

Penguins

NATURAL HISTORY AND CONSERVATION

Edited by

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and

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Galápagos Penguin

(*Spheniscus mendiculus*)

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1. SPECIES (COMMON AND SCIENTIFIC NAMES)

Galápagos penguin (*Spheniscus mendiculus*) (C. J. Sundevall, 1871)

The Galápagos penguin is also known as *pingüino de Galápagos* (Spanish), *manchot des Galápagos* (French), and *Galápagospinguin* (German).

2. DESCRIPTION OF THE SPECIES

ADULT. The Galápagos is the smallest of the *Spheniscus* penguins, with males generally larger and slightly heavier than females (table 16.1). The adult has a dark blackish to brown back and a white breast flecked with dark feather spots that are individually distinct (fig. 1). On the side of the head, a narrow white line of feathers extends from behind the eyes, around the ear coverts, and down to join at the throat. Galápagos penguins have a dark throat band and a second dark band on the breast that extends down both sides of the upper white breast and along the flanks to the legs (Williams 1995). Their markings are similar to those of the other *Spheniscus* penguins but are finer and subtler. Generally, the white feathers on the chin beneath the bill are more pronounced with less mottling in males than in females (Boersma 1977); the white chin is absent in the other *Spheniscus* penguins. Flippers are generally dark except for a pale central pattern on the ventral side. The bill is not as deep but nearly the same length as in its congeners, with males having deeper bills than females



FIG. 1 (FACING PAGE) Adult Galápagos penguin after the molt, when fully feathered around the bill and eyes. (P. D. Boersma)

FIG. 2 Male (left) and female (right) Galápagos penguin, showing the deeper bill depth and generally wider chin feathers of males. Both sexes lose feathers around the base of the bill and the eyes when in breeding condition. (P. D. Boersma)

(fig. 2). The maxilla is black and hooked at the tip, fitting into the groove of the lower mandible. Usually the distal third of the mandible is black, shading from white to yellowish white to pink at the base. The feet of adults are black with some light shading on the web and are less mottled than juvenile feet (fig. 3).

During the breeding season, Galápagos penguins shed feathers around the bill and eye, exposing bare skin, which is better for losing heat. When pigmented, the skin is black and individually distinct (fig. 4a). The unpigmented skin turns pink or red from blood flow



FIG. 3 The juvenile Galápagos penguin's foot (left) is more mottled and less pigmented than the adult's foot (right). (P. D. Boersma)



FIG. 4 When penguins are not breeding and spend more time in the water, they retain the feathers around the bill and eyes. (a) A Galápagos penguin that is about half defeathered; it has lost feathers around the base of the bill and the eyes and is ready to breed. (b) A Galápagos penguin fully feathered around the base of the bill, after the molt. (P. D. Boersma)

when the penguin is panting to reduce its body temperature. Body temperature can be estimated by counting the number of pants per minute (Boersma 1975). After the molt, when the penguins are not tied to a site, they spend more time in the water, and the skin around the bill and eyes is covered in white or black feathers (Boersma 1977) (fig. 4b). Before the molt, penguins stop oiling their feathers, so feathers become brown; after the molt, feathers are gray-black (Boersma, per. obs.). Unlike their congeners, Galápagos penguins always lack a white tail spot (Boersma, unpubl. data).

IMMATURE. The juvenile Galápagos lacks the white feathers on both sides of the head that outline the cheeks and the dark feather band around the breast to the legs (fig. 5). Like the adult, the juvenile has individually distinct dark feather spots on the breast. The back and head are dark, and the breast is white. The chin and lower throat are gray, and the face can be white to gray. Fledglings have more blue-gray plumage that becomes grayer as they age and eventually turns brown before the molt. They lose the feathers around the bill, and by the time they molt,



FIG. 5 Juvenile Galápagos penguin showing the gray plumage and lack of facial bands. (P. D. Boersma)

their facial skin is bare and their plumage brownish. Feet are pale with black mottling in the webbing that becomes blacker with age (see fig. 3). The coloration of the lower bill is variable but often black at the tip and whitish or pinkish at the base. Juveniles molt into adult plumage at about six months of age, often when adults are breeding (Boersma 1977).

CHICK. A newly hatched chick is covered in grayish-brown protoptile down (fig. 6a) that is eventually worn away, exposing the second coat of gray-brown down (clover down) on the back and white down on the belly (fig. 6b). The juvenile plumage pushes out the second coat of down and is exposed as the down is worn away. Recent fledglings may retain down on their heads and necks for several days.

3. TAXONOMIC STATUS

There are no subspecies recognized.

The oldest penguin fossil is about 55 million years old (Fordyce and Jones 1990). DNA evidence suggests that the genus *Spheniscus* split from the genus *Eudyptes*



FIG. 6 (a) Galápagos penguin chick, one or two days old, showing the first coat of down. (b) Galápagos penguin chicks approximately three to four weeks old, in clover down. (P. D. Boersma)



tula around 25 million years ago, diversifying less than 4 million years ago into the four *Spheniscus* species: Magellanic (*S. magellanicus*), Humboldt (*S. humboldti*), African (*S. demersus*), and Galápagos penguins (Baker et al. 2006; Goehlich 2007). DNA analysis suggests that the Humboldt is the closest relative to the Galápagos penguin (Duffy 1991; Thumser and Karron 1994; Baker et al. 2006; Bollmer et al. 2007). The heterozygosity measured at five microsatellites of the Galápagos penguin was 3%, significantly lower than the 46% found for Magellanic penguins, and reflects serial bottlenecks for the species (Akst et al. 2002).

Penguins are restricted to the Galápagos Archipelago but do move among islands (Harris 1973; Boersma 1977; Vargas et al. 2005a; Steinfurth 2007; Vargas et al. 2007). Nims et al. (2008) shows a symmetrical degree of gene flow between island populations and considers the population a single panmictic unit, which is reasonable, as the penguins move among the islands.

