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Past and present ornithology in Galápagos

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1. A short history of ornithological research in Galápagos

To understand the present state of ornithological research in Galápagos it is necessary to review the history and records that previous ornithologists and other researchers have left. For greater clarity, we have divided the time into four periods: that of Charles Darwin; of scientific expeditions; of David Lack; and of the Charles Darwin Foundation.

1.1. Time of Charles Darwin

It could be said that ornithological activities in Galápagos began with the collection Charles Darwin made of 15 species of birds while he visited the archipelago in 1835. Darwin noticed some morphological differences between the mockingbirds inhabiting various islands. Nevertheless, the historical record is not very clear in determining what he thought about the finches subsequently named for him. What we do know is that Darwin would come to understand the importance of the species he collected, above all the finches, several years later. On the basis of this and other knowledge that he acquired during his trip around the world, he came to formulate the theory of evolution of species by means of natural selection, the theory that broke paradigms and transformed humans' way of thinking.

1.2. Time of scientific expeditions

After Darwin's visit, a series of ornithological expeditions were made to the archipelago between the years 1839 and 1906. Of these, we can highlight the Webster-Harris Expedition in 1897, which collected 3,000 bird specimens, and the expedition of the California Academy of Sciences in 1905-06, which collected close to 6,000 bird specimens. These expeditions not only contributed to determining the taxonomy of the species, but also provided valuable data on the distribution of birds in Galápagos. The comparison of these past records with current data helps us to determine the present status of bird populations. For example, we now know that some island populations have diminished in numbers, while others have even become extinct.

1.3. Time of David Lack

David Lack studied Darwin's finches in 1938-39. His findings were published in 1947, in the classic book *Darwin's Finches*. With this book, he immortalized the birds' common name. Lack was a pioneer in competition studies and one of the first to assert convincingly the role of competition in vertebrates. For this he studied the finches in detail.

1.4. Time of the Charles Darwin Foundation

With the creation of the Charles Darwin Foundation (CDF) in 1959 and the inauguration of its operational arm — the Charles Darwin Research Station (CDRS) — in 1964, ornithological research intensified and diversified. Among others, we should mention the outstanding work done by David Anderson, Robert I. Bowman, P. Dee Boersma, Rosemary and Peter Grant, J. Faaborg, Jack P. Hailman, Michael Harris, Bryan Nelson, Barbara and David Snow, Carlos Valle, and Tjitte de Vries.

Some of these ornithologists came as visiting scientists, with their own funding, and others worked as resident scientists at the CDRS. There has been a tendency for visiting scientists to undertake basic research, while resident scientists necessarily have been concerned with conducting applied research and studies with a direct link to conservation. Basic research has contributed tremendously to the understanding of the evolution of species. Thanks to these studies, Darwin's finches are used now as a classic example of evolution in educational establishments where biology and evolution are taught. In addition, however, several of the basic studies have become, in the passing of time, of invaluable assistance to the Galápagos National Park Service (GNPS) in the making of management decisions.

Several ornithologists have been able to conduct their studies over a long period of time, for example, David Anderson, the Grants, and Tjitte de Vries, and

have contributed to the teaching and training of dozens of young ornithologists in their home countries as well as in Ecuador. The results of their research have been published in scientific journals with international standing.

The best-known case is that of the Grants. They have published two books about Darwin's finches, a popular book has been written about their scientific studies (The *Beak of the Finch*, by Jonathan Weiner), and they have written more than 100 articles. As well as maintaining their long-term studies of evolution in action, the Grants are also using microsatellite DNA analysis to work out the phylogeny of the finches.

Bryan Nelson, Michael Harris, P. Dee Boersma, Carlos Valle, and David Anderson have investigated the ecology, reproduction, and behaviour of seabirds. These studies are currently being used to redesign the management plan for the Galápagos Marine Reserve (GMR), where the birds feed. On the basis of knowledge about feeding sites of the seabirds, amongst other important marine organisms, and the increase of fishery bycatch, it was proposed in 1998 to increase the Marine Reserve from 15 to 40 miles around the baseline of the archipelago. This will give greater protection to seabirds and associated fauna. The protection will be afforded principally by means of excluding the expanding fishing fleet that uses the waters around Galápagos.

