	Inexpensive, opportunity to apply precautionary principle

1.4.3	Feral Cat control	**Moderate**	GNP	3 k	2010-2015	Report: Lower numbers in study sites compared to baseline (1997-2009)	Also benefits penguins and cormorants and other native species. Cat control in the area is already part of the GNP management plan.
1.4.4	Monitoring for absence/presence of *Solenopsis geminata* every 5 years	**Moderate**	CDF, GNP	Negligible	2010, 2015	Report	Dry years reduce numbers and detection probabilities A working protocol for ant monitoring exists (H. Herrera, CDF), however, it is often not executed but poison put directly into the field. Including this monitoring in a management plan would allow better deployment of poison.
1.4.5	Destruction of *Polistes versicolor* nests during bird breeding season to reduce eventual impact of these potential food competitors on Mangrove Finch breeding success.	**Low**	CDF, GNP	Negligible	2010-2014	Number of sites without wasps	Inexpensive, opportunity to apply precautionary principle. Invertebrate community might benefit from this action. As time consuming, this action might not be executed; however little is known about the possible impacts of these wasps on native invertebrate community which might impact feeding ecology of finches.

1.5	Generate holistic picture of genetic information	**High**	Ken Petren Lab, CDF	??	2010-2012	Report and publication	In case of translocation, it will be difficult to aim on individuals with higher genetic diversity and we cannot wait for genetic results before moving birds. Though this information will help in future decisions to add birds to the translocation sites.
2.1	Conditions and protocols for use of captive breeding and translocation	**Critical**	CDF, Durrell		2009-2010	Report and modeling	
2.1.1	Establish best practices for production of birds for release (captive breeding vs translocation	**Critical**	Durrell, CDF	1 month salary	2009	Protocol completed and tested	Helps other passerines
2.1.2	Establish requirements of a potential breeding/keeping facility in case of an emergency	**Moderate**	Durrell, CDF		2010	Number of sites evaluated	Depending on population size/ census data
2.1.3	Establish methodologies for capture of wild birds, transportation to holding/breeding facilities or translocation site and release including health and disease issues	**Critical**	Durrell, CDF		2010	Methodology completed	Developed protocols may help for other passerine projects There will be always changes in logistics and plan might have to be adapted in the short term.
2.1.4	Determine most suitable composition of translocated birds	**Critical**	Durrell, CDF		2009-2010	Evaluation made based on survival probabilities of MF and translocations from elsewhere.	Habitat variability at sites where birds are translocated
2.1.5	Establish methodology for releasing birds into the wild	**Critical**	Durrell, CDF		2009-2010	Methodology completed	Helps other passerines

2.2	Identify suitable site(s) for establishment of a new population.	**Critical**	Durrell, CDF, GNP		2009-2010		
2.2.1	Feasibility and risk assessment	**Critical**	CDF, Durrell	1.5k	2010	Report and modeling	Limited potential for field experiments to test risks
2.2.2	Habitat suitability survey for identified translocation site including invertebrate sampling as conducted in PTN and CB	**High**	CDF, Durrell	3 k	2010	Report and number of sites evaluated	From the data available so far, it is still very difficult to develop suitability criteria for the Mangrove Finch
3.1	Pride Campaign in Puerto Villamil to increase awareness and promote "pride" among community for the Ramsar site and the Mangrove Finch	**High**	CDF	28 k	2010-2011	Slogans developed, logo-mascot created, posters developed, collaborative initiatives of CDF and GNP Number of people/schools/organizations receiving message or participating in campaigns	Awareness and training opportunities for local people on Isabela
3.2	Mangrove awareness training for local guides and boat operators	**Moderate**	CDF, GNP		2010-2011	Additional signs set up in the Ramsar site Talks and workshops conducted Number of people trained	Awareness and training opportunities for local people on Isabela
3.3	Create education package for schools about mangroves, Ramsar and the Mangrove Finch.	**Moderate**	CDF		2010-2011	Educational package developed and distributed	Awareness and training opportunities for local people on Isabela
3.4	Include Isabela Ramsar (Sur de Isabela wetlands) site restoration as part of habitat restoration.	**Low**	GNP	See existing Action Plan		Number of hectares of mangroves jointly managed and protected.	Awareness and training opportunities for local people on Isabela

3. MONITORING AND EVALUATION PLAN

Indicators for each project are identified in **Table 7** to measure progress. A mid-term review will be held two years into plan implementation to see if the plan is on target. A workshop will be held towards the end of five years to develop the next plan. The M & E plan is the means by which progress towards achieving the projects/activities, objectives and aims of the action plan are determined. The M & E plan is to be prepared at the evaluation meeting by adding two columns to the Projects Table, one for recording the completion date of projects/activities and another for inserting additional remarks. The Mangrove Finch coordinator fills in the information over time. The completed Project Table provides easily accessible information on conservation progress for the species.

4. FUNDING STRATEGY

Funding from the Darwin Initiative is available until June 2011 to implement the basic research and population monitoring. The CDF and Durrell (Glyn Young) and external scientific advisors (Birgit Fessl and Hernán Vargas) will plan a funding strategy before the Darwin Initiative project ends. SUNY will continue to finance investigations on methodologies to control *Philornis* and a funding proposal to the National Science Foundation is encouraged. The Galápagos National Park has committed funding to control rats and cats at PTN and CB between 2010 and 2015, and this activity is included in the GNP operative plan on a yearly basis. The education campaign and sustainable activities at the Puerto Villamil Ramsar Site after June 2011 would need to be financed by GNP and the Municipality of Isabela.

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ANNEXE 1

VEGETATION CHARACTERISTICS OF MANGROVE FINCH HABITAT

Birgit Fessl & André Mauchamp July 2009

Up to now, knowledge of habitat use and needs of the Mangrove Finch (*Camarhynchus heliobates*) has been poor (Dvorak *et al*. 2004). Some complementary information comes from the thesis work of A. Loaiza on the feeding ecology and food availability of this finch in north-western Isabela (Loaiza 2009). Understanding the habitat needs is, however, the basis for decisions on choice of a potential re-introduction site and the vegetation characteristics of the two mangrove forests where the species is currently present: Playa Tortuga Negra and Caleta Black are described.

These forests (mangles) are almost exclusively composed of three mangrove species, Red Mangrove (*Rhizophora mangle*), White Mangrove (*Laguncularia racemosa*) and Black Mangrove (*Avicennia germinans*). This description focuses on the three species and related habitat characteristics such as the abundance of litter and deadwood important for the birds foraging. Both, a general description using a random design, and a description of sites chosen for nesting, were performed. Additional sets of measures were taken in the mangrove east of Puerto Villamil around the Laguna de Las Diablos, which is an historical site of Mangrove Finch distribution and thus a potential site for reintroduction.

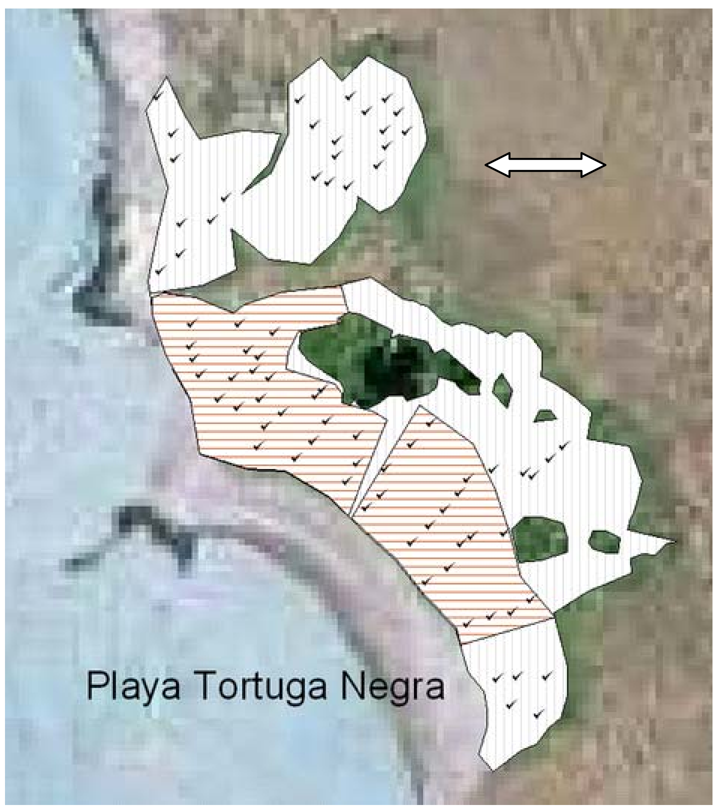
Methods

The mangles were separated into three sites, corresponding to units apparently used in a different way by Mangrove Finches: Caleta Black (CB), and Playa Tortuga Negra A (PTN) and B (PTNB) (**Figures 1a** an**d b**). In each site, points were located every 30m along transects used for finch studies (**Figures 1 a** and **b**), totalling 111 points (*L* points). It was not possible to establish a true random sampling design due to difficult access. However, the sampled zones represented most of the areas where finches were observed nesting, foraging and/or feeding. At each point, a set of variables was recorded describing the forest on a 5-metre-radius circle around the point:

- Inundated at high tide: 0 or 1
- Leaf litter: cm of the leaf layer
- Sum dead trees and trunks: number of lying and standing trees and trunks (SumTT)

- Sum branches and twigs: branches and twigs were categorized in: 0, 1-5=1, 6-10=2, >10=3 for each standing and lying. We used the sum of these four values as variable (SumBT).
- Ground cover (stone, dead wood, litter, mud/soil, moss, sand):%
- Number of trees (N trees)
- Maximum height: m (MaxHeight)
- Canopy cover: % obtained from a vertical photograph processed with image processing software to remove sky pixels. Canopy included both branches and leaves (CanopPhot).
- Proportion of mangrove species within the tree cover: % red RM, white WM, black mangrove BM
- Counts of juveniles (no, numbers of RM, WM, BM juveniles)
- Species of 5 randomly chosen trees in the 5 m radius
- Height of 5 randomly chosen trees in the 5 m radius
- Diameter (perimeter/3.14 at breast height 1,3m) of 5 randomly chosen trees in the 5 m radius (AvgDiam)

a)



b)

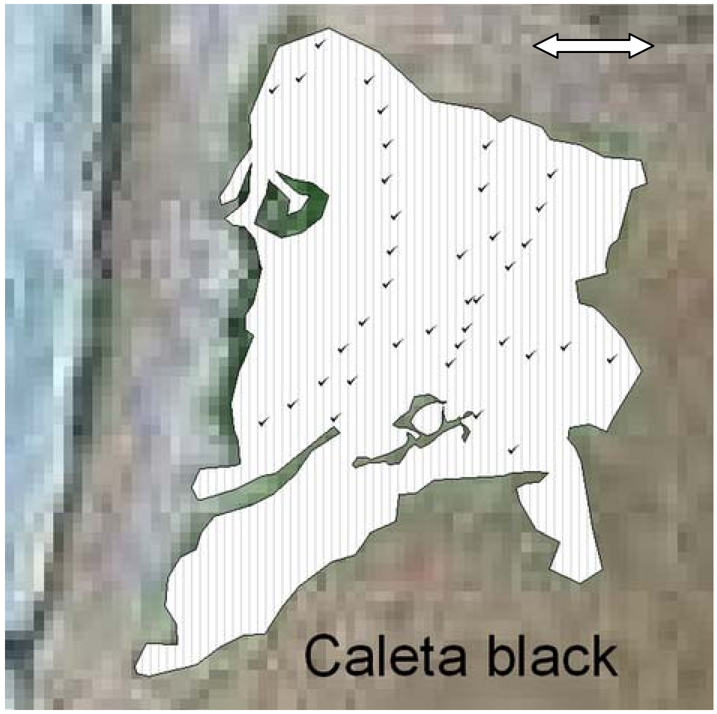
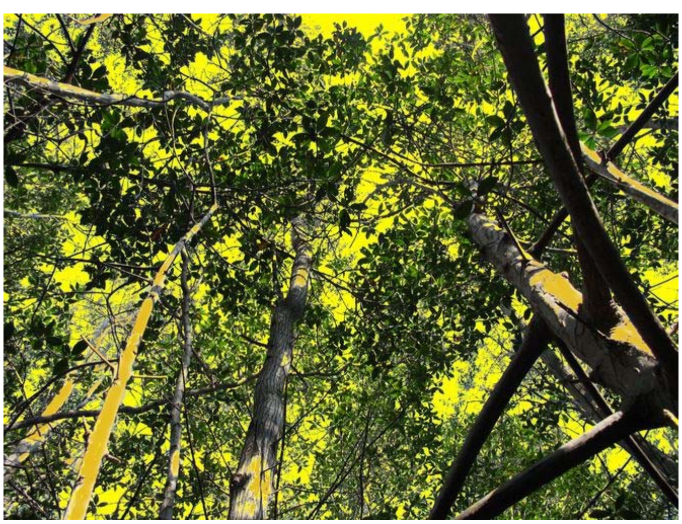


Figure 1: Location of the vegetation sampling points in the mangroves of a) Playa Tortuga Negra, mangrove A to the South (13.2ha) and B to the North (5.2ha), separated by a narrow stripe of bare lava, and b) Caleta Black (10.3ha). Arrows are approx 100m.

The same set of data was recorded in a 5m radius circle around each tree supporting a nest; 71 points combining 2007 and 2008 (N points). At the nest trees, the species of the chosen tree was additionally recorded, with its height, perimeter, the height of the nest and the approximate size of the branch supporting the nest.



Method for cover estimate:
Vertical picture of the canopy taken at a randomly located vegetation point or a nest site. All pixels of the colour of the sky (blue, grey to white) where replaced by a homogeneous background clearly different from all vegetation colour. Occasionally, bright sunlight on the trunks required "painting" them in another colour. Automatic selection allowed estimation of the total canopy cover, including branches and leaves.

Results

Characteristics of *L* points

The sites differed for a number of variables, particularly the covers of the three species of mangrove trees, the size of trees, and the amount of litter. The differences in amounts of deadwood were not as important as expected. Tukey HSD *Post hoc* tests after one-way ANOVAs are given in **Table 1**.

Table 1. Mean values of the variables measured along transects. P values are for one-way ANOVAs for the differences between sites. The *post hoc* column indicates the site/s that were significantly different from the others for $P < 0.05$.

		CB	PTN	PTNB	*P*	*Post hoc*
Leaf Litter	Mean	0,6	1,0	2,3	**0,000**	PTNB
	SD	1,3	1,4	1,5		
N Trees	Mean	21,5	14,3	9,3	**0,000**	PTN has more
	SD	10,7	8,2	5,1		
MaxHeight	Mean	13,3	17,0	11,9	**0,000**	PTN higher
	SD	2,8	5,5	4,7		
SumTT	Mean	8,5	6,5	5,3	**0,007**	CB has more
	SD	4,7	3,5	2,6		
SumBT	Mean	8,2	8,4	8,6	0,883	
	SD	3,1	2,5	1,5		
%stone	Mean	1,6	0,6	1,7	0,509	
	SD	7,0	2,3	5,1		
%deadwood	Mean	8,8	11,1	8,7	0,558	
	SD	12,2	11,1	7,9		
%litter	Mean	16,6	38,9	60,1	**0,000**	all different
	SD	24,2	25,9	23,9		
%mud	Mean	43,7	42,1	16,1	**0,008**	PTNB lower
	SD	40,5	30,0	20,0		
%moss	Mean	15,1	4,4	2,3	**0,005**	CB has more
	SD	26,1	9,4	6,2		
%RM	Mean	48,8	41,5	17,9	**0,003**	PTNB has less
	SD	30,7	32,1	25,5		
%WM	Mean	50,9	48,1	79,8	**0,001**	PTNB has more
	SD	30,2	30,7	24,5		
%BM	Mean	0,0	8,7	0,0	**0,000**	only at PTN
	SD	0,0	14,5	0,0		
AvgDiam	Mean	9,3	14,8	11,3	**0,000**	larger PTN
	SD	3,2	6,1	4,2		
CanopPhot	Mean	76,4	75,4	55,4	**0,000**	lower at PTNB
	SD	14,6	14,6	25,8		
N		38	55	18		

The flooding of the site was measured by a yes/no variable and hence frequencies calculated (**Table 2**). None of the Fisher exact tests comparing the *L* sites 2x2 for flooding frequency was significant, indicating no spatial difference among mangroves in the proportions of flooded areas.