4. RANGE AND DISTRIBUTION

The Galápagos penguin, the most northerly species, is endemic to the Galápagos Archipelago, breeding on

Isabela, Fernandina, Bartolomé, Santiago, and Floreana Islands (fig. 7a) (Boersma 1977; Vargas et al. 2007). About 95% are found in the westernmost islands, Isabela (including Rocas Marielas, #7 in fig. 7b) and Fernandina (fig. 7b) (Boersma 1977; Vargas et al. 2006). The population's stronghold is along the coasts of northern and eastern Fernandina Island and the southwestern areas of Isabela Island (Boersma 1977; Vargas et al. 2006). The Marielas Islands in Elizabeth Bay were the most important breeding area in the 1970s (Boersma 1977). Chick growth, reproductive success, and nest density were higher in the Marielas Islands than at any other site (Boersma 1977). The center of breeding activity shifted to southwest Isabela Island by 2000, with Caleta Iguana now supporting the largest breeding colony (Vargas 2006; Steinfurth 2007). The change likely occurred because of the introduction of rats on the Marielas Islands in the 1990s; the rats were eradicated, and as of 2011, the Marielas Islands remain rat free (Boersma and Merlen, unpubl. data). At the same time, the removal of dogs from the southwest coast of Isabela Island in the 1980s likely made sites more suitable for the penguins. The penguins' range (fig. 8) also includes the coasts of

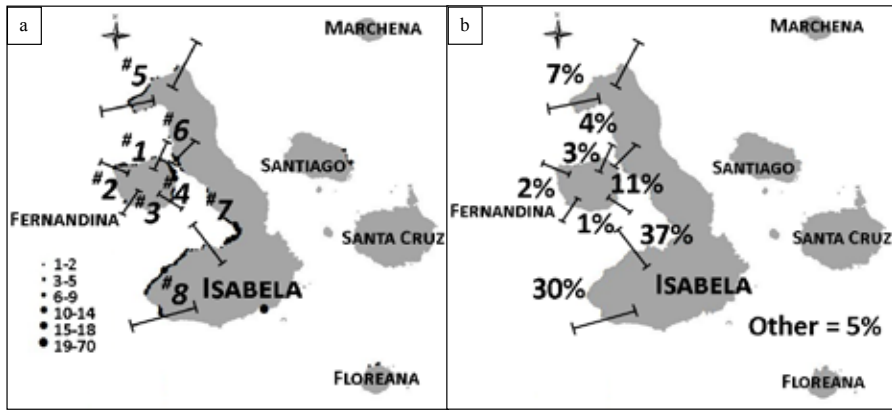


FIG. 7 (a) Distribution of Galápagos penguins (black dots) within eight census areas during the 2005 count. (b) Percentage of the Galápagos penguin population in each of the eight census areas, based on the 2005 count (Vargas et al. 2005).



FIG. 8 Distribution and abundance of the Galápagos penguin, with counts based on individuals.

Santiago Island from Bartolomé to Sombrero Chino and the west coast of Floreana Island to at least the village of Velasco Ibarra, where about 5% of the population resides (Vargas et al. 2006). Vagrants are seen throughout the archipelago, including at Baltra, Pinzon, Rábida, Santa Cruz, and San Cristóbal Islands (Boersma 1977; Vargas et al. 2005a; Naturalist Guide records at the Charles Darwin Research Station).

5. SUMMARY OF POPULATION TRENDS

The Galápagos population has declined substantially since the early 1970s because of increased frequency of El Niños, decreased frequency of La Niñas, and introduced predators. See section 8.

6. IUCN STATUS

The Galápagos penguin's small population size and restricted geographic range warrant its listing as Endan-

gered on the International Union for Conservation of Nature's Red List of Threatened Species (BirdLife International 2011; IUCN 2010). This species was first listed as Endangered in 2000 on the IUCN's Red List (Stattersfield et al. 2000), is classified as Endangered in the current Red Book of the Birds of Ecuador (Granizo 2002), listed as Endangered under the U.S. Endangered Species Act, and classified as Near Threatened in *Birds to Watch 2* (Collar et al. 1994). The species, although adapted to the unpredictable fluctuations between productive La Niña and unproductive El Niño events (Boersma 1974, 1978), faces new challenges with the increasing intensity and frequency of these events (Boersma 1998a; Vargas et al. 2007). Disease and parasites may be synergistic in combination with climate variation (Levin et al. 2009; Vargas et al. 2007). Introduced alien species (especially rats and cats) remain a problem, and their spread within the archipelago would further endanger the penguins.

Potential threats such as oil transport, fisheries, shipping (including shipwrecks), and tourism are also increasing in the islands.

7. NATURAL HISTORY

BREEDING BIOLOGY. Galápagos penguins breed in lava tubes, caves, and crevices formed by lava plates or fallen basaltic boulders, where they find shade (fig. 9) (Boersma 1975, 1977; Steinfurth 2007). They can breed in any month of the year, depending on food availability, up to three times a year, and in strong El Niño years, they may skip breeding or fail to breed (Boersma 1977, 1978). Steinfurth (2007) notes that 1 of 54 pairs (2%) laid eggs three times in a year, 31 bred twice (57%), and 22 (41%) bred once. Boersma (1977) reports that, in a 15-month period, 74% of 74 pairs laid eggs twice, 24% laid eggs three times, and 11 pairs skipped breeding because they were molting when others were laying eggs.

The penguins may bring sticks, feathers, bones, and leaves to cover the rough bottom of the nest (Boersma 1975, 1977). The eggshells are extremely thick and, even without any nesting material, are unlikely to break (Boersma et al. 2004). Males occupy the nest first, and the pair may stay in the nest until both eggs are laid. The two eggs are laid 3–4 days apart but hatch usually within 2 days of each other (table 16.2). Incubation of the eggs takes 38–42 days and is shared equally between the male and the female (Boersma 1977). The difference in the incubation period for the two eggs is likely a result of parental inattention to the first egg, as has been shown for the Magellanic penguin (Rebstock and Boersma



FIG. 9 Adult Galápagos penguin in a shady lava crevice nest. White guano is in front of the nest site's opening, and a chick is behind the adult. (P. D. Boersma)

2011). Upon hatching, chicks are often brooded for a few days and guarded for a few weeks. When chicks are 25–30 days old, they are left unattended while both parents forage for food. Adults usually return in the late afternoon to feed their chicks (Boersma 1977; Steinfurth et al. 2008). Chicks do not form crèches and do not leave their nest sites until they are ready to fledge. They venture out of their nests only when the nests are located in the most protected sites and close to the water (Boersma, pers. obs.). They fledge at approximately 60 days of age (Boersma 1974, 1977) (table 16.2). After fledging, chicks often return to the shore near the nest, beg for food, and are fed by their parents (Boersma, pers. obs.).

