THE IMPACT OF INTRODUCED HERBIVORES ON THE GALAPAGOS RAIL (*LATERALLUS SPILONOTUS*)[1]

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ABSTRACT

The Galápagos rail (*Latterallus spilonotus*) is known from seven islands in the archipelago. By affecting the ground vegetation, introduced herbivores, which live on six of the islands, are likely to affect rail populations. The results of a census made during 1986–1987 on six of the seven islands showed the Galápagos rail common only on the upper regions of Santa Cruz and southern Isabela islands. Pinta Island was not checked but the rails are believed to be common there. Rails were found on Fernandina Island, but the availability of suitable habitat likely limits the population to small numbers. Rails were very rare on San Cristóbal and were not found on Floreana. Rails were restricted to a few small sites on Santiago and were found less often than expected by chance in areas with herbaceous vegetation cover shorter than 30 cm tall, which appeared to be extensively grazed by feral goats (Bovidae). There is likely to be selection against use of low cover through predation by a large number of potential predators. Conservation of the native highland flora will likely benefit the Galápagos rail populations.

Students of Galápagos botany have expressed a great concern about the damage to the indigenous flora by introduced herbivores (Eliasson, 1968; Weber, 1971; Hamann, 1975, 1979a, b, 1981, 1984; Adsersen, 1976; de Vries & Calvopiña, 1977). Goats, cattle (Bovidae), horses (Equidae), donkeys (Equidae), and pigs (Suidae) are known to destroy island vegetation (Coblentz, 1978; Ralph & van Riper, 1985). By selective grazing, introduced herbivores may affect the flora by changing the frequency of plant species and by increasing the opportunities for invasion by introduced species (Hamann, 1979a). Birds are differentially affected by these changes: some will increase, others will decline (see Bock & Webb, 1984).

Ground-dwelling birds are more likely to be adversely affected than other groups, as damage to undergrowth vegetation is likely to be more severe, and trampling of nests may occur (see Coulter et al., 1985, for the dark-rumped petrel, *Pterodroma phaeopygia*). Several species of rails (Rallidae) appear to have been negatively affected by damage to ground cover (e.g., *Tricholimnas sylvestris;* King, 1981). Many island forms of rails occur, and this combined with their ground-nesting habits makes them a particularly vulnerable group. King (1981) listed 18 species of rails that are believed to have become extinct since 1600. All were endemic island forms. Currently, 16 extant species are considered endangered or threatened (King, 1981). With few exceptions, they occur on islands. Habitat destruction from introduced herbivores and human development, and predation by exotic mammals (e.g., rats (Muridae), cats (Felidae), and pigs), are believed to be largely responsible for the high number of threatened, endangered, or extinct rails (Baldwin, 1945; King, 1981, 1985; Atkinson, 1985).

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The endemic Galápagos rail (*Laterallus spilonotus*) is found on seven islands within the Galápagos Archipelago (Franklin et al., 1979). They occur only on islands with humid-zone vegetation; of these, Santa Cruz, Isabela, San Cristóbal, and Floreana have a permanent human population, and Santiago was temporarily inhabited and currently has a large feral goat and pig population (L. Calvopiña, pers. comm.). Of the remaining islands where the rail occurs, Fernandina lacks introduced animals but has a very limited area of humid-zone vegetation, and the rail population is small (see Results); and Pinta is free of introduced mammalian predators, and the goat population has been reduced to fewer than 20 individuals (L. Calvopiña, pers. comm.). However, goats that are still present threaten the rail population.

Franklin et al. (1979) believed the Santa Cruz Galápagos rail population to be fairly stable and not threatened in the foreseeable future. Because of the introduced herbivores and potential mammalian predators, they recommended that the status of the rail be reviewed throughout its range. A census was made of this species on six of the seven islands where it was known to occur; Pinta was excluded for logistical reasons. The relative abundances of the rail were compared among islands and the apparent avoidance of areas with low vegetation was demonstrated. It appears that the rarity of the San Cristóbal and possibly the Floreana populations and the restricted area of occurrence on Santiago were due to extensive grazing by introduced herbivores, chiefly goats, cattle, and horses, which reduced suitable habitat and possibly increased predation. Management recommendations are made that may be necessary to increase population levels, thereby reducing the rails' chance of early local extinction.