Table 2. Two way frequency table for flooded sites for random sampling "*L*"

		No	Yes	
L	CB	9	29	38
	PTN	12	43	55
	PTNB	8	10	18
		29	82	111

Additional comparison was obtained from the trees measured in the 5m radius plot around sampling points. Number of species, height and diameter of trees of *L* points (547 trees) are given in **Tables 3** and **4**. Proportions of species (**Table 3**) are very similar to those obtained from the estimates of species covers (**Table 1**). Trees were taller at PTN and the shortest at PTN mangrove B (**Table 4**).

Table 3. Number of the three mangrove species in the three study sites, *L* points

	CB	PTN	PTNB	
RM	97	129	24	250
WM	92	119	58	269
BM	0	28	0	28
	189	276	82	547

Table 4. Height (m) for the trees in 5m radius, *L* points. *P* < 0.005, one way ANOVA t test

Site			*N*
	Mean	SE	
CB	8,27	0,43	189
PTN	9,79	0,35	276
PTNB	7,71	0,65	82

<u>Sites chosen for nesting: comparison *N* and *L* points and nesting trees</u>

Comparing *N* with *L* sites, the clearer difference was in species covers. At PTN where Black Mangrove are present, sites with a higher density of this species were disproportionately chosen as nesting sites. Trees were also higher around nesting trees, thicker only at CB, SumTT was higher at PTN with a slight trend to more deadwood cover around nesting trees.

Table 5. Mean values of the variables measured around the nests *N* points. *P* values are for one-way ANOVAs for the differences between sites PTN and CB (PTNB had only one nest and was excluded). (To be compared with **Table 1**)

		CB	PTN	PTNB	**P**
Leaf Litter	Mean	1,1	1,0	1,0	0,957
	SD	1,6	1,5		
N Trees	Mean	24,4	15,4	12,0	**0,001**
	SD	13,8	7,1		
MaxHeight	Mean	15,8	19,0	10,0	**0,007**
	SD	4,9	4,8		
SumTT	Mean	6,7	10,1	10,0	**0,006**
	SD	2,8	6,1		
SumBT	Mean	7,4	8,7	12,0	**0,039**
	SD	2,4	2,5		
%stone	Mean	2,2	2,1	10,0	0,932
	SD	5,1	8,3		
%deadwood	Mean	14,1	14,9	25,0	0,804
	SD	14,0	13,0		
%litter	Mean	25,6	29,9	65,0	0,468
	SD	24,2	24,6		
%mud	Mean	25,5	25,9	0,0	0,953
	SD	25,7	31,4		
%moss	Mean	30,0	28,6	0,0	0,861
	SD	37,3	30,8		
%RM	Mean	39,5	21,1	10,0	**0,000**
	SD	19,9	14,5		
%WM	Mean	59,8	49,2	90,0	0,078
	SD	19,6	27,5		
%BM	Mean	0,0	29,7	0,0	**0,000**
	SD	0,0	30,7		
AvgDiam	Mean	13,4	15,8	12,0	**0,017**
	SD	3,1	4,6		
CanopPhot	Mean	69,8	74,1	70,3	0,182
	SD	16,4	11,0		

A total of 375 trees were measured around nest sites. Results of two way ANOVAs for individual variables are summarized in **Table 6**. Proportions of species are given in **Table 7**. They are similar to the results of cover measurements. The striking feature is the 3-time increase in the proportion of Black Mangrove when compared to the proportion of random points for PTN (30.5 % for *N* points versus 10.1 % for *L* points). That indicates that finches tend to favour patches of black mangroves for nesting. The proportion of Red Mangrove is also higher at CB.

Table 6. Results of two way ANOVAs comparing *N* and *L* sites on one hand and CB and PTN on the other hand. P values are for *t* tests, no values mean effect is not significant.

	N-L	CB-PTN	X
Leaf Litter			
N trees		>0.0001	
Max Height	0.002	0.000	
SumTT			
SumBT			
% stone			
% deadwood	0.023		
% litter		0.001	0.026
% mud	0.0012		
% moss	0.000		
% RM	0.000	0.002	
% WM			
% BM	0.000	0.000	
Avg diam	0.001	0.000	0.004
CanopPhot			

Table 7: Two way frequency table for flooded sites for nest sites "*N*"

		No	Yes	
N	CB	5	25	30
	PTN	3	37	40
	PTNB	1	0	1
		9	62	71

Fisher exact tests comparing *N* and *L* sites for flooding frequency were not significant (*P*=0.051).

Table 8. Number of trees of the three species in the three study sites, *N* points. PTNB is only one point. To be compared to **Table 3** and % covers in **Table 5**.

	CB	PTN	PTNB	
RM	50	60	2	112
WM	102	89	3	194
BM	0	66	0	66
	152	215	5	372

Table 9. Height (m) for the trees in 5m radius, *N* points. $P < 0.005$, one way ANOVA *t* test. See **Table 3** for *L* points.

Site			
	Mean	SE	
CB	11,66	0,48	152
PTN	11,52	0,40	215
PTNB	5,94	2,63	5

Two types of multivariate analysis were performed using all variables but flooding (yes-no data). An ordination based on similarity matrix (using Euclidian distance with standardized Square root transformed data, and Non Metric Multidimensional Scaling) is presented on **Figure 2**. It showed that PTN and CB sites were quite similar, PTNB points tended to group, and that *N* and *L* points were globally equally distributed. The method does not discriminate much among sites or *N*-*L* types.

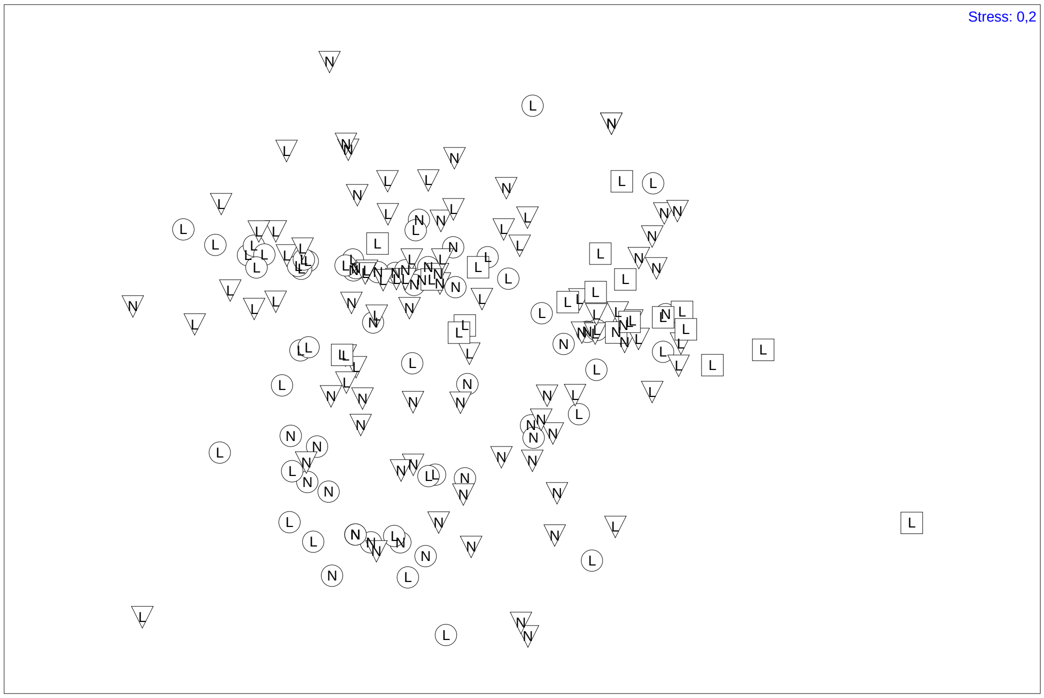


Figure 2. Distribution of sample points after a Non Metric Multidimensional Scaling using a similarity matrix (standardized, square root transformed). *L* are for random locations along transects, and *N* for nest sites. Circles for CB, triangles for PTN and squares for PTNB.

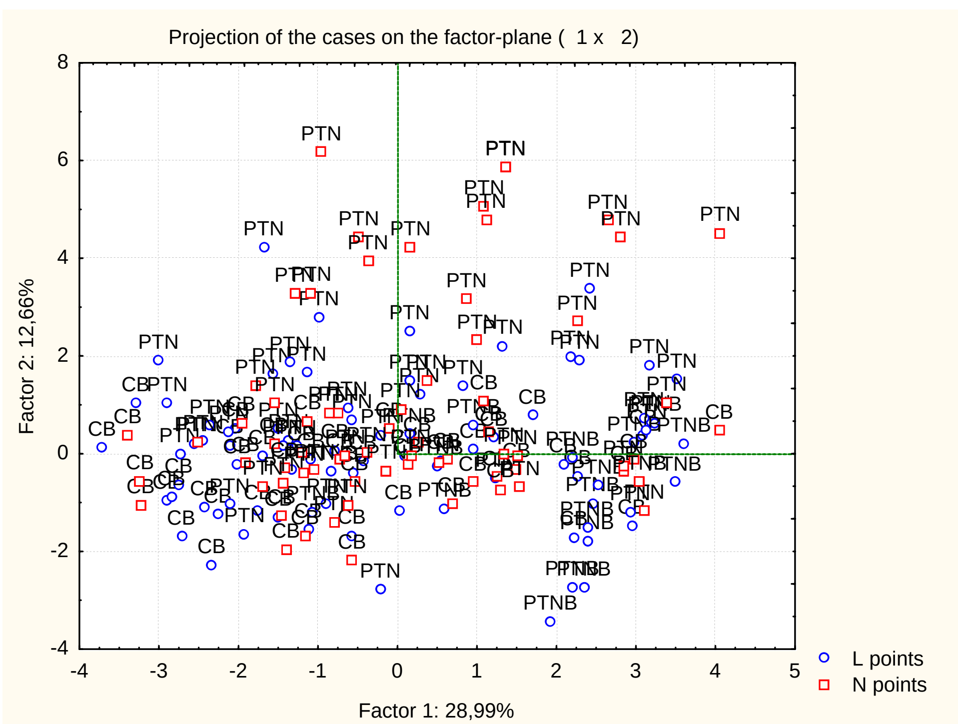


Figure 3. Distribution of samples according to axis 1 and 2 of a PCA calculated using only the random *L* sites. *N* points were plotted on the same 1x2 plane.

A principal component analysis groups PTNB points and position them intermediate between CB and PTN sites. Discrimination among sites is significant only along the axis 2 of the PCA (ANOVA for axis 2 scores, $P < 0.05$) that accounts for only 13 % of the variance (vs 30 for axis 1). Most of the discrimination along this second axis is due to the PTN Nest sites with their higher than average proportion of Black Mangrove. Axis 2 is indeed particularly correlated to the Black Mangrove cover (see **Figure 4**).

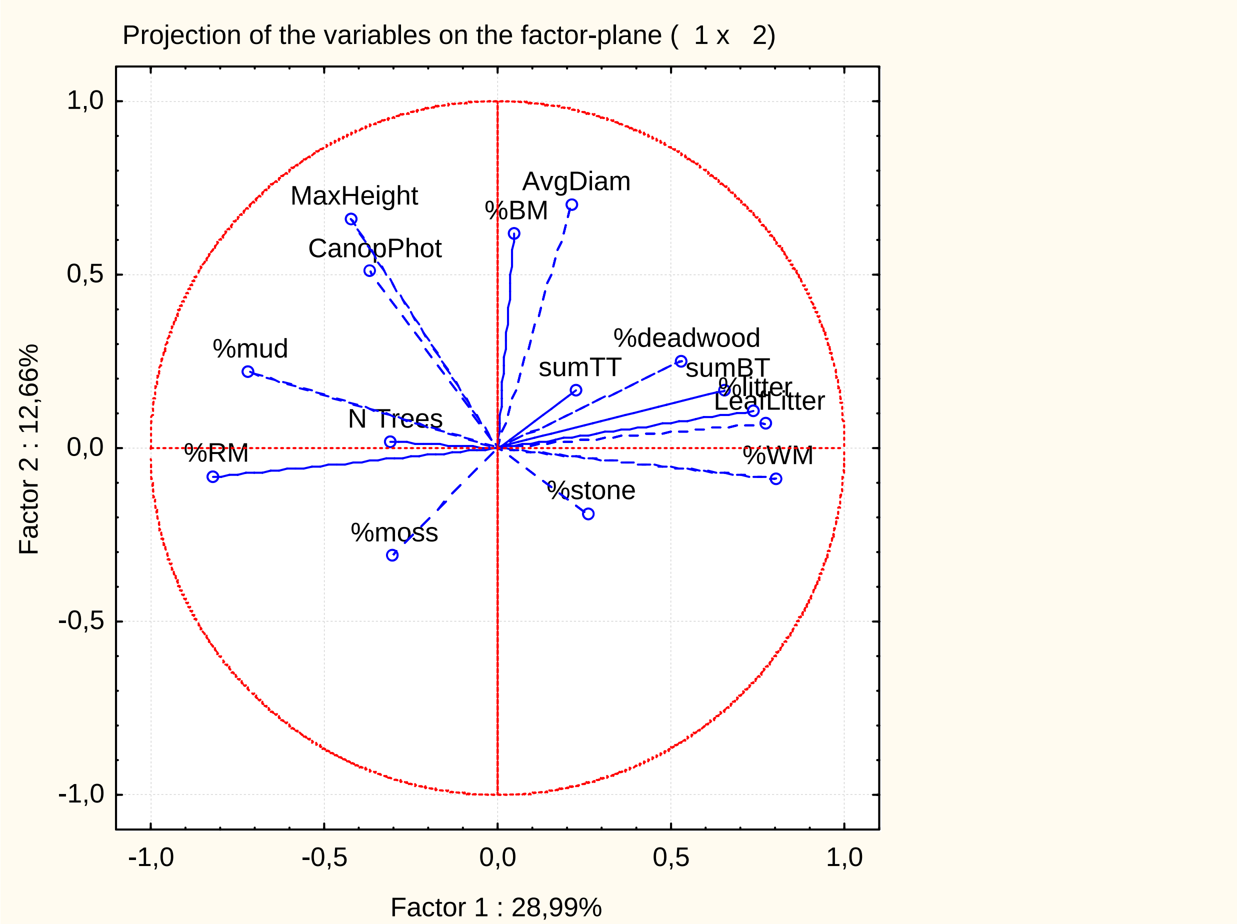


Figure 4. Projection of the variables on the factor plane 1x2 of the PCA

The choice of trees for nesting is not random. At Caleta Black where there are only Red and White Mangrove, finches nest exclusively in White Mangrove. At Playa Tortuga Negra where all three species are present, 17 nest on Black Mangrove and 24 on White (compared to 28 Black for 119 White on average for the forest, see **Table 3**, difference in proportions significant $P < 0.01$, Fisher exact test). Hence the finches not only prefer patches of Black Mangrove to nest in when available, but also the Black Mangrove within those patches. The size of trees is close to the maximum size in each site (even more at CB, see **Table 1**) and much larger than the average size of trees (**Table 10**, see diameter in **Table 1** and height in **Table 4**). Nests are located in the top quarter of the canopy on fine branches.

Table 10. Characteristics of the trees used for nesting (means and standard deviations). Only the diameter is significantly larger at PTN (ANOVA *t* test, *P* = 0.02). *Dist middle* is the distance between trunk and point below the nest.

	CB	PTN
Tree height	15,7	17,4
	5,5	4,9
Diameter	20,7	26,0
	8,8	9,5
Nest height	12,8	13,4
	5,6	4,6
Nest br diam	2,5	2,9
	0,2	1,5
Dist middle	2,7	2,7
	1,8	1,4
N	30	41

Table 11. Characteristics of the mangroves of Puerto Villamil (Via) compared to Northern mangroves (same data as **Table 1**). Values in bold characters indicate sites that do not differ from Puerto Villamil. Means and standard deviations of 87 observation points.