The Galápagos penguin is monogamous, faithful within and often between breeding attempts, and can live for more than 10 years. Of 75 penguins that nested two or more times, 93% stayed with the same mate in successive breeding seasons and 4% of the females switched mates, though their former partners were available, and moved into their new mates' nests (Boersma 1977). Three females divorced their mates, and one of the divorced males remained unmated for the next two breeding periods (Boersma 1977). Five banded males remained unmated for five breeding seasons; no female, once she laid eggs, remained unpaired (Boersma 1977). Galápagos penguins have high rates of nest fidelity. Steinfurth (2007) observes that 16 of 17 pairs returned to the same nest the next time they bred. At least 20 of the same nest sites have been used for 40 years (Boersma, pers. obs.).

Mate switching occurred when a pair failed to raise its brood, a mate was molting, or a partner disappeared and presumably died. Of 79 adults, 4 died over a 15-month period, suggesting survival is near 95% in some years. The recapture rate was 89% for banded individuals at Punta Espinosa, Fernandina Island, over a 10-month period from June 1971 to March 1972, which included part of the 1972 El Niño (Boersma 1977).

PREY AND FORAGING BEHAVIOR. The Galápagos is a generalist and opportunist that, within limits, eats what is available close to shore (Boersma 1977; Steinfurth 2007). These birds will herd fish toward obstacles such as rocks, beaches, or boats where they are trapped or will catch crustaceans and eat small fish held in the edges of a pelican's (*Pelecanus occidentalis urinator*) beak as the pelican strains out the water (Boersma and Merlen, pers.



FIG. 10 (a) Galápagos penguins (circled in red) feeding with pelicans and noddy terns at Punta Mangle, Fernandina Island. (b) The crustaceans that the birds are eating are mysids. (P. D. Boersma)

obs.) (fig. 10a). They normally swallow their prey underwater, catching it as they travel upward.

The penguins prey mainly on nearshore schooling fish typical of upwelling systems, dominated by Engraulidae (likely represented by Pacific anchoveta [*Cetengraulis mysticetus*]), followed by South American pilchard (*Sardinops sagax*) and mullet (*Mugil* spp.) (Boersma 1977; Mills 1998; Vargas et al. 2006; Steinfurth 2007; Steinfurth et al. 2008). Other prey species include *Salema*, an endemic schooling fish (Boersma and Merlen, pers. obs.), the striped herring or Pacific piquitinga (*Lile stolifera*) (Fitter et al. 2000; Vargas et al. 2006; Merlen, pers. obs.), fish in the families Sphyraenidae and Carangidae (Allain, pers. comm.), as well as crustaceans like mysids (fig. 10b) and cephalopods (Steinfurth 2007). In 2005, nonbreeding adults at Caleta Iguana in the southwest of Isabela Island fed almost exclusively on very young pelagic fish, as all prey in stomach samples were 30 millimeters or less in size (Steinfurth 2007). When customary prey are rare, penguins will take damselfish (Pomacentridae) and blennies (Blenniidae) (Boersma 1977, pers. obs.). In April 2007, Boersma saw a penguin come to the surface with a 20-by-6-centimeter large-banded blenny (*Ophioblennius steindachneri*) and try to position and swallow it twice before a sea lion stole the fish. In 1997, Romero Davila (pers. comm.) photographed a Galápagos penguin trying unsuccessfully to swallow an 80-centimeter tiger snake-eel (*Myrichthys tigrinus*) (fig. 11).

The Galápagos forages in shallow water alone or in small groups, following close to the shore, eating small fish 10–150 millimeters in length (Boersma 1977; Stein-

furth et al. 2008). They are a coast-hugging species and shallow divers, spending 90% of the time at depths of less than 6 meters with the deepest known dive being 52 meters (Steinfurth et al. 2008). Dives are short—generally less than a minute—but can last for more than three minutes (Boersma 1977; Steinfurth et al. 2008).

When prey is more plentiful and water temperatures are low, penguins are more likely to be seen in multispecies feeding flocks (fig. 10a) (Boersma 1977, 1978; Mills 1998). When feeding in association with species such as tuna (Scombridae), mackerel (Scombridae), sharks (Carcharhinidae), pelicans, boobies (*Sula* spp.), flightless cormorants (*Phalacrocorax harrisi*), brown noddy terns (*Anous stolidus*), and Galápagos shearwaters (*Puffinus subularis*), penguins can be well off shore and sometimes



FIG. 11 Galápagos penguin at Tagus Cove in 1997 trying to swallow an approximately 80-centimeter-long tiger snake-eel. Penguins normally swallow their prey underwater. This penguin tried several times to swallow the eel, allowing Fabian Romero Davila time to get the picture. (Romero Davila)

in groups of 200 (Boersma 1977). The presence of penguins increases the duration of feeding by mixed flocks (Mills 1998). Penguins sometimes have slashes on their flippers, legs, and feet, which probably are inflicted while they are feeding in these mixed foraging assemblages with large fish such as tuna, Sierra mackerel (*Scomberomus sierra*), or sharks, dolphins, and whales (Boersma, pers. obs.).

Galápagos penguins are daytime foragers. They generally leave at sunrise and return to land around sunset to rest or to spend the night, although weather and prey availability can modify this pattern (Boersma 1977; Mills 2000; Steinfurth et al. 2008). On southwestern Isabela Island, data loggers recorded penguins foraging during daylight, leaving their nests between 5:11 and 5:48 AM and returning between 11:04 and 5:00 PM (Mills 2000). Individuals may relieve their mates in the late morning or early afternoon when food is available close to their breeding site (Boersma and Steinfurth, pers. obs.). The mean distance traveled from their nest site was 5.2 kilometers, with one penguin traveling 24 kilometers, and foraging trips lasted on average eight hours. The foraging pattern of males and females were similar at two sites (Steinfurth et al. 2008).

MOVEMENT AND MIGRATION. The movement patterns of males and females are similar (Boersma 1977; Steinfurth et al. 2008). Boersma (1977) reports that males moved more than females and were less likely than females to be recaptured. Galápagos penguins move more often when they are not breeding and under poor food conditions. Juveniles wandered more and had higher mortality than adults. Further, adults were twice as likely to be recaptured compared to juveniles. Over a 16-month period, less than 10% of recaptured penguins were found in sites other than the ones where they were banded, indicating high site fidelity.