Nevertheless, not even a larger reserve will be sufficient to afford effective protection for the waved albatross, which nests on Española Island but feeds both within and outside the GMR. Studies by David Anderson on the foraging ranges of the waved albatross, using satellite technology, have shown that even when the albatrosses are nesting on Española, they may travel to feed in the waters off Peru. This means that the long-term preservation of the albatross can only be achieved with the commitment of various countries to its conservation. Since 1984, Dr Anderson has conducted studies on the ecology, behavior, and reproduction of boobies by means of a series of experiments with three species of boobies in Galápagos. The main hypotheses of his research have concerned clutch size, siblicidal behaviour, breeding success, genetic diversity, foraging ranges, nest site selection, and feeding sites.

Tjitte de Vries, who began working with the Galápagos hawk in the early 1960s, still continues developing studies about various aspects of this species. In the 1980s, John Faaborg and James Bednarz, who were joined more recently, in the 1990s, by Patricia Parker, formed a group to intensify and continue these studies. Among other results, they have reconfirmed polyandry in the hawk at the genetic level. In 1998, they also started to study the quality of territory and habitat structure as a possible explanation for the different degrees of polyandry on different islands. Recent studies on genetic variation suggest that gene flow between populations on different islands is lower with greater distance separating the populations. In addition, preliminary data suggest that genetic variation is greater in the larger populations (e.g. those at Alcedo and Santiago) and lower on islands with smaller populations (e.g. on Santa Fe and Española). Furthermore, preliminary results suggest strong population differentiation among the hawk populations from Santa Fe, Española, Santiago, and Isabela, including a moderate differentiation between Santiago and Isabela, despite their proximity (P. Parker, pers. comm.).

During the late 1990s, Martin Wikelski and Michaela Hau began conducting field studies on the mechanisms and physiological adaptations of birds to their climatically unpredictable environment. One part of their project revolves around the question of how Darwin's finches "know" when to breed. They observe the reproductive pattern of Darwin's finches in combination with physiological measurements such as the amount of reproductive hormones in the blood. By analyzing the correlation between reproduction and seasonal climatic changes in the environment they can predict which environmental cues the birds use to time their breeding. A second part of their project investigates the responses of the birds to stresses that are natural (e.g. impact of rainy years and dry years) or anthropogenic (e.g. the presence of tourists). For this, they compare the amount of the "stress-hormone" corticosterone in small blood samples of sea- and land birds during an El Niño and a La Niña year, and in birds close to or far away from tourist trails.

Since 1995, Sabbine Tebbich, Michael Dvorak, and Birgit Fessl have studied, respectively, the ontogeny of tool use in the woodpecker finch, the density of land birds, and the incidence of bird parasites. More recently, Jeffrey Podos, of the University of Arizona, began work on vocalization in Darwin's finches.

1.5. Changes in the nature of ornithological studies

From the foregoing, it is possible to identify certain changes or tendencies in the types of studies over the passage of time. Initially, collections of birds were made in the archipelago. Then there was a stage dominated by observational studies of ecology, reproduction, and behaviour. Now we have reached a phase of experimental studies based on genetics, physiology, and molecular biology. These latter studies have often served to back up, verify, or reject the results of observational studies. Molecular biology is being used to determine phylogenetic relationships (e.g. Darwin's finches, boobies, mockingbirds), genetic variation (e.g. hawk, penguin), hybridization (mangrove finch with other finch species), parentage determination (e.g. finches and hawk), and taxonomy (e.g. petrels, boobies, albatross).

1.6. Ornithological activities carried out by the CDRS

Ornithological research has been conducted since the inauguration of the CDRS in 1964, including studies made by the early directors, Raymond Lévêque and David Snow), who dedicated part of their time to ornithology, ringing various species of birds, especially seabirds, and obtaining data about their movements and

reproductive habits. The birds ringed during this time have more than once served to provide information on the longevity of the species (e.g. waved albatross).

The facilities provided for researchers by the CDRS have led to a great increase in the number of visiting scientists who arrive to conduct studies on a variety of topics. Ornithology is one of the sciences that have been invigorated as a result.