	CB	PTN	PTNB	VIA	*Post Hoc* Tukey HSD
Leaf Litter	0,8	1,0	**2,3**	**3,4**	Via differs from CB & PTN
	1,5	1,4	1,5	4,0	
N Trees	**22,8**	14,8	9,5	**23,5**	2 groups
	12,1	7,7	5,0	20,9	
MaxHeight	14,4	17,9	11,8	**8,5**	All different but PTNB and CB
	4,1	5,3	4,6	4,3	
SumTT	**7,7**	8,1	**5,6**	**4,2**	Via from PTN
	4,1	5,1	2,8	3,3	
SumBT	**7,9**	**8,5**	**8,8**	**8,8**	
	2,8	2,5	1,7	2,3	
%stone	**1,9**	**1,2**	**2,1**	**1,7**	
	6,2	5,8	5,4	4,7	
%deadwood	**11,2**	**12,8**	**9,6**	**8,8**	
	13,2	12,1	8,5	11,5	
%litter	20,5	35,0	**60,4**	**70,7**	all different but Via and PTNB
	24,4	25,6	23,3	30,1	
%mud	35,6	34,9	**15,3**	**3,1**	2 groups
	35,6	31,6	19,8	8,6	
%moss	21,6	15,1	**2,2**	**0,6**	2 groups

	32,2	24,7	6,0	3,5	
%RM	44,8	32,6	**17,5**	**8,9**	CB > others, Via differs PTN
	26,8	27,7	24,9	17,5	
%WM	54,7	48,6	80,4	**6,8**	all different but CB and PTNB
	26,3	29,2	23,9	15,1	
%BM	**0,0**	17,9	**0,0**	**6,0**	PTN differs
	0,0	25,2	0,0	19,4	
%ButM	0,0	0,0	0,0	**60,8**	Via
	0,0	0,0	0,0	40,9	
CanopPhot	**73,5**	**74,8**	56,2	**74,4**	PTNB different
	15,7	13,0	25,3	17,3	

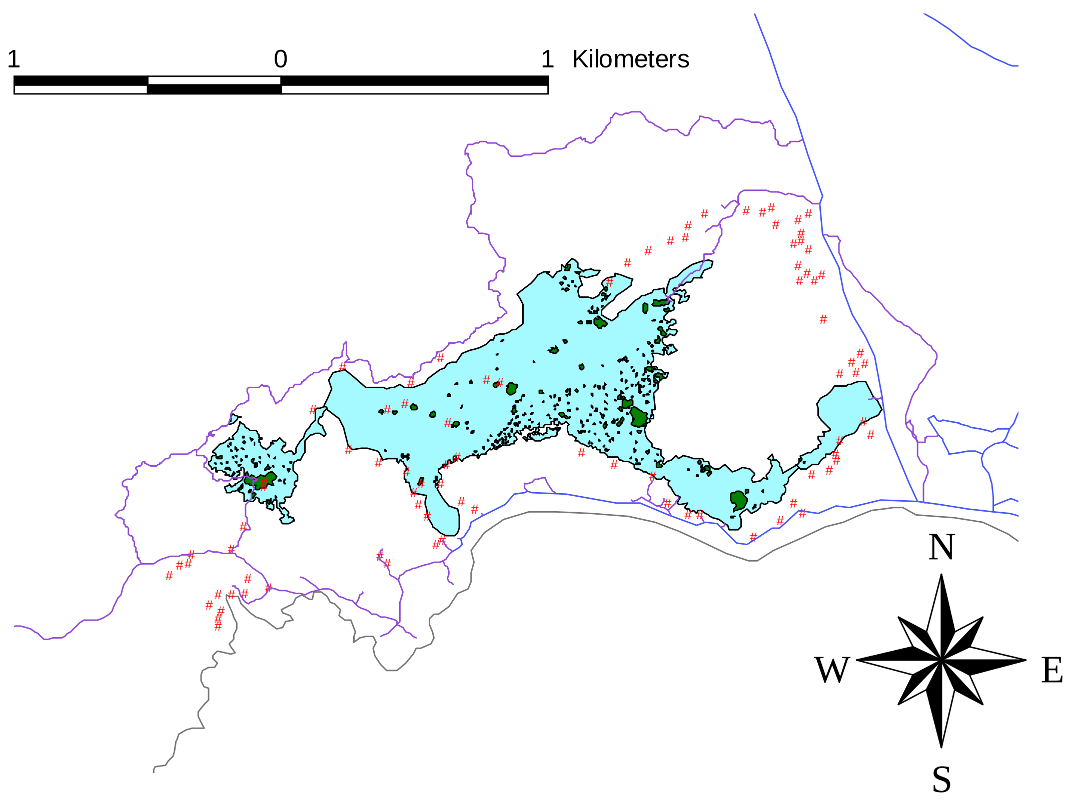


Figure 5. Location of the vegetation sampling points in the mangroves of the Ramsar site close to Puerto Villamil accessed either by foot or with a kayak.

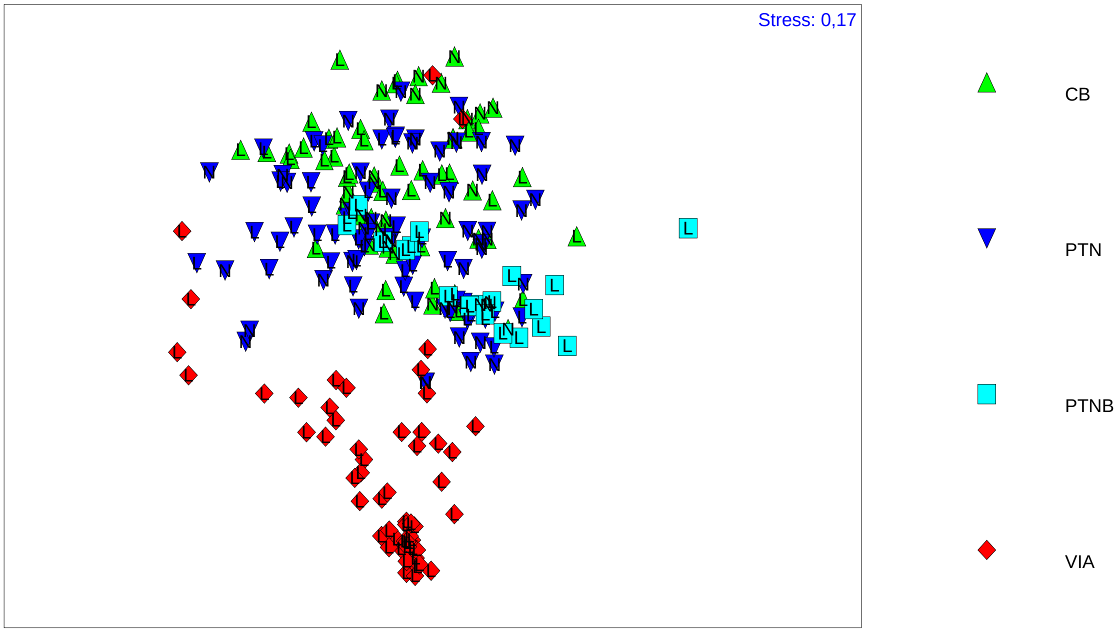


Figure 6. Ordination performed from the similarity matrix adding the data points from the mangroves of Puerto Villamil. Those are clearly different from the northern mangrove except for two points from the area of the "Estero". Distribution of other points is similar to **Fig. 2**

Conclusions

There is now a better description of some vegetation characteristics at the two remaining mangrove finch breeding sites that can be compared to any potential re-introduction site.

In general, points around nest sites and random points (*L* points) are very similar. Even so PTN and CB are quite different in some characteristics; they seem to be equally suitable for the nesting of Mangrove Finch. While birds do nest in White Mangrove in CB, they prefer Black Mangrove stands in PTN. At both sites, they choose old trees that are tall and thick, thus vegetation height could be an important habitat feature for territory choice.

PTNB, with few territories and only one nest site, has a significantly lower vegetation height. Another difference is % mud; e.g. PTNB is drier than the other two sites. It is possible that at drier sites, invertebrate community and thus food availability is different; unfortunately no data exist for comparison. Another characteristics being significantly different at PTNB from the two other sites is the % of Red Mangrove. Red Mangrove were identified as an important feeding habitat for Mangrove Finches especially during the dry season (Loaiza 2009).

Points from Villamil seem to be rather different following the similarity matrix (**Figure 5**), though they have many features in common with either site. For example it is equally dense as CB, with comparable amounts of deadwood, and considerable amounts of leaf litter. However, trees are especially low and tree species composition is very different, with Button Mangrove (*Conocarpus erecta*) largely replacing Red and White Mangrove. No data are available for invertebrate community at this site. With the present data, the suitability of this site is questionable, especially if vegetation height and % of Red Mangroves are more important than has been considered in the past.

References

Dvorak, M., H. Vargas, B. Fessl, and B. Tebbich. 2004. On the verge of extinction: a survey of the mangrove finch *Cactospiza heliobates* and its habitat on the Galápagos Islands. Oryx 38:1-9.

Loaiza, A. D. 2009. Comportamiento de alimentación del pinzón de manglar (*Cactospiza heliobates*), comparado en dos estaciones climáticas. Universidad Central del Ecuador, Quito.

ANNEXE 2A

MANGROVE FINCH MANAGEMENT INTERNATIONAL WORKSHOP Puerto Villamil, Isabela, Galápagos, Ecuador, November 17th-21st, 2008

Population modelling group

Participants: Birgit Fessl, Jorge Rodríguez and Richard Young

Modeller: Jorge Rodríguez

Introduction

The Mangrove Finch (*Camarhynchus heliobates*) lives in mangrove forest of the Galápagos Islands of Isabela and Fernandina, although recent studies suggest that it has disappeared in Fernandina (Grant and Grant 1997, Dvorak *et al.* 2004). This finch species has a very small population restricted to a few mangrove patches, making it vulnerable to different threats, the most important being predation of the eggs and fledglings by rats (*Rattus, rattus*) and fledging deaths caused by parasitisation of the Diptera *Philornis downsi*. Because of these factors, the species is classified as critically endangered by IUCN (BirdLife International 2009). The Mangrove Finch populations' conservation will depend in good measure to the study of its demographic dynamics, its biology, environmental factors that influence it and the identification of the quantitative impacts of the threats that affect the populations. With all this knowledge, management strategies that guarantee the long term survival of the species can be implemented.

Population Viability Analysis (PVA)

PVAs are quantitative analysis methods to determine the extinction probability of a population (Miller and Lacy 2005). Shaffer (1990) says that a PVA is any method used to determinate the minimum viable population (MVP) size of a species. Biologically, MVP is the minimum size of a population below which the fate of the population is dominated mainly by stochastic factors that characterize the extinction vortices (Miller and Lacy 2005). Therefore, a PVA is the estimation of extinction probabilities and other variables related to population stability, with the help of analysis that incorporate population threats in computer programmes that model the extinction process (Gilpin and Soulé 1986, Lacy 1993/1994).

In addition to estimating the probability of extinction of a population, PVAs can generate other types of information related to small population conservation (Lindenmayer *et al.* 1993). The application of these techniques can 1) identify data of the species ecology that are not well known but are important in assessing its viability 2) identify trends in population behaviour, 3) identify the factors that threaten the populations, 4) identify a minimal critical area for the survival of the species and 5) improve the management and decision making with respect to the population.

In practice it is difficult to determine the factors that potentially influence the survival of small populations. In addition, there are not many opportunities to test, in experimental ways, different long term management strategies. Simulations that model "virtual populations" offer a different approach and the results probably are more realistic than the ones obtained trough deterministic life tables, since simulations include stochastic events (Akçakaya 1992, Mathews and Macdonald 2001, Brook *et al.* 2002). It is important to notice that the results of a PVA are more useful as a tool that point out the relative importance of different management actions related with the maintenance and management of small populations, rather than absolute values (Boyce 1992, Lindenmayer *et al.* 1993, Bessinger and Westphal 1998, Harwood 2000, Peterson *et al.* 2003).

VORTEX

The population viability analysis was done with the help of computer software VORTEX 9.92 (Miller and Lacy 2005); using as base the participants' species population knowledge and natural history bibliographical references from this and other related species. VORTEX uses a Monte Carlo simulation to model the effects of deterministic and stochastic process (demographic, environmental and genetic) over populations. At the beginning, the programme generates individuals to start the initial population, and then each animal will go through a series of life cycle events (birth, breeding, dispersion, death). Demographic events such as breeding success, brood size and individual survival are determined according to the data entered in the model. Allowing the programme to generate random values for an event within certain limits VORTEX can predict: 1) the extinction risk at specified intervals (e.g. every 10 years during a 100 year simulation), 2) population's stochastic growth rate, 3) median time to extinction, 4) mean time to extinction of those simulated populations that became extinct and 5) mean size of, and genetic variation within, extant populations.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters used as input to the model and because of the random processes involved in nature. Interpretation of the output depends upon our knowledge of the biology and the environmental conditions affecting the species (Matamoros *et al.* 1996).

Baseline model parameters

Prior to the workshop population data was obtained from field through studies by Birgit Fessl as well as information gleaned from previously published research articles of this and other related species (Grant and Grant 1992, 1997, Dvorak *et al.* 2004). On the first day of the workshop, a revision of this data was made with the participants and the remaining input data necessary for the model was entered. Environmental variation (EV) was calculated from the field studies of Birgit Fessl and what experts believe can happen in reality.

The baseline model represents the actual status of the Mangrove Finch populations. The purpose of this model is to have a reference to develop different scenarios of the effects of the threats and possible management strategies to have better decision criteria at the time of implementing actions that guarantee the long term viability of the species.

General parameters of the model

Number of interactions: 500

Number of years: 100

Extinction definition: Only individuals of one sex remain

Number of populations: 3

Initial population size (N_0) and carrying capacity (K):

Population	N_0	K
Playa Tortuga Negra	48	74
Caleta Black	34	40
Bahía Cartago	10	135

Mating system: Monogamy

Age of first offspring: 1 year for females and 2 for males.

This data is not available for the Mangrove Finch; therefore, data from a study of Grant and Grant (1992) with the Common Cactus-finch (*Geospiza scandens*), a related species, was used.

Density dependent reproduction: No.

There is no evidence that in different population densities there is a change in the percentage of females and males that mate or in the quantity of eggs per clutch.

Percentage of adult females breeding: 90%.

This value was entered from the percentage of females that lay at least one egg in a regular year, either they hatch or not. Another piece of information taking in account is that in years when *La Niña* phenomenon occurs in the islands, the females do not successfully mate or the eggs do not hatch (see below in catastrophes).

Percentage of adult males in the breeding pool: 100%.

There is no information about this, but it is assumed that every male that has access to a female can breed.

Maximum number of progeny (eggs) per year: 9.

In years with much precipitation, the Mangrove Finch can produce up to three clutches in a year, each clutch with up to three eggs giving a maximum of nine. On average years females lay 3.14 eggs, but in years with heavy precipitation like *El Niño* years, this value can go up to 4.7 eggs.

Percentage of males at birth: 50%.

There is no evidence that sex ratio at birth differs statically from 1:1.

Mortality parameters

The available mortality data come from field studies of Birgit Fessl. Fessl found that egg mortality due to rat predation and to parasitisation by the Diptera *Philornis downsi* is very high. Mortality for class age 0-1 years reported for *G. scandens* varies from 48.8% to 56.6 % (Grant and Grant 1992), but the data from Fessl suggest that for the Mangrove Finch this value can be much higher. Taking into account both egg and fledglings, mortality can be as high as 84%.

In this species census, it has been reported a slightly higher number of males than females, similar to what Grant and Grant (1992) found in *G. scandens*, where they reported higher mortality in females than in males. Therefore, in this model female mortalities after one year old are higher than male mortalities.

Mortality rates

	Females (%)	**Males (%)**
0-1 years (EV)	84 (±5.04)	84 (±5.04)
1-2 years (EV)	18.37 (±2.25)	12.79 (±1.25)
2-3 years (EV)	-	12.79 (±1.25)

Inbreeding depression: Yes.