When not breeding, Galápagos penguins move among islands; no organized migration pattern is known. One nonbreeding penguin moved more than 120 kilometers in less than a month at the beginning of the 1972 El Niño (Boersma, unpubl. data). When not breeding, penguins may travel hundreds of kilometers, for example, from Cabo Douglas, Fernandina Island, to Elizabeth Bay, Isabela Island (Boersma 1977). Vargas et al. (2005a) note that penguins traveled from eastern Fernandina Island to Cabo Douglas, on northwestern Fernandina Island. Stein-

furth (2007) documents a nonbreeding penguin that went 64 kilometers. Two nonbreeding penguins marked by Boersma in May during the 1998 El Niño were captured a month later 27 kilometers and 59 kilometers, respectively, from the place where they had been marked (Vargas et al. 2005a). Penguins would likely die from lack of food if they left the islands. A swimmer caught one juvenile Galápagos, in the company of a larger (probably adult) penguin, in Panama. The other penguin escaped, but both likely came to Panama on a boat (Eisenmann 1956).

PREDATORS. Predation is rare. The Galápagos hawk (*Buteo galapagoensis*) preys on young penguins (Boersma 1977), and the short-eared owl (*Asio flammeus*) and barn owl (*Tyto alba punctatissima*) may prey on adults (Harris 1970, 1974). The Galápagos snake (*Alsophis* and *Antillophis* spp.) and the Sally Lightfoot crab (*Grapsus grapsus*) are native terrestrial predators and act as scavengers, feeding on starving and unattended penguin chicks and eggs (Boersma 1977). Hatchlings are killed mainly by introduced mammals such as black rats (*Rattus rattus*), domestic cats (*Felis catus*), and domestic dogs (*Canis familiaris*) (Boersma 1977). Cats and dogs can also kill adult penguins (Barnett 1986; Steinfurth and Merlen 2005; Steinfurth 2007). Gashes around the tails and on the sides of penguins observed in the 1970s suggest shark attacks (Boersma 1977; Vargas 2009). These marks were absent in 2010 and 2011 (Boersma, pers. obs.), probably because shark populations have declined substantially (Stevens et al. 2005).

MOLT. Following a 7- to 28-day period at sea, during which Galápagos penguins increase their body weight by about a third, molting occurs a week to months before the onset of breeding (Boersma 1975, 1977). During the approximately 10–15 days when penguins lose their old feathers and grow new ones, they fast and avoid the water, often molting in the shade at their nest sites. Many penguins, particularly juveniles and young adults, molt in small aggregations on the coast or in shady spots near water. The interval between molting is a minimum of 5 months and a maximum of 12 months with an average of just over 6 months. Unlike any other penguin species, juveniles molt into adult plumage at about 6 months of age and adults molt twice a year, before they breed, although the timing of molt and breeding is flexible (Boersma 1974, 1977).

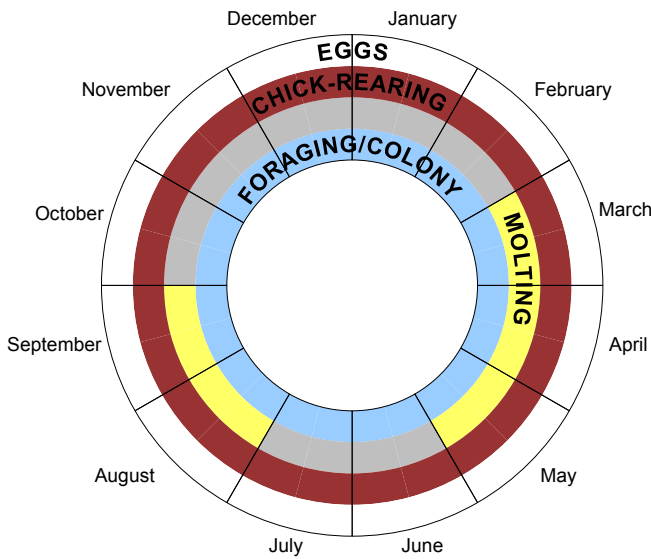


FIG. 12 Annual cycle of the Galápagos penguin.

ANNUAL CYCLE. The life history of the Galápagos penguin is well adapted to the unpredictable availability of food that characterizes the Galápagos marine environment (Boersma 1974, 1977, 1978). They molt as often as twice a year and then breed opportunistically when oceanographic conditions are favorable (fig. 12) (Boersma 1977, 1978). There is no strict breeding season, but sea surface temperatures are usually between 15° and 22°C when breeding occurs; there is no breeding when surface waters are above 25°C (Boersma 1978). Breeding is most frequent in the cool, dry season, generally May through December (Boersma 1978; Vargas et al. 2006; Steinfurth 2007). Galápagos penguins mate both on land and in the water (fig. 13) (Boersma 1977).

8. POPULATION SIZES AND TRENDS

The Galápagos is likely the rarest penguin species. Various estimates of the population in the 1960s were based on opinion and ranged between 500 and 5,000 (references in Boersma 1977). Boersma (1977) places the population at 6,000–15,000 individuals in 1972. Vargas and colleagues (2005a) estimate the 1999 population at 1,054–1,403 individuals and 600–4,000 individuals from 1970 to 2003. The current population is likely between 1,500 and 4,700 individuals. The population has declined and is likely less than half of what it was in the 1970s.

Boersma (1974, 1977) discusses a mark-recapture study conducted in 1972 to determine detection probability and population size. The author searched for



FIG. 13 Galápagos penguins mating on land. Note the upturned tail and distended cloaca of the receptive female as the male vibrates his bill and treads on her back. The two have lost the feathers around the base of the bill and around the eyes, displaying the individual pigmentation of their skin. (F. R. Davila)

banded penguins after 4:00 PM from a Zodiac around Punta Espinosa, Fernandina Island, where she knew how many resident penguins were banded. From 25 June to 23 September 1972, she did 22 searches and saw on average 22% of the banded penguins. The highest resighting rate for a survey was 46% and the lowest was 7% (Boersma 1977). On five surveys performed when the penguins were breeding, the author saw between 19% and 46% of the banded penguins, for a recapture rate of 30%. She did two additional counts around the Marielias Islands and found a 13% resighting rate. Population estimates of Galápagos penguins based on mark-recapture methods may be biased for two reasons. First, the population is not a closed population, and, second, bands and other marks are difficult to detect in the water, so marked penguins are counted as unmarked.