Although ornithological research was considered by the CDRS to be very important, there was no permanent ornithologist at the Station from 1990-95 because of lack of funds. However, in 1995 a resident ornithologist (Hernán Vargas) was hired, with the principal responsibility of revitalizing the ornithology programme.

2. The Current CDRS Ornithology Programme

2.1. Introduction

Many of the birds of Galápagos, especially the land birds, are thought to be declining in numbers and/or threatened by alien species or other factors. With limited availability of personnel and resources, the priorities of the Station's in-house ornithological programme have to be selected with care. Currently the programme is working on four projects:

- Censuses, monitoring, and investigation of rare birds
- Conservation of the dark-rumped petrel
- Conservation of the mangrove finch, the rarest of the Darwin's finches
- Minimizing the risks of introduced bird diseases

The first of these programmes is broad in scope, embracing all the investigations of bird species for which intensive conservation programmes do not yet exist.

2.2. Censuses, monitoring, and investigation of rare birds

2.2.1. General monitoring, including monitoring by naturalist guides

Annual censuses of flamingos, penguins, cormorants, and lava gulls were begun in 1967, 1970, 1977, and 1995, respectively. These birds have restricted ranges and small populations in Galápagos and are therefore vulnerable to introduced organisms and stochastic events.

In addition to the annual censuses, valuable data are provided by the tourist industry's naturalist guides, who report their observations, especially on lava gulls, flamingos, penguins, cormorants, Galápagos doves, frigatebirds, and boobies. The reports and monitoring sheets turned in by the guides are duly filed and periodically analyzed.

In 1998, the Station started monitoring birds using modern technology. Data collected with Global Positioning System (GPS) receivers were downloaded, in the field, to a small palmtop computer. The advantage of this method is that a large amount of data is transferred *in situ* directly to the computer. Among other data, the exact geographic position of each bird is recorded. This information is then incorporated into a Geographical Information System at the office of the CDRS. In the near future, this new methodology will be improved to enable rapid and efficient monitoring of birds in the Galápagos Islands. It is planned that the system should be used by naturalist guides and others assisting in monitoring programmes.

2.2.2. Monitoring birds during El Niño

In general, the immediate effects of the 1997-98 Niño phenomenon were negative for most seabirds, neutral for waterbirds, and positive for most land birds (for the latter, the long-term effects may turn out to be negative because of the advance of invasive species during El Niño). The penguin was probably the species most negatively affected by El Niño. Boobies and other large seabirds either migrated or had some mortality. The only seabird that could have benefited from El Niño appears to be the lava gull, and several juveniles of this species were observed. Dead animals probably provided more food for this carrion feeder. Pintail ducks were also an exception in the waterbird group, because chicks were observed in several lagoons and the numbers appeared to increase tremendously. Finches and other land birds nested more frequently, but fledging success was not apparent, at least on Santa Cruz, because many of the nests were found to be infested with parasites (BIRGIT FESSL, pers. comm.).

A prominent introduced bird, the smooth-billed ani (*Crotophaga ani),* expanded its range during El Niño. Anis became established on previously pristine Fernandina Island and also reached other small islands such as Pinta, Española, Marchena, Genovesa, and Daphne Major. There was an obvious increase in their population on Santa Cruz Island and Alcedo Volcano (Isabela Island).

Chickens became feral on southern Santa Cruz, probably taking advantage of the increased availability of food during the Niño year.

2.2.3. Monitoring flamingos

Flamingos have been recorded inhabiting nearly 50 saline lagoons in the archipelago. The total number of adult flamingos in Galápagos is almost certainly less than 500. Given this small size, it is necessary to evaluate the status of the population, so the CDRS and the GNPS conduct an on-going monitoring of the flamingos by three methods:

- The annual census, conducted since 1967, usually in January, of the birds in most of the lagoons in the archipelago where flamingos occur.
- The monthly census of the flamingo populations found in lagoons in southern Isabela Island, where the main breeding sites for these birds are located.

- The counts conducted by naturalist guides for the lagoons located near the visitor sites.

During the 1998 census, 380 were counted in 14 lagoons. Flamingos were nesting at Bainbridge Island in spite of El Niño conditions. It seems that flamingos are not negatively impacted by El Niño phenomena.