There are studies that show inbreeding depression as an important factor in small populations' viability (Ralls *et al.* 1998, O'Grady *et al.* 2006). VORTEX models the negative effects of inbreeding by reducing first year survival of individuals. The default value of the programme is 3.14 lethal equivalents, 50% of which were assigned to lethal alleles and subject to purging. This value is the median lethal equivalents calculated from a study of Ralls *et al.* (1998) on the effect of inbreeding on 38 captive mammal populations. However, a recent study by O'Grady *et al.* 2006 concluded that 12 lethal equivalents spread across survival and reproduction is a realistic estimate of inbreeding depression for wild populations. In this model a value of six lethal equivalents was used because it is the sum of the mean values of lethal equivalents of fecundity and juvenile survival from the study of O'Grady *et al.* (2006).

Concordance between EV in reproduction and survival: Yes

There is no information about reproduction and survival but it is believed that "good" years for reproduction are also "good" years for survival; conversely, "bad" years for reproduction are linked to "bad" years of survival.

EV correlation among populations: 0.75

Populations are in close proximity, so it is expected that a "good" year or a "bad" year simultaneously affects in similar ways, all three populations, but these may not be completely through particular conditions within each population.

Maximum age of reproduction: 15 years.

In VORTEX the individuals are removed from the population after they reach the maximum age of reproduction. The programme assumes that animals can reproduce throughout their adult life unless the contrary is specified. This value is unknown for the Mangrove Finch, therefore, the maximum age of survival reported for the cactus finch in the wild was used (Grant and Grant 1992).

Number of catastrophes: Not included in the baseline model.

In the case of the Mangrove Finch reproduction can be drastically affected by the *El Niño* and *La Niña* phenomena, the former increases the quantity of eggs that the females can lay, the latter produces the contrary: the eggs do not hatch or the females do not lay them at all. These phenomena affect Galápagos Islands in a cyclic year lapses (Vargas *et al.* 2006), a strong *El Niño* event can occur every 20 years, while a strong *La Niña* event can occur every 14 years (Vargas pers. comm.). Their effects were modelled with functions entered in the percent of adult females breeding (*La Niña*) and in the mean number of progeny (in these case eggs) that females have per clutch (*El Niño*).

Supplementation: Not included in the baseline model.

Harvest: Not included in the baseline model.

Table 1. Parameters input values for the VORTEX Mangrove Finch model.

Parameter	Value
Breeding system	Monogamy
Age of first offspring (♀/♂)	1/2
Density dependent reproduction	No
Adult females breeding per year (including *La Niña* effect) / (EV)	90+((Y%14 = (FLOOR [14*SRAND(R)])%14)*(-90)) / (10)
Males in breeding pool	100
Maximum brood (eggs) size	9
Mean brood size (including *El Niño* effect) / (EV)	3.14+((Y%20 = (FLOOR [20*SRAND(R)])%20)*1.6)) / (1.19)
Overall offspring sex ratio	1:1
% annual mortality ♀/♂ (EV) 0-1 1-2 2-3	 84 (5.04)/84 (5.04) 18.37(2.25)/12.79 (2.25) -/12.79 (2.25)
Inbreeding depression	6 lethal equivalents with 50% lethal alleles
Concordance between EV in reproduction and survival	Yes
EV correlation among populations	0.75
Maximum age	15 years
Catastrophes	None
Initial population size (N_0)/Carrying capacity (K) Playa Tortuga Negra Caleta Black Bahía Cartago	 48/74 34/40 10/135

Results

Under the actual high juvenile mortality rate the three surviving Mangrove Finch populations had negative stochastic growth rate that derive in a probability of persistence of zero for Caleta Black and Bahía Cartago and near zero for Playa Tortuga Negra; and all became extinct in a small period of time. The few scenarios that persist over the 100 year period were from Playa Tortuga Negra, with a mean extant population size of less than 10 birds and genetic diversity less than 0.65 (**Fig. 1**, **Table 2**). These results indicate that the species is in high risk of extinction in a very short period of time, with the Bahía Cartago population the most critical. It also reveals the importance of establishing immediate management actions to guarantee the long term viability of the species.

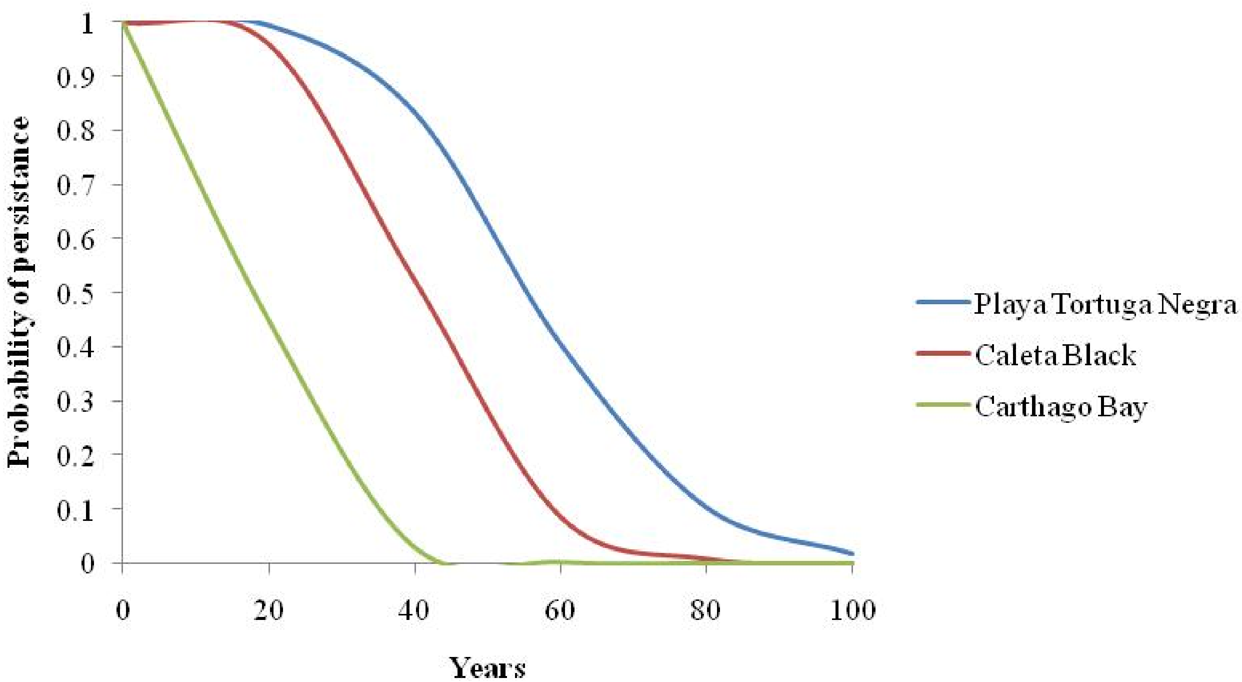


Figure 1. Probability of persistence of the three Mangrove Finch populations in the base model for a period of 100 years.

Table 2. Mangrove Finch base model results for a 100 year period. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: N-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Population	stoc-r	PE	N-extant	GD	MedianTE	MeanTE
Playa Tortuga Negra	-0.041	0.982	6.78	0.6411	56	56.7
Caleta Black	-0.046	1.000	0	0	41	42.1
Bahía Cartago	-0.051	1.000	0	0	19	20.3

Management actions

In this section results from different management actions scenarios are shown. Each action reflects the impact of different measures in the Mangrove Finch's viability.

Management Action I. Lowering juvenile mortality by implementing predator control actions

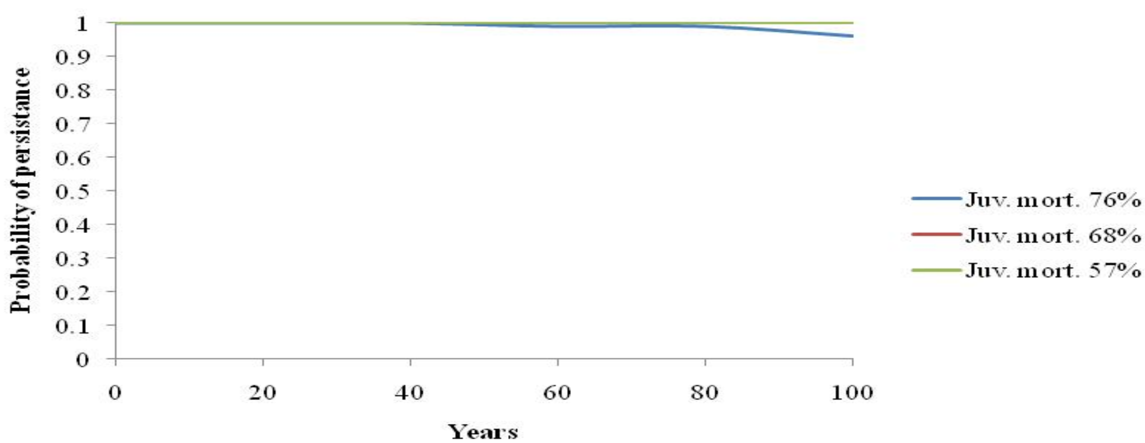
Introduction

The high mortality of eggs and fledglings is primary due to rat predation and *Philornis downsi* parasitism, factors that can be controlled by plague control actions. In this analysis different scenarios were run varying the juvenile mortality (0-1 year old) to simulate the effect measures to control these two species. Since the effect of these measures would not be immediately, a function where the base model mortality (84%) gradually decrease over a 10 year period was introduced. The different levels of juvenile mortality tested were 76%, 68%, and 57%.

Results

Controlling the rat and *Philornis downsi* populations can have a great impact in the viability of the Mangrove Finch by increasing the probability of persistence and the stochastic growth of all populations, however the genetic diversity values were low in all of them (**Fig. 2**, **Table 3**). The larger the population, the more stable it gets and higher gene diversity retains as juvenile mortality can be decreased. Is important to stand out that Bahía Cartago initial population is so small that even in scenarios with low juvenile mortality, it still can become extinct (**Fig. 2**, **Table 3**).

A.



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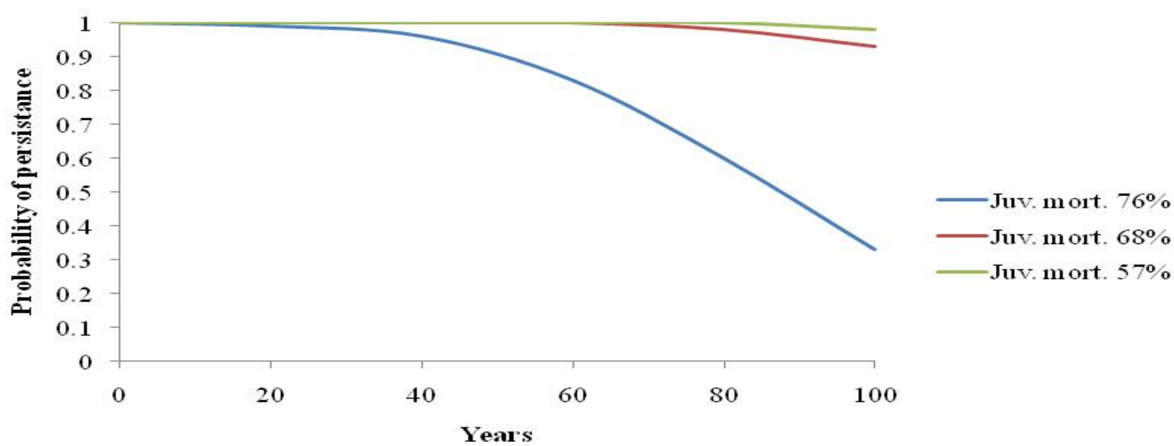

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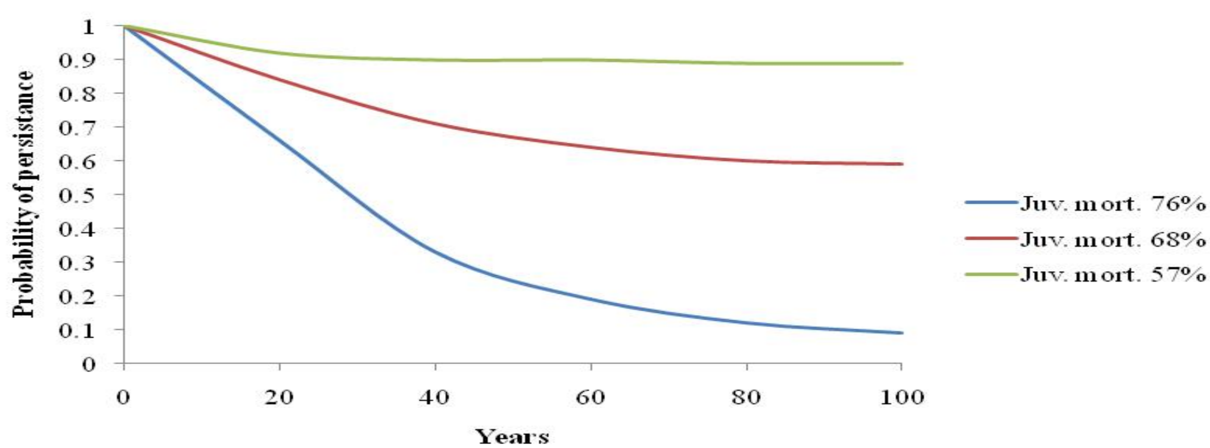

Figure 2. Probability of persistence of the three Mangrove Finch populations for a period of 100 years, when Management Action I is implemented. Juvenile mortality: Juv. mort. A) Playa Tortuga, B) Caleta Black, C) Bahía Cartago.

Table 3. Mangrove Finch Management Action I results for a 100 year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Population	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
76%	Playa Tortuga Negra	0.037	0.038	52.84	0.7575	0	79.9
	Caleta Black	0.002	0.668	15.23	0.5324	88	72.5
	Bahía Cartago	-0.015	0.908	76.96	0.6832	29	31.4
68%	Playa Tortuga Negra	0.099	0	68.76	0.7518	0	0
	Caleta Black	0.059	0.066	31.33	0.6144	0	85.8
	Bahía Cartago	0.058	0.412	126.78	0.7202	0	31.6
57%	Playa Tortuga Negra	0.164	0	70.73	0.7412	0	0
	Caleta Black	0.122	0.004	37.65	0.5948	0	92.5
	Bahía Cartago	0.141	0.11	132.57	0.7333	0	18.6

Management Action II. Extract eggs from Playa Tortuga population to establish a captive population to supplement other populations

Introduction

A management strategy that has been studied for the Mangrove Finch is to create a captive population with founder individuals from a wild population. The objective of this strategy is to maintain a population free of the natural threats that affect the species in the wild and later supplement individuals from this captive population to small size wild populations to reduce their extinction risk. To implement this kind of strategy first you have to evaluate the risk of extracting eggs from the wild population. The previous predator control scenarios were used for the analysis of this management action with the different juvenile mortalities entered from the beginning.

VORTEX Parameters

Scenarios where 10, 20 and 30 eggs are collected annually from Playa Tortuga for the first five years were tested. Since eggs cannot be harvested in VORTEX, this effect was simulated by increasing the equivalent value in the juvenile mortality in the first five years of the simulations. The objective of these scenarios is not to establish absolute values of the effect of harvesting eggs on the wild population, rather than serve as a guide in a measure that is been considered as a choice for the management of this species.

Results

Collecting eggs for the first five years of the scenarios does not have a significant impact on the viability of Playa Tortuga population (**Table 4**). The results are similar to those of previous scenarios where this element was not included (**Table 3**), suggesting that Management Action I is robust enough to absorb the effect of higher juvenile mortality for the five year period imposed in these scenarios of Management Action II.