Vargas et al. (2005a) report on a 1999 mark-recapture population estimate in which the authors marked 141 penguins on five islands with picric acid and ethanol. Two weeks later, from 10 to 17 September, they resighted 80 of the marked penguins (57%). The variance among islands was 67%. The recapture rate was lowest on Santiago and Bartolomé Islands (8%) and highest on Floreana Island (75%). On Fernandina Island, the recapture rate was 57%, the same as when all the islands were pooled. Vargas et al. (2005a) consider the population closed and states that marked individuals were not likely to have been resighted more than once because the small boat traveled at 12 kilometers an hour and *Spheniscus*

penguins usually travel at slower speeds. Counting penguins, particularly in the water, is challenging, and without individually identifiable marks, it is hard to assess whether penguins were sighted more than once. The authors found one marked penguin that had moved from the site where it had been marked to another island.

Recapture and resighting depend on a number of factors, especially whether the penguin is in the water or on land. A penguin is harder to see in the water, and on land is harder to see when lying with its dark back to the observer than when standing with its white chest facing the observer. Marks are also harder to see in the water. A penguin is most likely to stand on shore late in the afternoon or when its stomach is full or it is molting. Thus, Galápagos penguins are more likely to be seen on land resting when prey is abundant during La Niña events than when it is rare in El Niño periods. Census methods, type of mark, areas surveyed, time of day, weather conditions, and breeding status also influence the number of penguins seen. Detection of both penguins and marks is unlikely to be the same among areas, years, or even days, and a correction factor based on one set of conditions probably will not be constant. Unlike most other penguins, the Galápagos is not a strong seasonal breeder (Boersma 1978).

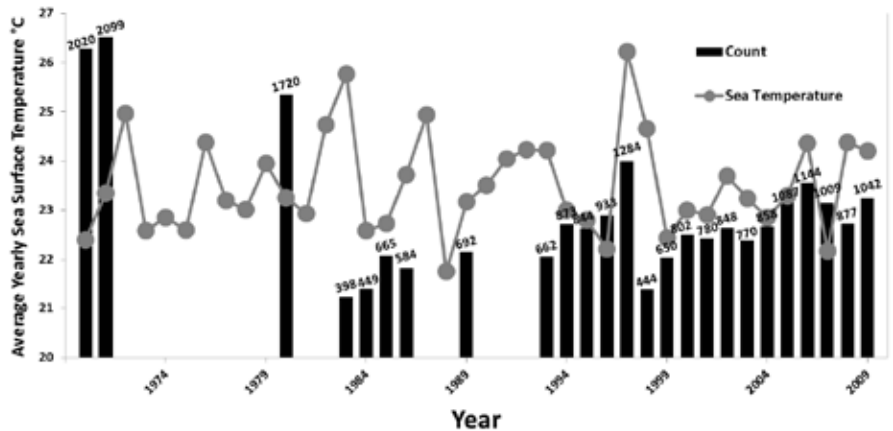
The two annual cycles in sea surface temperature have opposing forces that obscure a season pattern, and the western archipelago has a quasipermanent pool of cold productive water on the west side of Isabela and Fernandina Islands (Houvenaghel 1978; Palacios 2004). Maximum sea surface temperature occurs in March, when the southeast trade winds are weakest (Palacios

2004). Although penguins may be less likely to breed in March when surface water temperatures are higher and productivity likely lower, there is no best time of the year for surveying the population. The number of penguins seen was smaller during El Niño events (Boersma 1977, 1978, 1998a; Vargas 2006; Vargas et al. 2007) (fig. 14), probably because more penguins were at sea and harder to detect and also because the population crashed. The Galápagos penguin was in much poorer body condition during El Niño events (Boersma 1998b). Major population crashes likely occurred in 1972–73, 1982–83, and 1997–98 (Boersma 1978; Valle and Coulter 1987; Vargas et al. 2006, 2007). From 1970 to 2009, the population may have decreased by about half (Vargas et al. 2005a) (table 16.3).

Mills and Vargas (1997) try to standardize methods for counts and cover penguins around Floreana Island, Santiago Island, and other areas not surveyed in Boersma (1977). The number of counters and type of boat used, weather, time in the breeding cycle (breeding, molting, or not breeding), and time of day all create variation among counts. Most of the population is around Isabela and Fernandina Islands, which were counted 25 times between 1970 and 2009 (see fig. 7a; table 16.3). Before 2005, the counts were inconsistent in areas covered, number of observers, time of year, time of day, breeding status, size of vessel used, travel speed, the vessel's distance from shore, weather, sea state, and availability of prey.

The area counted may be the most important factor, as some areas always have more penguins than other areas (see fig. 7b). We divided the area into eight zones,

FIG. 14 Counts of Galápagos penguins around Isabela and Fernandina Islands, with the circles showing average yearly sea surface temperature, taken at Punta Ayora, Santa Cruz, Galápagos. Strong El Niño years were 1982–83 and 1997–98.



and for each count, we estimated what the count might have been had all the same areas around Fernandina and Isabela Islands been counted. For counts done before 2005, we determined how much of the census area was not counted or was poorly counted because of bad conditions and extrapolated a count based on that area (table 16.3). Although more area was surveyed starting in 2005, fewer than 200 penguins were found on these other islands (Vargas et al. 2005a). We increased early counts to estimate what would have been counted had all the census zones on Isabela and Fernandina been included but did not subtract the number of penguins counted at other islands in later counts as the number was small, always fewer than 50 (Vargas et al. 2005a).

In summary, the penguin population is small, though the exact population size is unknown. It is likely that counts underestimate the population in El Niño periods, as more penguins are likely to be in the water hunting for food and more should be counted when penguins are molting and standing on shore. The number of penguins missed is likely to vary among days, years, and areas. The correction estimate of 57% in Vargas et al. (2005a) and Boersma's average correction estimate of 22% suggest that the population has ranged from a low of 700 individuals in 1983 to a high of nearly 10,000 in 1971. Using the two correction factors, the 2009 population was likely between 1,800 and 4,700 penguins. Using the lower confidence interval of 1,500 in Vargas et al. (2005a) and our upper figure, we estimate the current population to be between 1,500 and 4,700 penguins.

9. MAIN THREATS

CLIMATE VARIATION. The breeding biology of the Galápagos penguin is adapted to the unpredictable oceanic productivity fluctuations (Boersma 1974, 1977) between productive La Niña and unproductive El Niño events. These climatic events influence the upwelling system and availability of prey for penguins and other seabirds (Boersma 1978). During El Niño events, the Galápagos's body condition declines and mortality increases (Boersma 1998b; Vargas et al. 2007); in response to strong El Niño events, breeding success and the population crash dramatically (Boersma 1978; Vargas et al. 2007). The penguins are a marine sentinel of climate variability in the Galápagos (Boersma 2008). If, as predicted, El Niño events become more frequent and intense, the Galápagos penguin will likely face a higher probability of extinction, which

has been estimated to be 30% within the next century (Boersma 1998a; Boersma et al. 2005; Vargas et al. 2007).