2.2.4. Monitoring and investigation of the Galápagos penguin

Past censuses have shown that the Galápagos penguin may be the bird species most severely affected by the natural El Niño phenomenon. The last two intense El Niño events (1982-83 and 1997-98) have caused apparent declines of 77% and 65%, respectively. After the 1982-83 event, the recovery of the population was slow and incomplete, climbing gradually to 60% of their pre-1982 levels. The 1998 post-Niño penguin population may be less than 25% of the original population before 1982. During the post-Niño census, only 444 individuals were counted, no signs of nesting were recorded, and not a single juvenile was observed. If the frequency of El Niño events were to increase through global warming, as some meteorologists predict, then the penguin population will be in great jeopardy.

The small population may also be affected by introduced predators. During 1998, the introduced black rat was discovered inhabiting the three Marielas Islands, which is an important nesting area for the Galápagos penguin. The GNPS and CDRS are currently conducting an experimental trial to determine how the recovery rate of penguins is affected by black rats, which are known to be predators on seabird eggs.

An increase in fishing and tourism activities within the penguins' range could also affect the recovery of the population. These activities could alter the habitat directly or indirectly. Increasing human activities will increase the probability of introduction of potential diseases such as Newcastle and Infectious Bursal Disease Virus (IBDV), which have been involved in population declines in penguin species in other parts of the world.

In general, there is a pressing need to learn more about the ecology of the world's only equatorial penguin and assess quantitatively the various factors that threaten its survival, in order to counter the threats and ensure the survival of the species.

2.2.5. Investigating the status of the Galápagos rail

The highly restricted habitats of the endemic Galápagos rail are being transformed rapidly by human activities and by the spread of exotic species. Over the decades of colonisation, people have cleared large portions of the rail's preferred breeding habitat, the moist highland zone, which fell outside the National Park boundaries on the island of Santa Cruz. Introduced cattle and goats are powerful agents of change in Galápagos ecosystems and have altered the structure and species composition of habitats on all islands occupied by the rails. Furthermore, introduced plants are increasingly common in Galápagos ecosystems, and the moist highlands are much more vulnerable to invasion than the arid lowlands. Four species are of particular concern: *Cinchona succirubra* (Santa Cruz), *Psidium guajava* (Isabela), *Rubus niveus* (San Cristóbal), and *Lantana camara* (Floreana).

Unfortunately, due to funding constraints, the project has yet to progress beyond preliminary surveys on Alcedo Volcano, where a population of rails was discovered in 1997-98. Also, during a study of the mangrove finch, four individual rails were observed in December 1998 and January 1999 at Playa Tortuga Negra, on northwestern Isabela. The presence of rails in the mangroves of Galápagos was not recorded after 1905-1906, when the California Academy of Sciences recorded rails in the mangroves of Santa Cruz. It is possible that the campaign to control introduced black rats, in order to protect the mangrove finch, could have had a positive effect on rails, which could be increasing in number after the reduction of rodents. Another likely factor is the extended period of very wet conditions during El Niño.

2.2.6. Bird conservation on San Cristóbal Island

San Cristobal Island, because of its relatively old age and geographical position, has several endemic taxa: vermilion flycatcher, woodpecker finch, warbler finch, large tree finch, San Cristóbal mockingbird, and lava heron. The island was one of the first to be colonised by man and has experienced the greatest human impact. Large areas of the highlands have been invaded by exotic plant species such as *Psidium guajava*, *Eugenia jambos,* and the recently introduced and aggressive *Rubus niveus*. These exotic plants, coupled with the effects of introduced animals such as rats, pigeons, and arthropods, are very likely having an impact on the island's endemic birds.

In 1996, initial bird surveys by the Station ornithologist indicated that several of the island's bird species had declined in population and range. In 1998, a local volunteer undertook further surveys, which showed that some of the bird populations have declined since the first surveys 100 years ago, when avian specimens were collected by ornithological expeditions. The most endangered bird on the island appears to be the vermilion flycatcher, because not a single individual was observed during the six-month survey. The status of the Galápagos dove, Galápagos rail, and dark-rumped petrel are also critical on the island.