Table 4. Mangrove Finch Management Action II results for a 100 year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Eggs collected	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
76%	10	0.040	0.038	53.80	0.758	0	88.70
	20	0.039	0.034	53.79	0.748	0	89.00
	30	0.038	0.040	54.90	0.757	0	85.00
68%	10	0.104	0	68.28	0.760	0	0
	20	0.104	0	69.14	0.765	0	0
	30	0.102	0	68.72	0.759	0	0
57%	10	0.171	0	70.41	0.734	0	0
	20	0.170	0	70.44	0.728	0	0
	30	0.170	0	70.41	0.735	0	0

Management Action III. Extract adults from Playa Tortuga population to establish a captive population to supplement other populations

Introduction

This management action is similar to the previous one with the difference that in these scenarios adult birds are extracted (equal numbers of females and males) instead of eggs. Another variation is that different harvest year periods were tested (1-5, 5-9, 10-14) because N_0 is so small that harvesting adult birds at the beginning of the simulations can have different results compared to simulations where harvesting is done in later years when the population size may be increasing.

Results

The results show that harvest adult birds from Playa Tortuga has to be done with extreme caution. The scenarios that had the lower risk of extinction were the ones that have the combination of 10 birds extracted per year with low juvenile mortality and harvest periods starting enough years after population growth is ascertain. To extract 20 or 30 birds per year causes high population instability even in scenarios with low juvenile mortality and harvesting periods starting after five years (**Table 5**).

Two factors important to consider in this scenarios are the relationship between N_0 and K, and the *La Niñ*a effect. Carrying capacity of Playa Tortuga is 24 birds higher than the initial population, but if K is nearer to N than the scenarios established, the population may not grow enough to maintain any harvesting level. In addition, if *La Niña* event occurs during the harvesting years this could generate additional stress to the population. This is shown when you compare the PE of scenarios with a harvesting period in years 9-14 with the others. The way the scenarios are built there is about 36% probability that a *La Niña* event hit the population by year 5, about 64% by year 9 and 100% by year 14, thus giving a higher PE when harvesting is made in years 9-14.

Table 5. Mangrove Finch Management Action III results for a 100 year period. Juvenile mortality: Juv. mort. Harvesting period: Harv. period. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Birds collected	Harv. period (year)	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
76%	10	1-5	0.013	0.35	48.87	0.7261	0	36.6
		5-9	0.029	0.134	53	0.7407	0	41.7
		10-14	0.027	0.192	52.82	0.7547	0	45.7
	20	1-5	-0.466	0.998	70	0.804	4	3.8
		5-9	-0.039	0.876	43.31	0.6907	9	13.9
		10-14	-0.021	0.88	46.98	0.7026	14	20.6
	30	1-5	-0.755	1.000	0	0	3	2.5
		5-9	-0.149	1.000	0	0	7	7.6
		10-14	-0.043	1.000	0	0	12	12.4
68%	10	1-5	0.092	0.028	68.54	0.7506	0	11.9
		5-9	0.098	0	68.68	0.7532	0	0
		10-14	0.097	0	68.74	0.7553	0	0
	20	1-5	-0.149	0.958	67.57	0.6883	4	4.8
		5-9	0.069	0.366	68.32	0.7424	0	15.6
		10-14	0.066	0.426	66.52	0.7253	0	19.3
	30	1-5	-0.674	1.000	0	0	3	2.8
		5-9	-0.05	0.962	66.63	0.6685	8	8.2
		10-14	0.01	0.968	63.25	0.7034	13	13.2
57%	10	1-5	0.163	0.004	70.34	0.7322	0	5
		5-9	0.166	0	70.23	0.7366	0	0
		10-14	0.167	0	70.44	0.7427	0	0
	20	1-5	0.071	0.75	70.82	0.6951	5	5.4
		5-9	0.148	0.09	70.33	0.7283	0	11.8
		10-14	0.15	0.106	70.59	0.7234	0	15.2
	30	1-5	-0.623	1.000	0	0	3	3.1
		5-9	0.094	0.748	68.94	0.7116	9	8.5
		10-14	0.111	0.752	69.5	0.7101	14	13.6

Management Action IV. Supplement adult birds from a captive population to Bahía Cartago

Introduction

The participants wanted to evaluate if supplement 4, 10 or 20 birds (half males, half females) annually for the first five years have a rescue effect on the Bahía Cartago population. The scenarios of Management Action I where taken as base to run these scenarios.

Results

The Bahía Cartago population had an increased stability as the number of birds supplemented augmented (**Table 6**). Some simulations in every scenario became extinct in the first years, but were successfully recolonised by the supplemented birds (see MeanTE in **Table 6**). Also, the supplemented birds contribute to increase gene diversity of the population compared to previous scenarios where this element was not modeled (**Tables 4** and **6**). However, as stated in the last management action the relationship between *N* and *K* is also a factor to consider in these scenarios. In this model it was established an initial population of 10 birds and a carrying capacity of 135, but if *K* is more approached to *N* in reality this results may not be realistic and the supplementation may not have the effect shown here.

Table 6. Mangrove Finch's Management Action IV results for a 100 year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Birds supplemented	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
84	4	-0.019	0.988	18.5	0.7516	47	48.2
	10	-0.007	0.758	22.84	0.737	79	69.4
	20	0.006	0.446	32.74	0.7819	0	76.3
76	4	0.059	0.038	122.62	0.8334	0	37.5
	10	0.08	0	127.43	0.8719	0	3.5
	20	0.09	0	127.02	0.8744	0	3.1
68	4	0.126	0	131.84	0.8406	0	3
	10	0.141	0	132.49	0.8618	0	3.4
	20	0.149	0	132.23	0.864	0	3.8
57	4	0.193	0	132.74	0.8243	0	3.2
	10	0.206	0	133.1	0.845	0	3
	20	0.215	0	133.07	0.849	0	2.9

Risk Analysis

In this section we evaluated the impact of external elements that cannot be entirely controlled and represent a risk factor even when management actions are implemented.

Risk Assessment I. Habitat reduction

Introduction

Habitat loss is an important factor that endangers the Mangrove Finch and is one of the causes responsible of its actual fragmented distribution in small mangrove forests (Dvorak *et al.* 2004). Habitat loss of 25%, 50% and 75% at the end of 100 years were tested taking 68% as starting juvenile mortality to simulate habitat reduction caused by events such as mangrove diseases or human development.

Results

Habitat loss is an important element to take in account in Mangrove Finch conservation. Even though the stochastic growth is positive in the majority of scenarios thanks to the predator control that helps to decrease juvenile mortality, Caleta Black and Bahía Cartago populations had moderate to high levels of extinction risk accompanied with small final population sizes, and in the case of Bahía Cartago the simulations that got extinct did it in a short period of time (**Fig. 3**, **Table 7**). This scenarios show that even though Caleta Black has a higher initial population size than Bahía Cartago it has a higher risk of extinction, because it has a smaller carrying capacity. Again the importance of a good estimation of this parameter is significant because if this value is overestimated in any of the populations and a habitat reduction occurs then the real extinction risk could be higher than the scenarios tested here.

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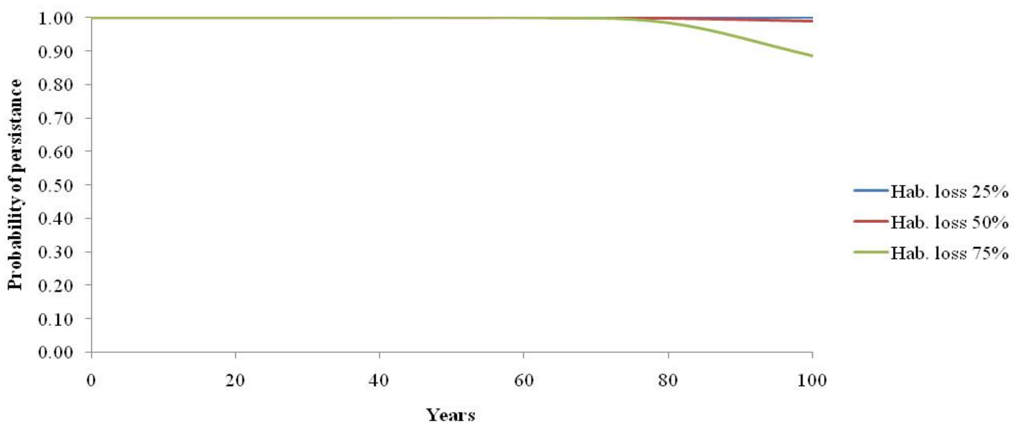

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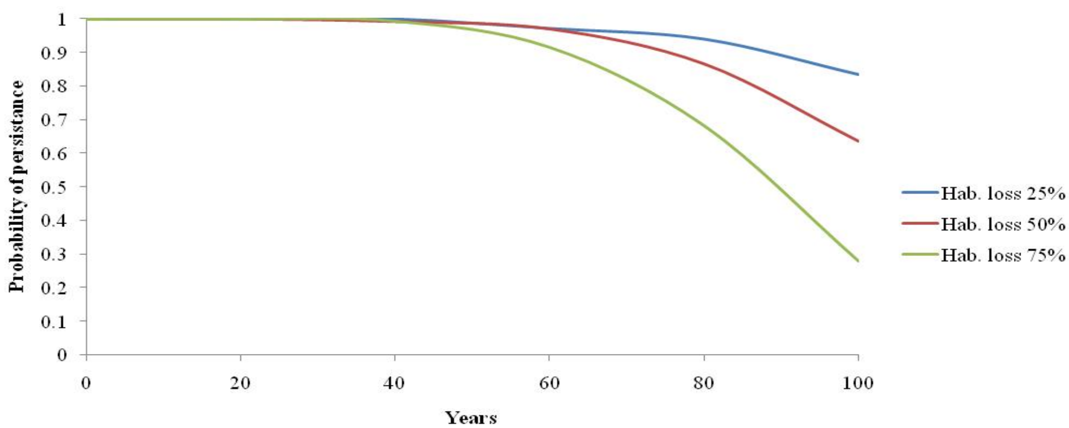

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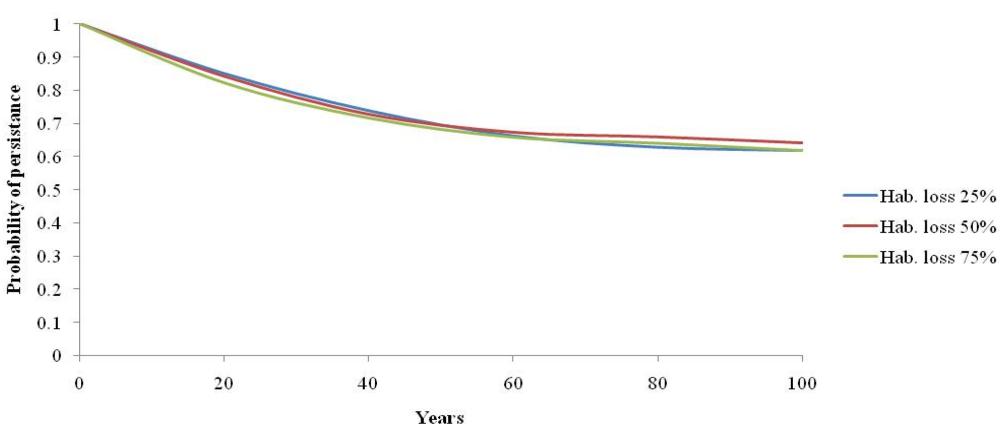

Figure 3. Probability of persistence of the three Mangrove Finch populations for a period of 100 years, of Risk Assessment I. A) Playa Tortuga, B) Caleta Black, C) Bahía Cartago.

Table 7. Mangrove Finch Risk Assessment I results for a 100 year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Habitat loss per year	Population	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
0.25%	Playa Tortuga Negra	0.092	0	50.55	0.7256	0	0
	Caleta Black	0.05	0.166	20.54	0.5525	0	82.1
	Bahía Cartago	0.056	0.382	95.05	0.71	0	31.5
0.50%	Playa Tortuga Negra	0.085	0.01	32.11	0.6834	0	89.6
	Caleta Black	0.043	0.364	12.18	0.5026	0	82.6
	Bahía Cartago	0.056	0.358	63.48	0.6915	0	29.1
0.75%	Playa Tortuga Negra	0.074	0.114	15.01	0.5954	0	91
	Caleta Black	0.037	0.722	6.54	0.4167	90	81
	Bahía Cartago	0.05	0.382	31.79	0.6459	0	29.2

Risk Assessment II. Epidemic Disease

Introduction

There is a risk that an unknown disease to the finches can appear and generate an epidemic outbreak in the population. An epidemic event with a frequency of once every 100 years and increased mortality to 90% for age 0-1 years and 50% for the other classes was simulated. The effect on mortality decreased linearly until it reached the starting value of the scenario after 5 generations; here 6 years were taken as a generation, average value calculated for *G. scandens* by Grant and Grant (1992).

Results

Populations are very sensible to an epidemic event, even if a high predator control is established. Results show a positive stochastic growth but a low probability of persistence which indicates that the predator control is very good maintaining the populations stable when there is not a epidemic disease, but when this kind of event affects the species the population get extinct (**Fig. 3**, **Table 8**). These scenarios suggest that investigation concerning prevention and effect of potential epidemic diseases is important to take into consideration for future management plans.

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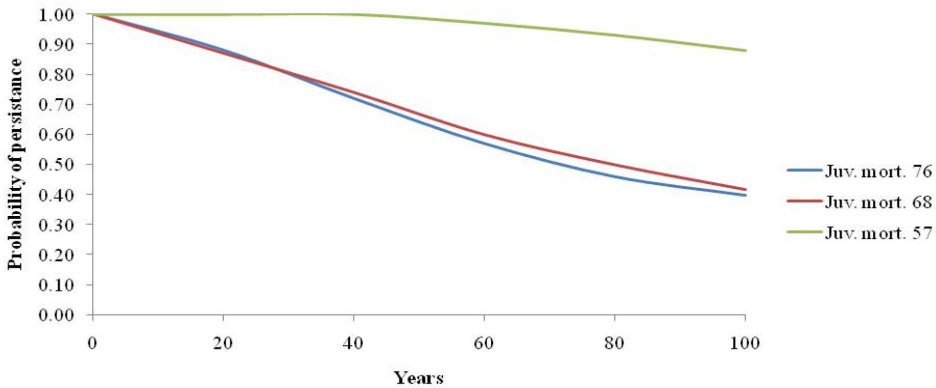

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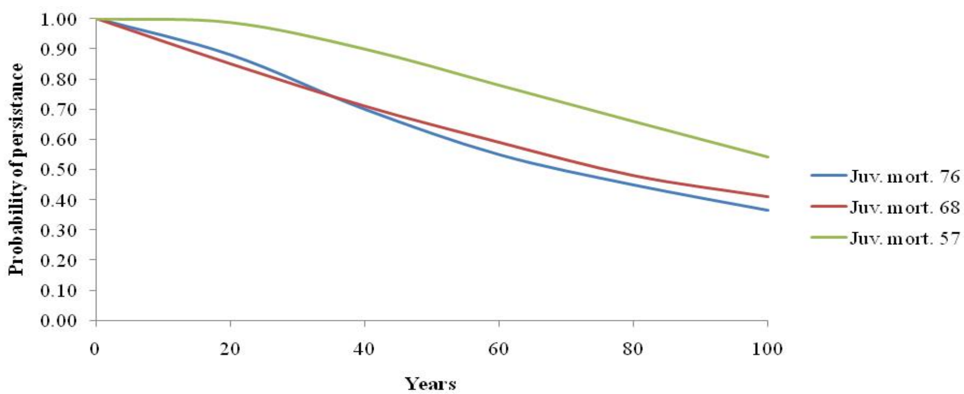

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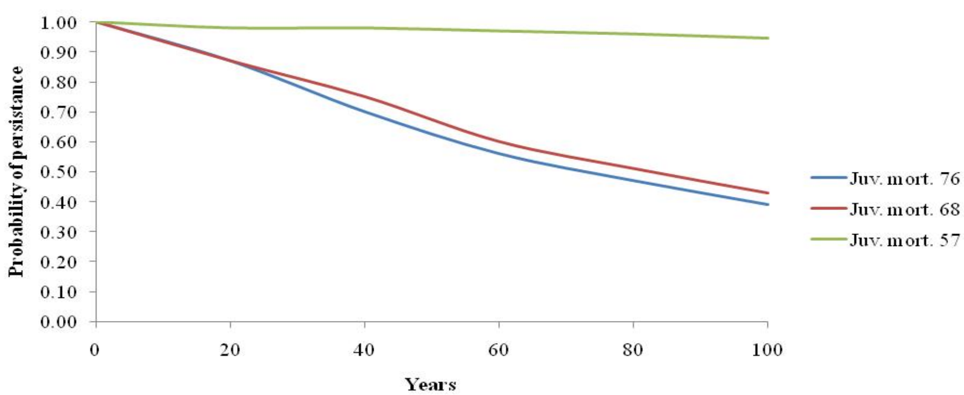

Figure 3. Probability of persistence of the three Mangrove Finch populations for a period of 100 years, of Risk Assessment II. A) Playa Tortuga, B) Caleta Black, C) Bahía Cartago.