Overview of the Habits and Habitats of the Galapagos Rail

The rail has been studied most extensively by Franklin et al. (1979) in the highlands of Santa Cruz. They found rails occurring in the farms and all of the highland vegetation zones. Their work showed it to be largely insectivorous, taking primarily small invertebrates. The Galápagos rail appears to be monogamous and territorial and builds semidomed ground nests in dense vegetation. They also found incubation to be relatively long, lasting about 23–25 days. The Galápagos rail is loath to fly, and when seen, it travels through runways it makes in the herbaceous vegetation.

Methods

Rails were censused using playback recordings of the territorial call of the Galápagos rail recorded on Santa Cruz by A. Franklin and deposited in the Library of Natural Sounds at Cornell University. Calls were played for 15 seconds in each of four 90° directions from a Sony TCS-450 recorder, hand held approximately 1.5 m from ground height. Vocal responses from rails were counted during the one-minute playback period and for two minutes following the end of the playback. Birds responding within an estimated 25-m radius (0.20-ha circular plot) were counted; only responses that were clearly from different birds were included. Therefore, density estimates of responding birds were probably lower than actual occurrence. Such a method likely reduces bias in relative abundance measures, as rails may call more frequently at higher densities (see Glahn, 1974, for *Porzana carolina* and *Rallus limicola*). Rails were censused at 100-m intervals, except on the southeastern rim of Fernandina and in several areas on Isabela, San Cristóbal, and Floreana, where they were censused at 50-m intervals in order to census more effectively rails in areas of restricted habitat. Vegetation type was recorded in 25% units for each 0.20-ha circular plot, except for the farm zone of Santa Cruz, where vegetation type was noted in the area of responding rails. Vegetation was classified in the tall herbaceous height class if the plot contained at least 25% cover greater than 30 cm tall. If the plot had less than 25% cover by tall herbs and greater than 25% cover by low herbs ($\leq$ 30 cm tall) it was included in the low herbaceous height class.

The term "density" refers to the number of calling rails during the three-minute playback–listening period. Density, as expressed per ha, is the number of calling rails in five 0.20-ha circular plots. The rail density for Pozo Colorado is based on the total number of rails heard in the wet area (ca. 1 ha).

SANTA CRUZ

Fourteen farms were randomly selected from a list of all farms greater than 20 ha (N = 151) on Santa Cruz. For each farm four–six 500-m transects were randomly located using a grid system on a map of the farm zone made by Ingala (Instituto Nacional Galápagos). Rails were censused in the farm zone from 16 September to 1 October 1986. In the highlands of Santa Cruz within the Galápagos National Park (GNP), a 4.5-km transect beginning about 1.3 km south of Media Luna to about 0.8 km north of Puntudo was established. Data analysis reported for Santa Cruz (GNP) includes eight censuses made from 16 October 1986 to 5 March 1987. Territorial calls were heard throughout this period without any apparent seasonal trends in frequency of response.

OTHER ISLANDS

The other islands were censused in a similar fashion, although each transect was only censused once. Rails were censused in areas previously reported to have had rails or that appeared as suitable habitat. Santiago was censused from 21–26 November 1986; Floreana, 19–25 January 1987; San Cristóbal, 28 January–1 February 1987; Isabela, 6–11 February 1987; and Fernandina, 5–6 April 1987.

STUDY SITES

On Santa Cruz, the sampled farm zone was primarily composed of introduced elephant grass (*Pennisetum purpureum*) pastures, introduced guayava (*Psidium guajava*) shrub patches, and a mixture of herbaceous plant pastures and scattered forests, primarily cedar (*Cedrela odorata*) and avocado (*Persea americana*). Almost the entire southern highlands of Santa Cruz have been altered by agricultural interests. The transects in the GNP on Santa Cruz were located in *Miconia*, fern, and herbaceous meadow areas.