Funds are being sought to extend the survey work and assess the causes of the decline, in order to plan remedial measures. There is great scope for participation of conservationists in this work, perhaps with practical cooperation and financial support from one or more foreign bird conservation groups.

2.3. *Dark-rumped petrel conservation project*

One species for which a research and conservation project has been undertaken since 1980 is the dark-rumped petrel (formerly known as the Hawaiian petrel and increasingly, though informally, being called the Galápagos petrel). Based on geographical separation, morphological, behavioural (SIBLEY and MONROE, 1993), and genetic (BROWNE *et al.*, 1997) differences, it is being suggested that the Galápagos and Hawaiian petrel subspecies should be elevated to species status. This elevation has implications for the conservation of both species. In Hawaii, the Hawaiian petrel (*Pterodroma sandwichensis*) is on the brink of extinction, while in Galápagos major efforts are underway to save the dark-rumped or Galápagos petrel *(Pterodroma phaeopygia).*

The past populations of this petrel were immense and many nesting sites were lost when man began to use the rich volcanic soil areas of the highlands for agriculture. This species is currently threatened by many introduced predators: rats and pigs eat the eggs and nestlings, while dogs and cats kill the chicks and adult birds. Invasive introduced plants are spreading and are rapidly altering the bird's nesting habitat with unpredictable consequences.

Because of the steep population decline during the 1980s, the GNPS and the CDRS began an intensive predator control programme at the petrel's main nesting colonies on Floreana and Santa Cruz. The current programme involves control of predators, monitoring nests, locating new nests, and banding.

The management component of the project is fully funded by the Ecuadorean government through the GNPS, while the CDRS continues to provide technical advice and to study the breeding colonies.

Thus, the project has been successful in its aim of enhancing breeding success of this species. However, breeding success is only part of the story, as fledglings must survive to adulthood and breed if the species is to survive. In 1997, the data from 26 years of operation of the CDRS were evaluated. The results of the analysis of banding data showed a very low juvenile recruitment rate. Out of more than 1,000 juveniles banded in the past 35 years, less than 3% have returned to the colonies on Floreana and Santa Cruz. This figure is alarmingly low. Furthermore, only two juveniles have returned as breeding adults. To quantify the effects of the apparently low recruitment, some modelling that incorporates recruitment, adult survivorship schedules, and fledgling success must be done. The modelling may also indicate possible causes of post-fledging, pre-breeding loss. If juvenile mortality occurs at sea, there may be nothing that conservation authorities can do about it, particularly if it occurs outside the Marine Reserve. Whatever the results of this work prove to be, the present programme of reducing mortality factors at the breeding colonies is enhancing the chances of the species surviving.

Thus, the dark-rumped petrel project is enabling the petrel to breed, and the protection of nesting colonies must be maintained indefinitely, for the black rats cannot be totally eradicated with present technology. Additional efforts are needed to ensure the recovery of the population. Other nesting colonies should be looked for and protected on San Cristobal and Isabela islands. On San Cristobal only 30 nests have been found, and on Isabela three nests were located on Alcedo Volcano in 1995. The apparent problem of low survival to adulthood must be investigated.

2.4. *Saving the rarest Darwin's finch - the mangrove finch*

This project aims to combine emergency protection measures with in-depth research to find out why the population of the mangrove finch *(Cactospiza heliobates)* has declined. The process includes the protection of the known mangrove finch habitats, the location of other populations, control of introduced animals (rats, cats, anis, and wasps), and a study of the survival and reproduction of the bird, with particular attention given to impacts of introduced animals.

Recent research has shown that the mangrove finch is the rarest of the 13 species of Darwin's finches in Galápagos. It is restricted to only three mangrove patches of Isabela, where its population is very likely less than 100 individuals. Species with restricted distributions and small populations are liable to become extinct if the environment where they live changes due to natural or anthropogenic factors.