FISHERIES. Development of large-scale fisheries for small, schooling species that penguins depend on could indirectly affect the population. Removal of predatory fish that drive small fish toward the surface where they are available to penguins and other seabirds may also have indirect impacts. Direct effects of fisheries, such as incidental catch, will be high if fishing gear such as gill nets, which kill Galápagos penguins (Merlen, pers. obs.), are allowed in the penguins' range.

INTRODUCED PREDATORS. Introduced predators kill adult penguins or eat their eggs and young, decreasing the species' reproductive success (Boersma 1977; Hoeck 1984; Valle 1986; Cruz and Cruz 1987; Loope et al. 1988; Steinfurth and Merlen 2005; Steinfurth 2007; Vargas 2009). Many of the problems currently faced by seabirds in the Galápagos started in the 1600s–1800s, when pirates, whalers, and fur sealers introduced black rats and house mice (*Mus musculus*) (Hoeck 1984). In 1832, when Ecuador officially claimed the islands, alien plants and animals, including domestic pigs (*Sus scrofa*), goats (*Capra hircus*), dogs, and cats, were introduced with human colonization (MacFarland and Cifuentes 1996; Snell et al. 2002; Jiménez-Uzcátegui et al. 2007). Steinfurth (2007) records cat predation on penguins at Caleta Iguana, Isabela Island, in 2005 and calculates that a single cat could increase adult penguin mortality by 49% per year at this site.

POLLUTION. As economic and political interest in the islands accelerates, demand for resources increases. Human impacts will remain a major problem and threaten not only penguins but the islands' biodiversity; for this reason, UNESCO added the Galápagos to its List of World Heritage in Danger (UNESCO 2007). The islands were removed from the list in 2010 (UNESCO 2010, 2011) without fully addressing the issue. Waste management and growing infrastructure problems put considerable pressure on the managers of Galápagos National Park (Boersma et al. 2005). More than 173,000 tourists visited the islands in 2008, and as land-based tourism increases, visitor impact is hard to control. Growing numbers of visitors and colonists traveling to and from the islands mean more boats, flights, and

supply ships (FCD et al. 2007; Naula, pers. comm.). Contamination from oil spills poses a severe threat to many marine organisms, including penguins (Edgar et al. 2003), but few, if any, spill-prevention measures are in place in the islands.

DISEASE. The naive nature of most island populations, due to their evolution in a pathogen-scarce environment, is thought to make them more susceptible to introduced exotic diseases and parasites and thus prone to extinction (Diamond 1984; Groombridge 1992; Dobson and Foufopoulus 2001; Wikelski et al. 2004; Parker et al. 2006). Small populations in particular, such as Galápagos penguins, may be compromised by the loss of genetic diversity (Lyles and Dobson 1993), which often results in reduced ability to react to new pathogens. In addition to extremely low estimates of nuclear genetic diversity (Akst et al. 2002; Nims et al. 2008), this species has extremely low MHC (major histocompatibility complex) diversity (Bollmer et al. 2007), leaving it likely more susceptible to the arrival of new pathogens.

A health assessment of the Galápagos penguin found antibodies to *Chlamydophila psittaci* and *Toxoplasma gondii*, although the penguins showed no symptoms of infection (Travis et al. 2006; Deem et al. 2010). The Galápagos has the hemoparasite extraerythrocytic microfilaria (*Nematoda*) (Parker et al. 2006; Travis et al. 2006; Merkel et al. 2007) and the protozoan parasite of the genus *Plasmodium* (Levin et al. 2009). The latter raised serious concerns, as parasites of this genus can cause avian malaria and are known to result in severe mortality in other birds (Miller et al. 2001; Levin et al. 2009). The mosquito *Culex quinquefasciatus*, a vector of avian malaria, has been established in the Galápagos Islands since the 1980s (Fonseca et al. 1998; Whiteman and Parker 2005; Parker et al. 2006), but to date the most pathogenic strain known of the malarial parasite *Plasmodium relictum* has not been found in the Galápagos (Parker et al. 2006; Levin et al. 2009). The parasite identified in Galápagos penguins is most similar to *Plasmodium elongatum* (Levin et al. 2009), which is also highly pathogenic in some avian hosts. Since evidence of all of these pathogenic agents was found during relatively benign times, concern remains that any of them, but particularly *Plasmodium*, may have greater impact when the penguins are under physiological stress such as during an El Niño event. In 1972 and 1997, both El Niño

years, penguins were seen with avian pox-like symptoms, and in 1972, an El Niño period, about three times as many juveniles had the disease as adults (Boersma 1977, pers. obs.).

TOURISM. The Galápagos penguin is a major tourist attraction in the Galápagos Islands (Vargas 2009). Although tourists per se do not cause damage to the islands, the touristic infrastructure creates avenues by which degrading influences such as diseases, alien species, and habitat degradation reach the islands. Tourist sites are generally well controlled, with defined paths and boardwalks. Penguins at Bartolomé and Floreana Islands can be viewed from passing Zodiacs or by snorkeling. No tourism-induced negative effects on the Galápagos penguin are documented, but penguins on shore may enter the water when approached too closely. Generally, other species of penguins tolerate intense tourism, but stress hormones are elevated (Walker et al. 2005). The Galápagos's adrenocortical response to stress depended on its body condition and was higher in 1998, an El Niño year, than in 1999 (Wingfield, unpubl. data).

10. RECOMMENDED PRIORITY RESEARCH ACTIONS FOR CONSERVATION

Recommendations for research and conservation actions should focus on increasing persistence and reducing the risk of extinction. The following are the most important recommendations:

1. Monitor for threats including disease, disease vectors, and invasive alien species and analyze human activities that may indirectly and directly harm penguins.
2. Develop a reliable and cost-effective monitoring program with the aim of determining population trends, demographic parameters, disease, availability of food, reproductive success, and health of the penguin population.
3. If the population declines because of climate variation, disease, fishing, or volcanic activity, consider removing eggs and starting *ex situ* breeding programs.
4. Study the physical and ecological requirements for successful nesting to evaluate and mitigate the impacts of extreme climate variability. Consider the impacts of temperature, solar radiation, humidity, substrate, and presence and absence of predators on penguin survival and success.