Table 8. Mangrove Finch Risk Assessment II results for a 100 year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Scenario	Population	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
76%	Playa Tortuga Negra	0.07	0.6	67.13	0.84	75	45.7
	Caleta Black	0.06	0.63	33.8	0.74	71	45.5
	Bahía Cartago	0.05	0.61	127.05	0.843	73	44.2
68%	Playa Tortuga Negra	0.12	0.58	69.69	0.822	80	46.3
	Caleta Black	0.1	0.59	37.69	0.721	77	45
	Bahía Cartago	0.11	0.57	127.99	0.834	82	46.2
57%	Playa Tortuga Negra	0.16	0.12	61.64	0.724	0	76.2
	Caleta Black	0.13	0.46	35.44	0.652	0	60.9
	Bahía Cartago	0.16	0.05	121.79	0.798	0	52

Risk Assessment III. An increase in *El Niño* and *La Niña* events

Introduction

As stated before *El Niño* and *La Niña* affect Galápagos Islands in a cyclical way; the former has positive effects on reproduction whereas the latter has the contrary effect. What would happen if these cycles of good and bad years for reproduction become more frequent in time because of global warming? To answer this question, scenarios where the frequency of each event is shortened 5 or 10 years were tested.

Results

If the occurrence of both phenomena increases, the positive effects of *El Niño* cannot counter the negative ones of *La Niña*, making small populations even more unstable than ones that kept the base values. Extinction risk of Playa Tortuga Negra decline as juvenile mortality decreases because the combination of population size and predator control surpasses the effect of *La Niña*. Populations of Caleta Black and Bahía Cartago are not big enough so the juvenile mortality has to be dropped to the lower level tested to see a reduction in the extinction risk and even so, Bahía

Cartago maintains a moderate risk of extinction if the phenomena frequency increases (**Table 9**). It is important to mention that this scenarios assume that the frequency increase of both phenomena is proportionally, which may be not true in real life.

Table 9. Mangrove Finch Risk Assessment III results for a 100 year period. Frequency of phenomena occurrence: Freq. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Freq. (years)	Juv. mort.	Population	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
20 (*El Niño*) 14 (*La Niña*) (Base)	76%	Playa Tortuga Negra	0.037	0.038	52.84	0.7575	0	79.9
		Caleta Black	0.002	0.668	15.23	0.5324	88	72.5
		Bahía Cartago	-0.015	0.908	76.96	0.6832	29	31.4
	68%	Playa Tortuga Negra	0.099	0	68.76	0.7518	0	0
		Caleta Black	0.059	0.066	31.33	0.6144	0	85.8
		Bahía Cartago	0.058	0.412	126.78	0.7202	0	31.6
	57%	Playa Tortuga Negra	0.164	0	70.73	0.7412	0	0
		Caleta Black	0.122	0.004	37.65	0.5948	0	92.5
		Bahía Cartago	0.141	0.11	132.57	0.7333	0	18.6
15 (*El Niño*) 9 (*La Niña*)	76%	Playa Tortuga Negra	0.025	0.12	47.7	0.7479	0	82.8
		Caleta Black	-0.006	0.812	12.09	0.5342	80	72.1
		Bahía Cartago	-0.02	0.93	63.86	0.6842	27	30.9
	68%	Playa Tortuga Negra	0.089	0	67.93	0.7626	0	0
		Caleta Black	0.049	0.12	28.63	0.5982	0	83
		Bahía Cartago	0.049	0.438	122.73	0.7185	0	30.6
	57%	Playa Tortuga Negra	0.153	0	69.65	0.7384	0	0
		Caleta Black	0.111	0.008	36.72	0.6109	0	89.5
		Bahía Cartago	0.13	0.108	131.53	0.7351	0	16.9
10 (*El Niño*) 4 (*La Niña*)	76%	Playa Tortuga Negra	-0.017	0.664	20.92	0.6538	87	72
		Caleta Black	-0.03	0.978	5.82	0.5603	54	54.4
		Bahía Cartago	-0.043	1.000	0	0	22	24.5
	68%	Playa Tortuga Negra	0.048	0.012	58.38	0.7586	0	85.3
		Caleta Black	0.012	0.494	18.96	0.5732	0	74.4
		Bahía Cartago	-0.01	0.88	90.42	0.647	31	32.7
	57%	Playa Tortuga Negra	0.11	0	67.21	0.7543	0	0
		Caleta Black	0.071	0.05	32.93	0.6048	0	85.5
		Bahía Cartago	0.073	0.31	123.57	0.7168	0	28

Conclusions

The Mangrove Finch has a high risk of extinction under the present conditions making it important to establish the management actions to guarantee the long term viability of the species. The main requirement is to implement a predator control action that lowers juvenile mortality. The option of supplementing birds to Bahía Cartago from a captive population has good effects on this population; however, to extract birds from Playa Tortuga Negra to create the captive population has to be done with caution because it can put it at risk.

Even with established predator control actions, the small size of the populations put the species at risk to external events some of them very difficult to control, that is why it is important to do more research concerning the carrying capacity of the populations and find actions that can increase it over time. This is because of the three populations, the one that was more robust to these events was Playa Tortuga Negra which has the biggest size and is second in carrying capacity. To finish, it is important to continue demographic studies on the species to obtain more precise values for future Population Viability Analysis that help to establish more specific management that guarantees the long term viability of this species.

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ANNEXE 2B
MANGROVE FINCH VORTEX MODELS
(PLAYA TORTUGA NEGRA AND CALETA BLACK AS ONE SINGLE POPULATION)

Jorge Rodríguez

CBSG Mesoamérica

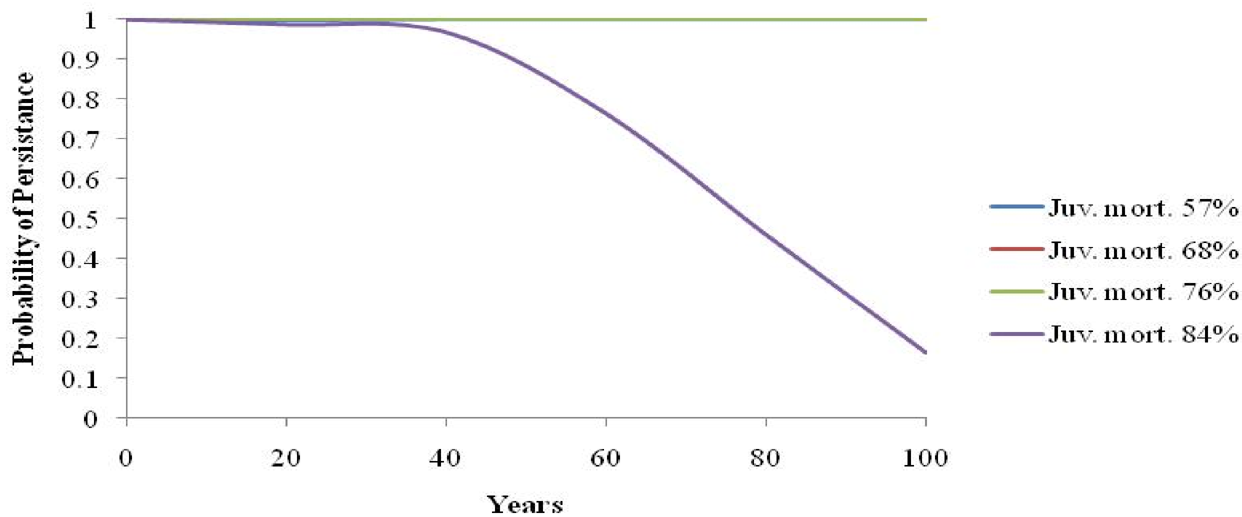
The models below are the same as the ones run at the International Workshop on Management of Mangrove Finch (*Camarhynchus heliobates*) held in 2008, with the difference that in these ones the populations of Playa Tortuga Negra and Caleta Black are considered a single population named PTN-CB; this is because recent information reveals that they may be considered a unique population (Birgit Fessl, pers. comm.).

Table 1. Parameter input values for the VORTEX Mangrove Finch baseline model.

<table>
<tr><th>Parameter</th><th colspan="4">Value</th></tr>
<tr><td>Breeding system</td><td colspan="4">Monogamy</td></tr>
<tr><td>Age of first offspring (♀/♂)</td><td colspan="4">1 year/2 years</td></tr>
<tr><td>Density dependent reproduction</td><td colspan="4">No</td></tr>
<tr><td>% adult females breeding per year</td><td colspan="4">90 (0 in La Niña years); EV = 10
90+((Y%14 = (FLOOR [14*SRAND(R)])%14)*(-90))</td></tr>
<tr><td>Percent males in breeding pool</td><td colspan="4">100%</td></tr>
<tr><td>Maximum number of eggs / year / female</td><td colspan="4">9</td></tr>
<tr><td>Mean number of eggs / year / female</td><td colspan="4">3.14 (4.74 in El Niño years); EV = 1.19
3.14+((Y%20 = (FLOOR [20*SRAND(R)])%20)*1.6))</td></tr>
<tr><td>Overall offspring sex ratio</td><td colspan="4">1:1</td></tr>
<tr><td rowspan="4">% annual mortality</td><td>Age class</td><td>Females</td><td>Age class</td><td>Males</td></tr>
<tr><td>0-1</td><td>84 ±5.04</td><td>0-1</td><td>84 ±5.04</td></tr>
<tr><td>Adult</td><td>18.37±2.25</td><td>1-2</td><td>12.79 ±2.25</td></tr>
<tr><td></td><td></td><td>Adult</td><td>12.79 ±2.25</td></tr>
<tr><td>Inbreeding depression</td><td colspan="4">6 lethal equivalents with 50% due to lethal alleles</td></tr>
<tr><td>Concordance between EV in reproduction and survival</td><td colspan="4">Yes</td></tr>
<tr><td>EV correlation among populations</td><td colspan="4">0.75</td></tr>
<tr><td>Maximum age</td><td colspan="4">15 years</td></tr>
<tr><td>Catastrophes</td><td colspan="4">El Niño every 20 years; La Niña every 14 years</td></tr>
<tr><td>Population size (N_0)/Carrying capacity (K)
PTN-CB
Bahía Cartago</td><td colspan="4">
N_0 = 82; K =112
N_0 = 10; K = 135</td></tr>
</table>

Management Action I. Lowering juvenile mortality by implementing predator and parasite control actions

A.



B.

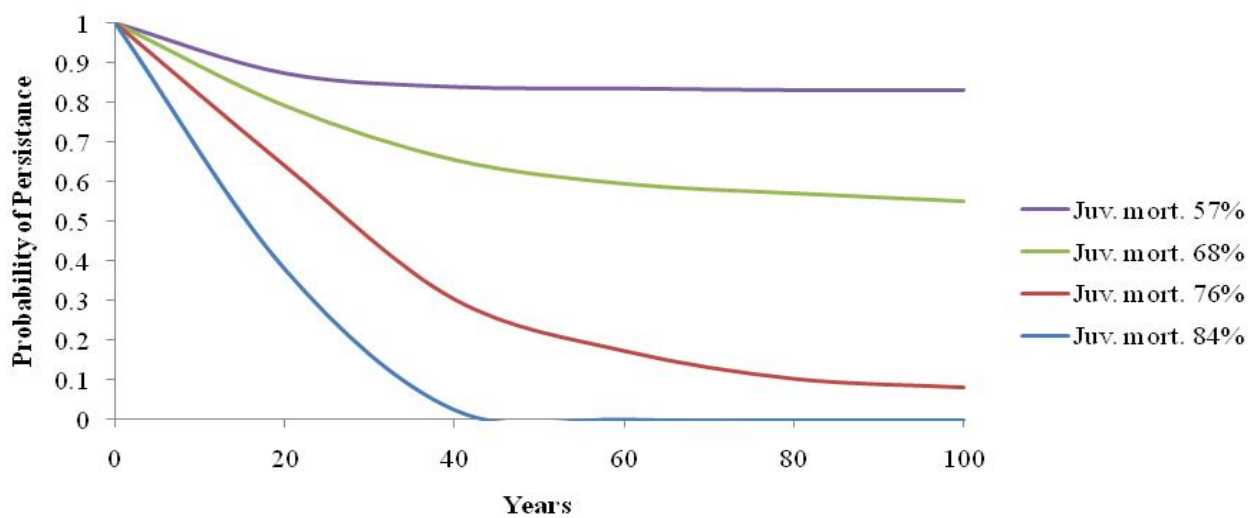


Fig. 1. Probability of persistence of the three Mangrove Finch populations over a period of 100 years, when action management I is implemented. Juvenile mortality: Juv. mort. A) PTN-CB, B) Bahía Cartago.

Table 2. Mangrove Finch Management Action I results for a 100-year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. Mort.	Population	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
84%	PTN-CB	-0.034	0.836	15	0.701	78	72
	Bahía Cartago	-0.056	1.000	0	0.000	17	19
	Metapopulation	-0.036	0.836	15	0.701	78	72
76%	PTN-CB	0.058	0.000	102	0.839	--	--
	Bahía Cartago	-0.019	0.918	69	0.675	28	30
	Metapopulation	0.054	0.000	107	0.843	--	--
68%	PTN-CB	0.119	0.000	109	0.833	--	--
	Bahía Cartago	0.052	0.448	124	0.706	--	28
	Metapopulation	0.108	0.000	177	0.860	0	0
57%	PTN-CB	0.188	0.000	111	0.817	--	--
	Bahía Cartago	0.132	0.168	132	0.711	--	17
	Metapopulation	0.172	0.000	220	0.866	--	--

Management Action II. Remove eggs from PTN-CB population to establish a captive population to supplement other populations.

Table 3. Mangrove Finch Management Action II results for a 100-year period. Juvenile mortality: Juv. mort. Juvenile mortality with egg removal: Juv. mort. egg. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Eggs collected	Juv. mort. egg.	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
84%	10	85.57%	-0.036	0.836	18	0.719	72	67
	20	87.24%	-0.042	0.886	15	0.699	67	64
	30	89.00%	-0.051	0.946	15	0.700	58	57
76%	10	77.76%	0.066	0.000	104	0.842	--	--
	20	79.53%	0.061	0.000	103	0.844	--	--
	30	81.42%	0.057	0.000	102	0.844	--	--
68%	10	70.22%	0.125	0.000	109	0.833	--	--
	20	72.44%	0.124	0.000	109	0.835	--	--
	30	74.80%	0.123	0.000	109	0.835	--	--
57%	10	59.87%	0.195	0.000	110	0.820	--	--
	20	62.85%	0.194	0.000	110	0.816	--	--
	30	65.78%	0.193	0.000	110	0.819	--	--

Management Action III. Remove adults from PTN-CB population to establish a captive population to supplement other populations.