From 1996 to 1998, an intensive study of the mangrove finch was conducted by the CDRS with the following results:

1. The current distribution of the mangrove finch was determined. Research indicates that the distribution is smaller than it was one hundred years ago. The finch was only found at Playa Tortuga Negra, at Caleta Black on northwestern Isabela, and near Cape Woodford on southeastern Isabela. No finches were recorded from Fernandina, where they formerly existed.
2. The size of the mangrove finch population in the archipelago was estimated to be more or less 100 adult breeding birds. The largest population was found at Playa Tortuga Negra, where a maximum of 18 active nests have been located at any one time and where the maximum number of pairs was estimated at around 37. At Caleta Black no more than four active nests have been located at any one time and the maximum number of pairs was estimated at 21, while at the location between Cape Woodford and Cape Barrington not more than three birds have been observed.
3. Potential causes of population declines were identified: black rats, anis, cats, and fire ants; diseases; and hybridization. The study of plumage variation suggests that the mangrove finch may be hybridizing with other species of closely related species at Playa Tortuga Negra and Caleta Black. Possible candidates include the small ground finch (*Geospiza fuliginosa*), medium ground finch (*Geospiza fortis*), and woodpecker finch (*Cactospiza pallida*). In 1998, a study of the genetic structure of these species was begun in collaboration with Peter Grant's

team. The genetic analysis is expected to be completed by the middle of 1999.
4. Data on habitat quality and structure was collected on most of the mangroves of the archipelago. It is possible that the distribution of the mangrove finch may be limited by the quality of the mangrove patches.
5. Fire ants and anis were successfully controlled at Playa Tortuga Negra.
6. Experimental trials were initiated at Playa Tortuga Negra and Caleta Black to determine if introduced black rats (*Rattus rattus*) can cause declines in the populations of mangrove finches. This project has successfully controlled black rats at Playa Tortuga Negra in breeding seasons.

2.5. Introduced bird diseases - minimizing the risks

The objective of this project is to assess the prevalence and incidence of introduced avian diseases on the endemic and native birds of Galápagos. It has been documented that in Hawaii and New Zealand introduced avian diseases have played a major role in the extinction of the endemic land birds. Several avian diseases could have arrived in the Galápagos Islands with the introduction of chickens, pigeons, ducks, and turkeys. Diseases such as Newcastle, Marek, *Mycoplasma gallisepticum*, and gumboro have already been recorded in chickens. Pox-like lesions, which were already recorded in 1905, are frequently observed in several species of land birds. The mosquito *Culex pipiens quinquefasciatus*, first recorded on San Cristóbal in 1989 and now also on Santa Cruz, is known to carry avian malaria, but we do not know if this desease is present in Galágapos.

Introduced domestic pigeons (*Columba livia*) carried *Trichomonas gallinae,* a parasite that has since been recorded in the endemic Galápagos dove (*Zenaida galapagoensis*). The impact of *T. gallinae* on the endemic dove is not known. Whether or not this parasite is one of the causes (cats are another obvious factor), endemic doves seem to be declining rapidly on the inhabited islands. A new parasite (*Philornis downsi*) has recently been detected in nests and chicks of several species of Darwin's finches and other land birds from Santa Cruz; preliminary data suggests that this parasite may significantly lower fledgling success (BIRGIT FESSL, pers. comm.). Endoparasites (*Dispharynx spiralis*) were found in dark-billed cuckoos and may have been, at least in part, responsible for high cuckoo mortality in 1998.

Since diseases have caused extinctions of birds in other archipelagos, such as Hawaii, the CDRS is making disease research the only totally new area of ornithological research in its priority programme. It will not be started until sufficient funds have been raised to cover both this and the existing programmes.

3. Conclusions

Birds have been the subject of some of the most important scientific research undertaken in Galápagos, or anywhere in the world, in the fields of evolution and ecology. As is so often the case in these fields, much of the ''pure'' scientific research actually has important implications for conservation; for example, to plan the conservation of Darwin's finches one must understand how they are related, how they live, and how they are evolving.

Within CDRS, research priorities are driven by identified or predicted bird conservation needs, of which there are all too many. Following the regrettable five-year suspension of the ornithology programme, the Station is building a clearer picture of the status of the islands' avifauna, maintaining long-term projects such as Galápagos petrel protection, working intensively on the highly endangered mangrove finch, and intensifying studies of the Galápagos penguin, which was once again hard hit by El Niño. Once the existing programmes are well established and funded, the priority for expansion in ornithology is the investigation of introduced avian diseases, potentially a threat to numerous species from the finch to the flightless cormorant.

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