11. CURRENT CONSERVATION EFFORTS

The Galápagos penguin is protected under laws of the Republic of Ecuador that established the Galápagos National Park and the Galápagos Marine Reserve, both of which are administered by the staff of the national park. Access to breeding sites is strictly regulated, collection of adults, juveniles, chicks, and eggs is prohibited, and the national park regulates research. The Galápagos Islands were also designated a UNESCO World Heritage site in 1978 and a Man and the Biosphere Reserve in 1984.

Since 1970, Galápagos penguins were counted from small boats around their main breeding areas of Fernandina and Isabela Islands, and counts were conducted annually from 1993 to 2009. The Galápagos population declined by perhaps more than half from its numbers in the early 1970s, and the fewest penguins are seen in El Niño years. An inexpensive and robust system for monitoring the population is needed. About 900 penguins were marked with microchips between 2001 and 2010 (Vargas 2009).

Regulations are in place to reduce the introduction of disease vectors (especially flying insects, including mosquitoes) to areas where penguins occur through the use of lights that are less attractive to insects and installation of insect-elimination equipment on boats.

In response to the growing risk of invasive disease transmission via airplanes and vessels (Wikelski et al. 2004; Travis et al. 2006), the Saint Louis Zoo and the University of Missouri–St. Louis, in cooperation with the Charles Darwin Foundation and Galápagos National Park, initiated an avian-disease surveillance program in 2001 (e.g., Parker et al. 2006; Parker 2009; Gottdenker et al. 2005). In addition, all flights to the Galápagos from continental Ecuador should be fumigated to minimize ongoing introduction of arthropod disease vectors.

Efforts to eradicate or control invasive alien species and predators such as rats are ongoing.

Since 2010, the use of two-stroke engines for tourist boats was banned within the Galápagos Marine Reserve, eliminating discharges that could harm penguins.

The infrastructure that supports a growing human population increases the risk of threats such as oil spills, introduction of alien species, and diseases that threaten penguins. Immigration is strictly controlled through the Special Law for Galápagos, approved by the Ecuadorian Congress in 1998.

12. RECOMMENDED PRIORITY CONSERVATION ACTIONS FOR INCREASING POPULATION RESILIENCE AND MINIMIZING THREATS AND IMPACTS

The substantial decline of Galápagos penguins requires a number of immediate conservation actions.

1. Pay greater attention to the impact of introduced species at the penguins' main breeding sites. Increase efforts to control and/or remove alien species such as feral cats, rats, and mice on islands where penguins breed and make such efforts a high priority.
2. Continue the experiments building shaded nests initiated by the Galápagos National Park and Boersma in 2010 until there are results (Boersma 2010). Penguin breeding success may be limited by a lack of quality nest sites. Breeding attempts may be increased by building shady nest sites or grouping nests. If most of the population can be induced to breed and successfully raise chicks when conditions are favorable, these fledglings, learning to forage when food is abundant, may have a better chance of survival. Penguins able to nest close to other penguins may benefit from group foraging and have higher reproductive success.
3. Initiate efforts to prevent the introduction of new diseases and parasites to the Galápagos ecosystem, especially those that have insect vectors, such as West Nile virus and avian malaria. In addition to preying on native fauna, alien species can introduce infectious diseases and parasites, and people can augment their spread. It is imperative that direct international flights to the Galápagos continue to be prohibited and fumigation of marine vessels, including cargo holds, visiting the islands from the mainland be reinforced. Continue the avian health and baseline study in the Galápagos Archipelago, which will enable early detection of novel avian diseases or parasites, and make timely recommendations to the Galápagos National Park to prevent further spread of diseases and parasites that have already been detected in the islands.
4. Protecting the species where it is most successful would benefit the population and reduce the penguins' risk of extinction. The Galápagos penguin is an icon that attracts tourists and an endangered species. The highest-density breeding area for the penguins (nests per square meter) was on the Mari-

elas Islands until rats were introduced. By mid-2005, more penguins were breeding in Caleta Iguana on Isabela Island than in the Marielas, perhaps because dogs were removed from the southwest coast of Isabela Island in the 1980s and 1990s. The shallow, productive bay around the Marielas Islands has supported the penguin population even during El Niño events. Elizabeth Bay has higher reproductive success, and chicks grew faster there than at sites on Fernandina Island (Boersma 1977). Protection of southwestern Isabela Island is critical for the penguins. The Galápagos National Park has already taken two important steps by removing black rats and restricting tourism activities around the Marielas Islands, with protection zones extending about 3.5 kilometers from the shoreline. Restricting tourist or fishing vessels from anchoring near the island would reduce the chance of harmful rat introduction and petroleum leakage. Protecting the penguins' feeding and breeding area in southwestern Isabela by making the area from Punta Essex, Isabela Island, to Elizabeth Bay, including the Marielas Islands, a no-take zone will help protect the population. The seabirds, including penguins, shearwaters, pelicans, boobies, and terns, depend on large fish, sharks, and dolphins to concentrate their prey. Making this area a no-take zone would be an important step toward maintaining the productive and dynamic nature of this system, benefiting not only penguins but many other species of seabirds, marine mammals, reptiles, sharks, and fish.

5. Maintain regular control and vigilance of feeding and breeding areas to ensure strict compliance with fishery regulations, especially regarding fishing techniques that are responsible for penguin deaths, such as the use of gill nets.

6. Develop a contingency plan for responding rapidly to the appearance of new threats (e.g., oil spills, introduced animals, diseases, shipwrecks, and volcanic eruptions).
7. Reduce human conflicts with wildlife and biodiversity. Reducing human impact on the islands and the surrounding ocean should be woven into all aspects of governance and development.
8. Continued marking and recapturing penguins provides information on population dynamics and helps assess the health of the population. An external mark, like a web-tag, would aid in measuring the failure rate of microchips (Boersma and Rebstock 2010).
9. Conservation in the Galápagos, particularly of the inhabited islands, depends on the local community. Comprehensive environmental education and awareness programs are critical for success. The Galápagos is one of the few places where the natural world should be favored over the human world. The islands are a treasure for all humans and deserve stronger political protection than they currently receive.