Table 4. Mangrove Finch Management Action III results for a 100-year period. Juvenile mortality: Juv. mort. Harvesting period: Harv. period. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Birds extracted	Harv. period. (years)	stoc-r	PE	N-extant	GD	MedianTE	MeanTE
84%	10	1-5	-0.063	0.962	12	0.679	45	45
		5-9	-0.058	0.966	12	0.657	47	46
		10-14	-0.052	0.946	18	0.694	47	46
	15	1-5	-0.128	0.996	15	0.603	5	17
		5-9	-0.087	0.992	14	0.674	9	25
		10-14	-0.076	0.990	12	0.699	14	28
	20	1-5	-0.354	1.000	0	0.000	4	5
		5-9	-0.138	0.998	9	0.642	8	12
		10-14	-0.097	0.998	3	0.722	13	16
76%	10	1-5	0.052	0.014	102	0.834	--	52
		5-9	0.057	0.002	102	0.845	--	83
		10-14	0.056	0.006	101	0.838	--	34
	15	1-5	0.033	0.226	98	0.813	--	23
		5-9	0.048	0.046	100	0.832	--	31
		10-14	0.046	0.072	101	0.834	--	45
	20	1-5	-0.011	0.706	90	0.766	5	13
		5-9	0.032	0.296	98	0.820	--	23
		10-14	0.035	0.310	100	0.822	--	27
68%	10	1-5	0.120	0.000	109	0.831	--	--
		5-9	0.122	0.000	109	0.834	--	--
		10-14	0.121	0.000	109	0.831	--	--
	15	1-5	0.113	0.026	109	0.823	--	7
		5-9	0.119	0.000	109	0.832	--	--
		10-14	0.119	0.002	109	0.832	--	29
	20	1-5	0.098	0.192	109	0.814	--	8
		5-9	0.113	0.030	109	0.826	--	17
		10-14	0.112	0.034	109	0.828	--	21
57%	10	1-5	0.191	0.000	110	0.815	--	--
		5-9	0.192	0.000	110	0.815	--	--
		10-14	0.192	0.000	110	0.816	--	--
	15	1-5	0.188	0.000	110	0.815	--	--
		5-9	0.189	0.000	110	0.815	--	--
		10-14	0.189	0.000	110	0.815	--	--
	20	1-5	0.179	0.046	110	0.810	--	6
		5-9	0.186	0.000	110	0.818	--	--
		10-14	0.186	0.014	110	0.816	--	14

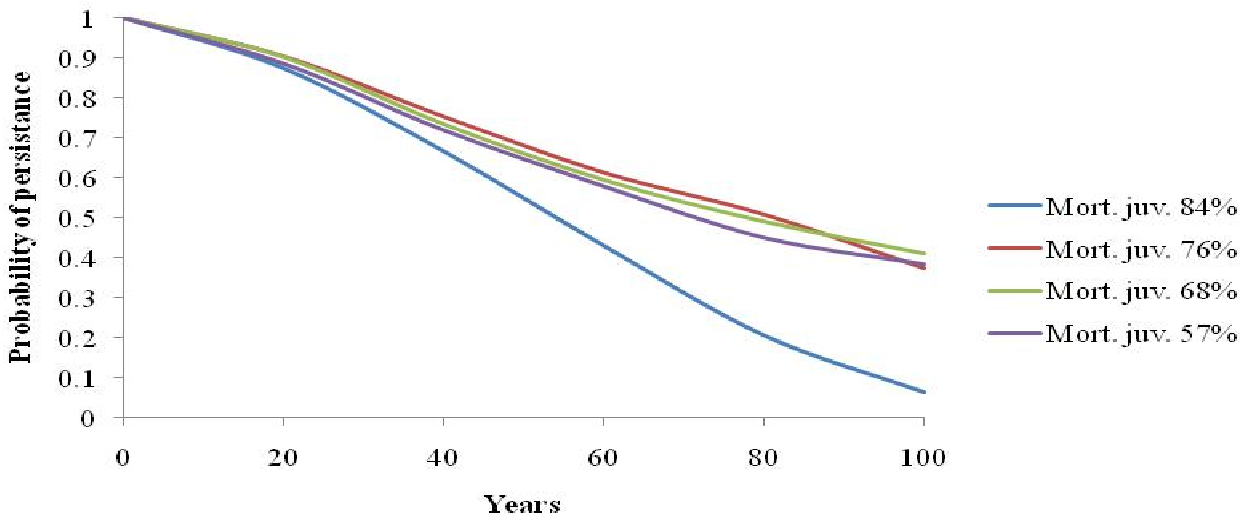
Risk Assessment I. Habitat Reduction.

Table 5. Mangrove Finch Risk Assessment I results for a 100-year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Habitat loss	Population	stoc-r	PE	N-extant	GD	MedianTE	MeanTE
84%	25%	PTN-CB	-0.034	0.824	14	0.642	76	70
		Bahía Cartago	-0.053	1.000	0	0.000	17	19
		Metapopulation	-0.035	0.824	14	0.642	76	70
	50%	PTN-CB	-0.033	0.854	11	0.636	77	71
		Caleta Black	-0.056	1.000	0	0.000	18	19
		Bahía Cartago	-0.035	0.854	11	0.636	77	71
		Metapopulation	-0.036	0.926	9	0.650	70	69
	75%	PTN-CB	-0.054	1.000	0	0.000	18	19
		Bahía Cartago	-0.038	0.926	9	0.650	70	69
		Metapopulation	0.054	0.000	74	0.828	--	--
76%	25%	PTN-CB	-0.018	0.916	57	0.649	27	31
		Bahía Cartago	0.050	0.000	79	0.832	--	--
		Metapopulation	0.050	0.002	48	0.791	0	88
	50%	PTN-CB	-0.016	0.902	48	0.661	25	30
		Bahía Cartago	0.046	0.002	53	0.798	--	88
		Metapopulation	0.041	0.038	23	0.723	--	91
	75%	PTN-CB	-0.020	0.920	23	0.600	29	30
		Bahía Cartago	0.037	0.030	24	0.731	--	90
		Metapopulation	0.117	0.000	81	0.813	--	--
68%	25%	PTN-CB	0.050	0.454	94	0.689	--	29
		Bahía Cartago	0.106	0.000	133	0.845	--	-
		Metapopulation	0.083	0.227	88	0.751	--	29
	50%	PTN-CB	0.111	0.000	54	0.782	--	--
		Bahía Cartago	0.045	0.490	62	0.681	--	27
		Metapopulation	0.101	0.000	86	0.821	--	--
	75%	PTN-CB	0.102	0.006	27	0.713	--	98
		Bahía Cartago	0.046	0.432	31	0.648	--	26
		Metapopulation	0.092	0.002	44	0.780	--	100
57%	25%	PTN-CB	0.183	0.000	83	0.791	--	--
		Bahía Cartago	0.129	0.186	99	0.710	--	17
		Metapopulation	0.168	0.000	163	0.856	--	--
	50%	PTN-CB	0.177	0.000	55	0.762	--	--
		Bahía Cartago	0.128	0.152	67	0.682	--	17
		Metapopulation	0.163	0.000	112	0.842	--	--
	75%	PTN-CB	0.167	0.002	28	0.711	--	100
		Bahía Cartago	0.122	0.150	34	0.637	--	21
		Metapopulation	0.155	0.002	56	0.812	--	100

Risk Assessment II. Epidemic Disease

A.



B.

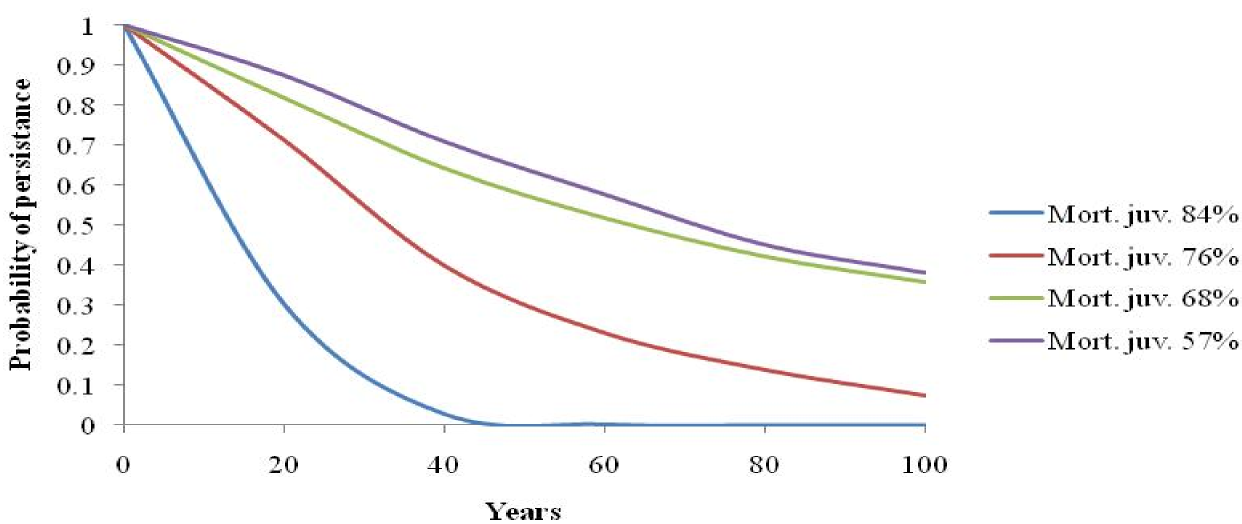


Fig. 2. Probability of persistence of the three Mangrove Finch populations for a period of 100 years, with epidemic disease. A) Playa Tortuga Negra, B) Caleta Black, C) Bahía Cartago.

Table 6. Mangrove Finch Risk Assessment II results for a 100-year period. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Juv. mort.	Population	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
84%	PTN-CB	-0.051	0.936	15	0.719	53	51
	Bahía Cartago	-0.062	1.000	0	0.000	16	17
	Metapopulation	-0.053	0.936	15	0.719	53	51
76%	PTN-CB	0.031	0.624	94	0.833	81	51
	Bahía Cartago	-0.017	0.926	85	0.708	31	35
	Metapopulation	0.023	0.624	111	0.845	81	52
68%	PTN-CB	0.092	0.590	104	0.829	78	48
	Bahía Cartago	0.055	0.642	122	0.744	63	41
	Metapopulation	0.076	0.576	203	0.878	80	48
57%	PTN-CB	0.154	0.614	106	0.818	71	46
	Bahía Cartago	0.125	0.620	128	0.770	72	46
	Metapopulation	0.136	0.610	230	0.889	74	48

Risk Evaluation III: An increase in *El Niño* and *La Niña* events

Table 7. Mangrove Finch Risk Assessment III results for a 100-year period. Frequency of phenomena occurrence: Freq. Juvenile mortality: Juv. mort. Stochastic growth rate: stoc-r. Probability of extinction: PE. Size of extant populations: *N*-extant. Genetic Diversity: GD. Median time of extinction in years: MedianTE. Mean time of extinction in years: MeanTE.

Freq. (years)	Juv. mort.	Population	stoc-r	PE	*N*-extant	GD	MedianTE	MeanTE
20 (*El Niño*) 14 (*La Niña*) (Base)	84%	PTN-CB	-0.034	0.836	15	0.701	78	72
		Bahía Cartago	-0.056	1.000	0	0.000	17	19
		Metapopulation	-0.036	0.836	15	0.701	78	72
	76%	PTN-CB	0.058	0.000	102	0.839	--	--
		Bahía Cartago	-0.019	0.918	69	0.675	28	30
		Metapopulation	0.054	0.000	107	0.843	--	--
	68%	PTN-CB	0.119	0.000	109	0.833	--	--
		Bahía Cartago	0.052	0.448	124	0.706	--	28
		Metapopulation	0.108	0.000	177	0.859	--	--
	57%	PTN-CB	0.188	0.000	111	0.817	--	--
		Bahía Cartago	0.132	0.168	132	0.711	--	17
		Metapopulation	0.172	0.000	220	0.866	--	--
15 (*El Niño*) 9 (*La Niña*)	84%	PTN-CB	-0.040	0.928	13	0.700	69	67
		Bahía Cartago	-0.060	1.000	0	0.000	17	18
		Metapopulation	-0.042	0.928	13	0.700	69	67
	76%	PTN-CB	0.048	0.008	98	0.838	--	96
		Bahía Cartago	-0.026	0.948	71	0.607	25	28
		Metapopulation	0.045	0.008	101	0.840	--	96
	68%	PTN-CB	0.110	0.000	108	0.837	--	--
		Bahía Cartago	0.036	0.588	119	0.701	51	29
		Metapopulation	0.101	0.000	157	0.856	--	--
	57%	PTN-CB	0.176	0.000	109	0.822	--	--
		Bahía Cartago	0.119	0.196	131	0.712	--	21
		Metapopulation	0.160	0.000	214	0.867	--	--
10 (*El Niño*) 4 (*La Niña*)	84%	PTN-CB	-0.064	1.000	0	0.000	47	49
		Bahía Cartago	-0.071	1.000	0	0.000	15	16
		Metapopulation	-0.067	1.000	0	0.000	47	49
	76%	PTN-CB	0.005	0.152	58	0.804	--	80
		Bahía Cartago	-0.047	1.000	0	0.000	20	22
		Metapopulation	0.004	0.152	58	0.804	--	80
	68%	PTN-CB	0.068	0.000	103	0.839	--	--
		Bahía Cartago	-0.007	0.852	92	0.686	29	29
		Metapopulation	0.063	0.000	116	0.845	--	--
	57%	PTN-CB	0.130	0.000	107	0.831	--	--
		Bahía Cartago	0.063	0.420	125	0.712	--	27
		Metapopulation	0.119	0.000	179	0.860	--	--

Conclusions

Even with PTN-CB as a single larger population the Mangrove Finch has a high risk of extinction under the present conditions, making important to continue the establishment of management actions to promote the long-term viability of the species. The implementation of a predator control programme to lower juvenile mortality is still considered as the main management action. The extraction of birds from Playa Tortuga Negra to create the captive population has to be done with caution taking account the adult mortality of the population in order not to put this population at risk.

Even with established predator control actions and PTN-CB as a single population the Mangrove Finch is still at risk to external events, some of them very difficult to control. That is why it is important to do more research concerning the carrying capacity of the finch habitat and identify actions that can increase carrying capacity over time. Finally, it is important to continue demographic studies on the species to obtain more precise values for future Population Viability Analysis that can help to establish more specific management actions to promote the long-term viability of this species.

ANNEXE 3

RINGING AND RADIO TRACKING OF RELEASED WOODPECKER FINCH (*Camarhynchus pallidus*)

Principal investigators: Dr. Sabine Tebbich, Dr. Birgit Fessl and Irmgard Teschke. Assistants: Sophia Stankewitz, Mari Cruz, Erica Cartmill, Jose Luis Ruiz.

Dates: 1st December 2008-27th January 2009

Island: Santa Cruz, Galápagos

Sites: Charles Darwin Foundation, Finca de Maria Elena near Bellavista, Los Gemelos

Introduction

The study was conducted firstly to get an impression of whether and how Woodpecker Finch adjusted to their natural habitat after extended periods in captivity and also as a pilot study to help assess whether telemetry might be a useful monitoring tool for the Mangrove Finch Project.

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Methodology

Telemetry of arid zone Woodpecker Finches

Four arid zone Woodpecker Finch were captured in September near aviaries at CDF. They were held in captivity for 76-81 days and participated in learning experiments during this time. After the experiments were completed, they were prepared for release following the protocol below (Soft release for Woodpecker finch). A radio transmitter was attached to the interscapular area of the birds' backs with superglue following the protocol given at the end of the report. They were then released near the aviaries in which they had been held and tracked for at least seven days and up to 16 days. Additionally, one Woodpecker Finch in the arid zone was caught and fitted with a radio-transmitter as a control bird in order isolate the effect of radio transmitter attachment to the birds from the effects of duration in captivity.

We did not capture more "control" birds because we did not end up having enough reliable transmitters and enough people to track a sufficient sample size. Also, we originally intended to quantify and compare behaviour such as feeding rate and time between the groups in order to more clearly ascertain possible negative effects of captivity. However, following and tracking the birds on very uneven terrain and through dense vegetation turned out to be so difficult, that gathering this kind of behavioural information was unfeasible.