On Floreana, rails were censused throughout the farm zone (similar vegetation as on Santa Cruz) and in the GNP highland areas. Guayava forests with a fern understory were most common in the GNP areas censused. Several areas were open and mesic with sedges and other herbs. On Santiago, rails were censused in the guayavillo (*Psidium galapagensis*) forests near the southern summit and in meadow areas at the plateau of La Central. The high northern section of Santiago ("Jaboncillo") was surveyed, listening for calls without using tape recordings. On San Cristóbal, rails were censused in the farm region of El Chino and the upper plateau in the region of San Joaquin and El Junco. The plateau area was primarily pasture and short, dense, guayava shrubs. On Isabela, rails were censused in the grass–fern area on the southeastern slope of Sierra Negra, including Pozo Colorado, a small (ca. 1 ha) wet area. At Pozo Colorado, rails were censused at 50-m intervals. The census was extended to 500 m from the center of the wet area to the west and east, and ca. 1 km to the north and south. During 1985 a large area of Sierra Negra was burned; data reported here do not come from sites that had evidence of burning. I censused the southeastern rim and south-southwest slope of Fernandina in densely vegetated areas with herbaceous cover. Hamann (1981) described floristics for most of the areas in the study sites.

Table 1. Numbers of 0.20-ha circular plots with 0, 1, 2, or >2 rails responding to tape recordings on 12 sites on 6 islands, Galápagos, 1986–1987.

Islands / Sites	Elevation (m)	Numbers of rails per plot: 0	1	2	>2	Total plots
Santa Cruz						
Farm zone	120–455	314(96.6)[1]	10(3.1)	1(0.3)	0(0)	325
Highlands (Galápagos National Park)[2]	490–700	196(64.3)	90(29.5)	19(6.2)	0(0)	305
Isabela[3]						
Southeastern Sierra Negra	950–1,060	26(57.8)	15(33.3)	4(8.9)	0(0)	45
Northeastern Sierra Negra	810–1,020	14(93.3)	1(6.7)	0(0)	0(0)	15
Poza Colorado	590–630	45(91.8)	3(6.1)	1(2.1)	0(0)	49
Fernandina						
Southeastern rim	1,330	29(100)	0(0)	0(0)	0(0)	29
South-southwestern slope[4]	800	—	—	—	—	
Santiago (southern highlands)						
Wooded areas	480–600	43(100)	0(0)	0(0)	0(0)	43
Herbaceous meadows	580–660	59(84.3)	7(10.0)	2(2.9)	2(2.9)	70
San Cristóbal						
Upper plateau	400–650	78(100)	0(0)	0(0)	0(0)	78
El Chino	130–230	23(95.8)	1(4.2)	0(0)	0(0)	24
Floreana						
Highlands	230–480	150(100)	0(0)	0(0)	0(0)	150

[1]Percent of total plots for each site.
[2]Includes all plots in the replicated censuses (October 1986–March 1987).
[3]Nonburned sites.
[4]Area not systematically censused; free-calling rails found.

Results

Santa Cruz

Rails were found in the farm zone from 125 m to 445 m elevation. Although rails were more often found in higher-elevation plots, the difference between the mean elevation of plots with rail response and without was not significant in the farm zone (Wilcoxon test, $P > 0.10$). Rails were found in a variety of vegetation types, occurring in wooded areas as well as in tall herbaceous pastures. They were not found in low height class pastures, although a small number of plots occurred in this height class ($N = 21$, 6.4% of total number of plots). Based on this number of plots and the low number of rails located, they would not have been expected to have been found in the low height class pastures if they were distributed randomly among vegetation classes. Rail density was low throughout the farm zone (Tables 1, 2) and tended to be lower than other sites when densities of playback areas with rails were compared (Table 2). However, densities in plots where rails were found were similar among islands and sites ($X^2 = 3.4$, $P > 0.3$). Density of responding rails was greatest in the higher elevations of the GNP and varied among census days with a mean of 2.1 rails/ha (Table 2). Density increased with increasing elevation ($r_s = 0.92$, $P < 0.005$; Fig. 1). The plot with the highest elevation (695 m) had a mean density of 5.2 rails/ha.