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TABLE 16.1 Biometric data for the Galápagos penguin (showing mean, standard deviation, and sample size)

VARIABLE	MALES	FEMALES	UNSEXED	REFERENCES
Body mass (kg) ¹	2.2±0.2 (n=61) ¹⁰	1.9±0.2 (n=50) ¹⁰		Boersma 1977
	2.3±0.3 (n=103)	1.9±0.3 (n=62)		Travis et al. 2006
	2.1±0.2 (n=11) ¹¹	1.8±0.3 (n=12) ¹¹		Steinurth et al. 2008
	2.2±0.3 (n=141)	1.7±0.3 (n=90)		Boersma unpublished data
Body length (mm) ²	526.7±23.56 (n=107)	489.4±28.40 (n=66)		Boersma unpublished data
Body height (mm) ³			360±11.4 (n=5)	Boersma unpublished data
Body girth (mm) ⁴	352.4±17.2 (n=105)	335.1±12.7 (n=63)		Boersma unpublished data
Head length (mm) ⁵	122.8±3.1 (n=108)	114.8±3.31 (n=64)		Boersma unpublished data
Bill length (mm) ⁶	58.2±2.89 (n=93)	53.9±1.82 (n=83)		Boersma 1977
	58.8±2.40 (n=136)	54.7±2.03 (n=86)		Boersma unpublished data
Bill depth (mm)	19.84±2.77 (n=158)	16.68±0.89 (n=161)		Boersma 1977
	18.67±0.93 (n=136)	16.10±0.76 (n=86)		Boersma unpublished data
Bill gape (mm) ⁷	23.1±2.15 (n=108)	20.1±2.44 (n=65)		Boersma unpublished data
Flipper length (mm) ⁸	118.66±6.17 (n=126)	113.25±6.33 (n=119)		Boersma 1977
	128.46±4.64 (n=135)	121.0±4.84 (n=85)		Boersma unpublished data
Toenail (mm) ⁹	16.41±1.16 (n=134)	15.09±0.96 (n=114)		Boersma 1977
	17.09±0.96 (n=81)	15.60±1.15 (n=52)		Boersma unpublished data
Egg length (mm)			First	Boersma 1974
			62.51±2.32 (n=74)	
			Second	
Egg width (mm)			61.74±2.42 (n=65)	Boersma 1974
			First	
			47.88±1.20 (n=74)	
			Second	
			48.62±1.61 (n=65)	

1 Weight depends on life cycle stage (see Boersma 1977).

2 Body length is taken from tip of beak to end of the tail when bird is held outstretched horizontally.

3 Body height is taken from standing penguin, base of their feet to the top of their flat head.

4 Body girth is circumference of penguin taken underneath flippers.

5 Head length is tip of bill to the back of the base of skull.

6 Bill length is taken from tip of bill to the base of the "V," where feathering starts on forehead.

7 Bill gape is mouth slit (rima oris).

8 Flipper length measurements are taken from elbow joint to tip of flipper.

9 Length of the middle toenail on the right foot.

10 Nonreproductive, nonmolting period.

11 Brooding chicks.

TABLE 16.2 Key life-history parameters of the Galápagos penguin

PARAMETER	VALUE	REFERENCE
Age at first breeding	unknown	
Sex ratio	1.1 males:females (n=212)	Boersma unpublished data
Eggs	1 st longer, 2 nd wider, 2 nd more likely to be addled	Boersma 1977
Incubation period	38–42 days	Boersma 1977
Hatching interval	2 to 3 days	Boersma 1977
Guard period	2 weeks	Boersma 1977
Crèche behavior	nest density too low for crèching	
Chick period	50–60 days	Boersma 1977
Molt	before breeding, 2x/year	Boersma 1977
Molt duration	17–43 days	Boersma 1974, 1977
Distance between nests	>1.8m, often >10m	Boersma unpublished data
Max dive depth	52m (most dives less than 6m)	Steinfurth et al. 2008
Juvenile survival rate	variable (0–30%, possibly higher)	Boersma 1977
Adult survival rate	variable (2x higher than juveniles in El Niño events 23–35%); 89% in 10 month period	Boersma 1977 Vargas et al. 2006
Maximum lifespan	unknown (>11 years, n=3)	Boersma 1977

TABLE 16.3 Counts of Galápagos penguins around Isabela, Fernandina, Floreana, Rabida, Santiago (including Logie and Sombrero Chino) and Bartolomé islands made from a small boat

YEAR	COUNT	REFERENCE
1970	1584 (2020)*	Boersma 1974, 1977
1971	1931 (2099)**	Boersma 1974, 1977
1980	1720	Harcourt 1980, Rosenberg et al. 1990
1983 (Sep)	398	Valle and Coulter 1987, Vargas et al. 2005
1984 (Jan)	463	Valle and Coulter 1987, Vargas et al. 2005
1984 (Sep)	435	Valle and Coulter 1987, Vargas et al. 2005
1985	665	Rosenberg et al. 1990
1986	584	Rosenberg and Harcourt 1987
1989	692	Mills and Vargas 1997
1993	662	Mills and Vargas 1997
1994	873	Mills and Vargas 1997
1995	844	Mills and Vargas 1997
1996	933	Vargas et al. 2005b
1997	1284	Vargas et al. 2005b
1998	444	Vargas et al. 2005b
1999	650	Vargas et al. 2005b
2000	802	Vargas et al. 2005b
2001	780	Vargas et al. 2005b
2002	848	Wiedenfeld and Vargas 2002, unpublished
2003	770	Vargas and Wiedenfeld 2003, unpublished.
2004	858	Wiedenfeld and Vargas 2004, unpublished
2005	1087	Vargas et al. 2005b, unpublished
2006	1144	Jiménez-Uzcátegui et al. 2006, unpublished
2007	1009	Jiménez-Uzcátegui and Vargas 2007, unpublished
2008	877	Jiménez-Uzcátegui and Vargas 2008, unpublished
2009	1042	Jiménez-Uzcátegui and Devineau 2009, unpublished

Note: Counts for the eight areas around Fernandina and Isabela were estimated for 1970 and 1971 by ranking of the % of penguins counted in the eight areas (fig 7b). From 1970 to 1986 counts were of Fernandina and Isabela islands. Floreana, Rabida, Santiago, or Bartolomé were not counted from 1970 to 1989. When they were counted, less than 50 penguins were seen.

* About 45% of the coastline was not counted. Actual count is 1584, but using the % of penguins in each zone (Fig. 1, Vargas et al. 2005), the count was adjusted to 2020.

** About 20% of the coastline was not counted. Actual count is 1931, but using the % of penguins in each zone (Fig. 1, Vargas et al. 2005), the count was adjusted to 2099.

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