Telemetry of Scalesia zone Woodpecker Finch

Four *Scalesia* zone Woodpecker Finch were captured in October, November and December 2007 at Los Gemelos in the *Scalesia* zone of Santa Cruz Island. They were held in captivity for between 382-437 days. From their time of capture until February/March of 2008, they participated in learning experiments. Originally, we planned to release the birds in March (end of the experiments); however, they contracted avian pox in March, shortly before a planned release. Since there is only a very small incidence of pox in the *Scalesia* zone, these birds were not released as planned due to the risk of spreading the disease there and/or introducing a new strain of the virus into the *Scalesia* zone populations. The birds were held until January 2009, at which point they had been free from any symptoms of pox for six months. After the decision was made to release the birds into the agricultural zone, the birds were prepared for release following the same protocol as for preparation of the arid zone birds (see below). However, given the amount of time these birds spent in captivity (for all birds more than one year) they were trained longer than the arid zone birds which had only spent a few months in captivity. Once the training of the birds had been completed, the birds were released into the agricultural zone at a finca (estate) close to Bellavista. We released two birds at a time, the first two on 5th January 2009 and the second two the next day. Upon release, we attached a radio transmitter again following the protocol given below. Again, the goal was to obtain at least one sighting or signal per bird per day. The birds were followed for a maximum of 21 days following release.

Field results

Telemetry of arid zone Woodpecker Finch

Overall, telemetry of the birds in the arid zone proved extremely difficult because of the difficulty in negotiating the terrain and probably because the large home ranges/territories of arid zone Woodpecker Finch. Birds quickly returned to normal behaviour following release. Where it was possible to see the birds on the morning of release, we saw that the bird did direct some action towards their transmitter but did not seem impeded by it in their movement. Later observations of the birds showed that they quickly habituated to the transmitter and directed relatively few actions towards the transmitter. The initial goal was to obtain a signal or sighting of each bird each day. However, this was often not possible, as movement of the researchers was limited by the vegetation. Also, arid zone birds are known to have large territories (Tebbich *et al.* 2002) within which they move extensively. This diminishes the chance to relocate small birds that can only be equipped with light transmitters that have a very limited range. We followed one bird over several kilometres and probably lost the signal of the other birds because they moved to far away. The birds were followed for a maximum of 16 days.

Result for four individual birds

Green/green. We were able to find and sight this bird for four days following release. After this, we lost the bird's signal entirely, though we tried for 10 days following its release. On each day this bird was sighted, it was observed to forage and a few times during observation we witnessed the bird attain food while foraging. This bird's observed foraging behaviour and its extensive movement as well as the overall impression that we got while observing this bird, indicated that the effects of captivity and transmitter attachment did not have a profound influence on the birds subsequent survival during its first few days following release.

Purple/pink. This bird was released sighted only once, and that on the day of release. However, we were able to obtain a signal for this bird for 17 days. We tried repeatedly to home in on this bird, but the spread of the directional fixes which we attained, as well as the change of signal direction several times when very close to the bird, indicated that it was extremely mobile and, therefore, presumably survived the first 17 days following release from captivity. The direction of the signals indicated that it had moved from the release sight to the area around las Cascadas neighbourhood, possibly even having spent time within this neighbourhood. This area was located about 1.5km from the release sight. The only sighting we had of this bird was on the release day. The bird did not exhibit any signs of lethargy or extreme stress sometimes seen in birds after extensive handling. In fact, when we sighted the bird, about an hour after release, it was foraging in a mixed species flock (with four Small Ground-finch (*Geospiza fuliginosa*) and one Vegetarian Finch (*Platyspiza crassirostris*)) in a *Parkinsonia* tree.

Purple/black. We only had a signal for this bird on the morning of its release. Thereafter, there was no signal to be found, though we tried for 10 days following release.

Red/blue. This bird was caught near the aviaries as a control bird (control bird needed for the reasons stated above). Following transmitter attachment, and ringing, the bird was released, but seemed very lethargic and stressed from the treatment. We observed it sitting in a tree, only moving very little for about an hour. It seemed very disturbed by its rings, directing most of its actions against these rather than the transmitter. We could not sight the bird following the morning of release, but found that the bird removed the tag, probably on the afternoon of the release day, since we followed it to the bush in which the removed tag was found the following day (released on 16th December 2008, removed tag found on morning of 17th). The bird was resighted by Birgit Fessl a week later and seemed healthy.

Black/green. We were only able to follow this bird for two days. On the first day, we sighted the bird in the afternoon, on the second day, we had a weak signal in the morning and thereafter no signal or sighting for the nine subsequent days during which we looked for it. Based on the bird's movement, which was extensive during these first two days, it seems that the bird was healthy, at least clearly mobile and not lethargic. Because of the difficulties in locating and sighting the bird, we did not have the opportunity to observe its behaviour for periods of more than a few seconds making it difficult to ascertain if and how successfully it was foraging for example. However, this bird was sighted near the tortoise pens on the 6th day after its release by a tourist who reported this observation to a CDF staff member.

Telemetry of *Scalesia* zone Woodpecker Finches

We immediately started tracking the birds, but lost the signals of all of the birds at the latest by the afternoon on which they were released. On the third day of tracking, we had lost track of all of the birds (except for one bird, *metal*, we had signal early that day, then nothing). On 8th January we took the CDF car and went searching for the birds in all conceivable sites near and between Bellavista and Los Gemelos. Finally at the end of the day, we went to Los Gemelos and received signals from all of the birds. That means that within 3-4 days, all the birds had flown the 11km to Los Gemelos, returning to their area of capture. In Los Gemelos, we were able to sight three of the four birds repeatedly. One of the birds, *metal*, must have removed its transmitter fairly soon after reaching Los Gemelos and we were not able to sight this bird after release. However, the fact that the transmitter was found in Los Gemelos shows that the bird flew there from the finca.

Another bird, *red*, also lost its transmitter (found on 10th January) but we sighted the bird nearby and were able to locate this bird on subsequent days by song.

Red. We sighted this bird the last time 21 days after release. The bird was foraging normally, singing almost perpetually and seemed to be very stable in the area which it initially chose. On the last occasion it was observed (26th January), this bird was seen to be nest building, though based on its behaviour; it was not clear whether there were eggs in the nest.

Black/pink. We sighted this bird the last time 20 days after release (26th January) when it was seen to be foraging normally, singing almost perpetually and seemingly very stable in the area in which it initially chose. At the beginning of observation in Los Gemelos, this bird was seen carrying nesting material, though no nest could be located. This observation was not repeated later.

Blue/blue. This bird was found and observed in the same area of Los Gemelos for four days before we lost the signal (eight days after release). It was not subsequently found. Based on the time we could observe it, it seemed that the bird was doing well, foraging normally and occasionally singing. The signal seemed to become increasingly muffled during those days of observation, so it is possible that the tag battery lost power and that the bird stayed in the same area. Since the bird did not sing as much as *red* and *black/pink*, it is possible that it stayed in the same area but it was not possible for us to locate it without the signal.

Metal. As mentioned above, it is known that this bird must have survived at least three days, which is the time between release and time of finding this bird's tag at Los Gemelos. However, despite searching for this bird extensively (with playback and sight), we were not able to find the bird and positively identify it in Los Gemelos.

CONCLUSIONS

Feasibility of telemetry studies and effect of transmitters on individual birds

Telemetry with Woodpecker Finch and related species is feasible. However, the terrain, and the range of the species/population might strongly influence feasibility and success. For instance behavioural observation might be possible, but this is very much dependent on density of vegetation and terrain as well as how quickly and how far the animals move. During our study period we could not detect detrimental effects on the survival of the individuals equipped with transmitters but could not relocate one bird two days after its release. The fact that we found three tags that the bird removed, indicates that we probably also would have found dead birds with transmitters within the area we searched.

Application of the transmitter It needs some practice to glue the transmitters to the birds (especially to find the right position on the back of the bird) but handling time is relatively short (we needed between 7-9min). Three out of nine birds were able to remove the transmitter so it might be advisable to try out alternative techniques such as harnesses with the Woodpecker Finch in captivity.

Survival and adjustment after captivity Our results show that at least some individuals seem to be able to establish territories upon release, even after extensive periods in captivity. Also, all birds that we were able to re-sight, resumed normal feeding activity after release. We had no confirmation that any of the released birds died. Out of eight released Woodpecker Finch seven individuals were re-sighted for at least four days. This clearly shows that they were able to find enough food to survive.

Relevant information for the Mangrove Finch Project:

1) Application of transmitters is feasible and contains low risks for the individual birds;

2) Woodpecker Finch can fly relatively long distances in order to return to the site where they were captured.

SOFT RELEASE OF WOODPECKER FINCH

<u>Goals</u>:

Birds should:

- gain independence from prepared food and unlimited access to water
- get used to searching for and finding insects in natural substrates in a sufficient amount
- increase their physical fitness.

<u>Procedure</u>:

1. We provided each aviary with different types of natural substrates and tools, which were:

- dead trunks and branches with bark and holes
- dead leaves (to put on the ground)
- twigs with green leaves and inflorescences
- parts of dead *Opuntia* trunks
- twigs of *Scutia* (dead and green)
- patches of *Opuntia* spines
- fine dry twigs with sufficient stability to be used as tools (especially for arid zone birds)

2. We decreased the amount of prepared food and started hiding insects in different substrates:
   - on first day the birds were observed for one hour to see how quickly they were able to find the insects
   - insects were counted and the places exactly where they were hidden noted, so that we could check later if the insects were found
   - insects were hidden in natural holes in trunks and branches, under the bark of trunks and branches, under the dead leaves on the ground, inside of the tissue of *Opuntia* trunks and placed on leaves (larvae, small moths)
   - spines and twigs that can be used as tools were tied to perches or mesh so that birds could rip them off easily
   - we changed positions of logs and branches with every feeding!

Diet:

- for the first two days we gave half a teaspoon 2x per day (Thursday and Friday); for the next two days we gave only a quarter of a teaspoon 2x per day (Saturday and Sunday); after that we did not give any prepared food
- we gave the same amount of insects every day: It was approx. the equivalent of *15 medium sized moths* (including small moths, medium sized moths, huge moths, mealworms, various larvae if available)
- we hid moths three times a day: at 8:00, 11:00 and 16:00 (four moths each time), and gave prepared food in between (10:00 and 14:00) → so birds did not go for the prepared food first time in the morning, but were forced to first look for insects

3. We gave live moths to let the birds catch them instantly and/or to let them hide the moth themselves in the substrate
   - We made sure moths were still able to fly and set them free in the aviaries
   - first we used big moths to attract the attention of the birds, later we continued with smaller moths to increase the necessary amount of work per amount of energy
   - we provided the equivalent of three moths this way (this number is included in total of 15 per day)

4. We decreased the amount of available water
   - We stopped using birdbaths, but kept plates under the food bowls (ants!)
   - We hid a small plate/bowl with water somewhere in the aviary and changed its position twice a day
   - We sprayed twigs with water once a day (so the birds could get the drops)

5. Control weight
   - We weighed birds twice a day: every time when giving prepared food! The birds were previously trained to hop on the scales and were not caught up for weighing.
   - We noted weights in prepared tables outside each aviary.

ATTACHING TRANSMITTER

We used one stable cotton primary cloth (cotton mending fabric). The piece of fabric was slightly larger than and similar in shape to the transmitter (it should have rounded corners). In preparation, the transmitter was tied with two threads to the piece of cloth (and glued with a strip of superglue on the bottom of the transmitter). The extra thread from the knots was trimmed and sealed with a dab of superglue each.

Spinal tract feathers on the bird's interscapular region of the back and immediately posterior to the back were cut to 1-2mm length from their base.

To attach a transmitter, the bird is held firmly in one hand (left hand) and the spinal tract feathers in the interscapular region are pushed forward. A few drops of water will help to keep the surrounding feathers clear of the attachment site. A patch of feathers slightly larger and about the same general shape of the transmitter is then clipped to 1-2mm from their base. The cloth on the underside of the transmitter is coated with superglue. The use of excess adhesive should be avoided to prevent soiling the feathers around the clipped area. Feathers are held away from the clipped area and transmitter will be carefully aligned along the body axis of the bird so that the whip aerial projects past the centre of the tail. You should try and place the transmitter so that it does not restrict wing movement and also should be close enough to the bird's neck so that the bird cannot easily turn and peck at it. The transmitter is then held in place 3-6 minutes to permit the adhesive to dry. The transmitter should not be pressed down upon the back, thus avoiding binding of the superglue to the skin.

The attachment procedure requires two people, one of whom holds the bird while the other cuts the feathers and does the gluing. A sugar solution will be offered to the birds before, during and after the procedure.

Removal of transmitter: cut threads holding transmitter to primary cloth, then trim loose edges of cloth which remain on the bird. One author states "we found that radios could be removed from problem birds by carefully cutting the radio from the feather stubs with a sharp razor and applying a few drops of liquid band-aid (Nexiband ©)".

Reference

Tebbich, S., M. Taborsky, B. Fessl, and M. Dvorak. 2002. The ecology of tool-use in the woodpecker finch (*Cactospiza pallida*). Ecology Letters **5**:656-664.

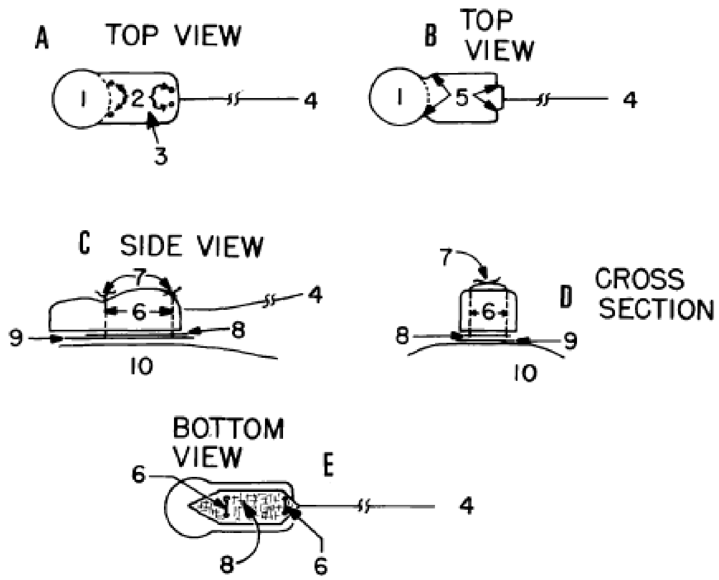

FIGURE 1. Transmitter: A (1) Battery, (2) holes, (3) transmitter proper, (4) antenna. B (5) Grooves. C, D, E, (6) Threads, (7) knots, (8) primary cloth, (9) secondary cloth, (10) bird. X 1.1.

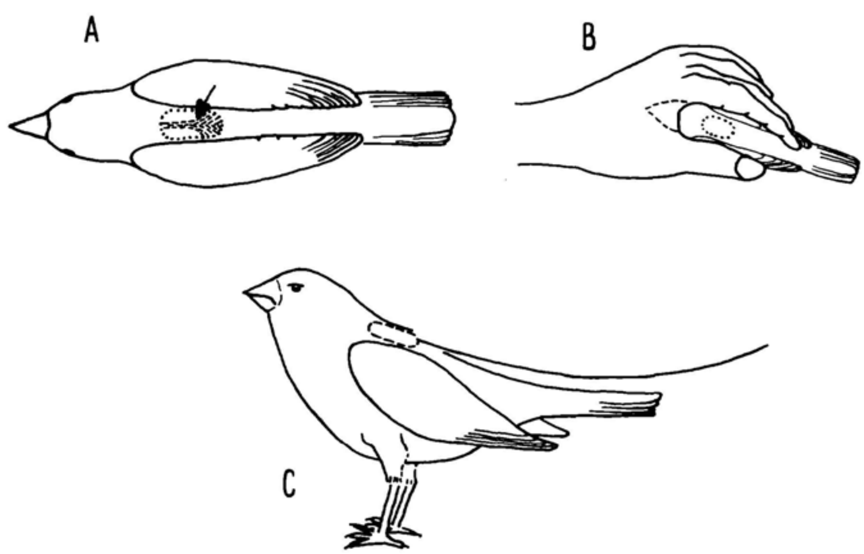

FIGURE 2. Attachment: A. Area of feather and down removal (dotted lines) and cut ends of spinal feather shafts (arrow). B. Method of holding bird with back and tail exposed. C. Transmitter (dashed lines) covered by feathers after attachment.