Isabela

Excluding burned sites, rail density was slightly higher on southeastern Sierra Negra than on Santa Cruz (Table 2). There was no difference in the frequency of rails responding in playback areas

TABLE 2. Densities ($\bar{X} \pm$ SE) of responding rails during playbacks among selected islands, Galápagos, 1986–1987.

Islands Sites	Rails/ha All plots	 Plots with rails responding
Santa Cruz		
Farm zone	0.18 ± 0.05	5.45 ± 0.45
Highlands (Galápagos National Park)	2.10 ± 0.19	6.65 ± 0.55
Isabela		
Sierra Negra (SE)	2.45 ± 0.50	6.05 ± 0.50
Poza Colorado	—[1]	4.00[1]
Santiago		
Southern highlands	—[2]	8.50 ± 1.65

[1]Density reported for entire area (see Methods).
[2]Not reported due to large area censused and the patchy rail distribution (see Results).

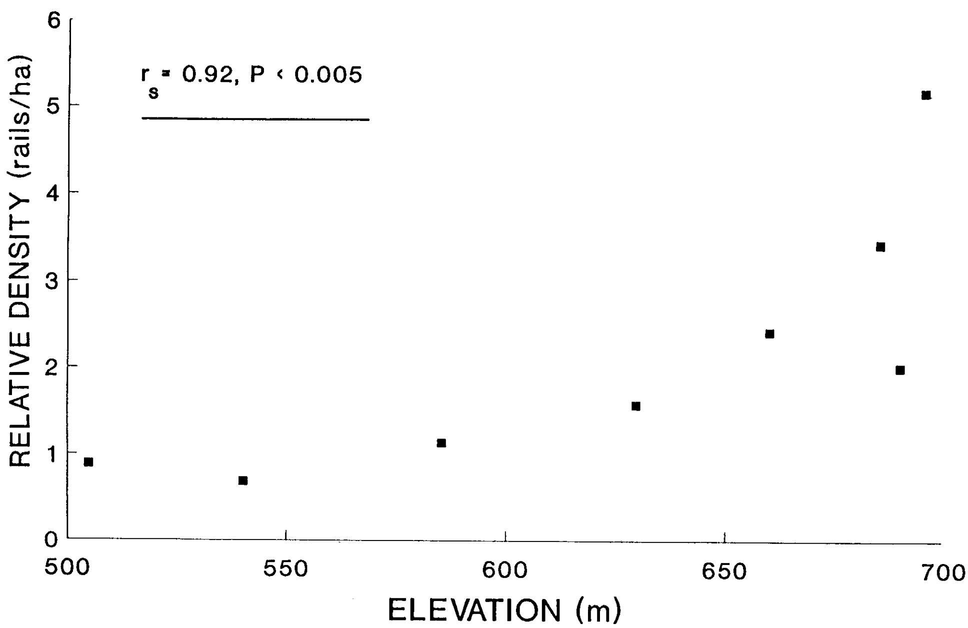

FIGURE 1. Relationship of relative density of responding Galápagos rails to elevation, southern highlands (GNP), Santa Cruz Island, Galápagos, October 1986–March 1987.

with 100% cover of tall vegetation and playback areas with 25–50% low herbs (Fisher's exact probability test, $P > 0.40$). All nonburned playback areas had greater than 50% tall herbaceous cover. Fourteen horses were seen in the eastern portion of the upper area of Sierra Negra; they may have been responsible for the patchy areas of low herb cover that appeared grazed.

At Pozo Colorado, four rails responded in the wet areas (approximately 1 ha) and none were observed greater than 300 m from this area. Evidence of herbivore grazing was found throughout the area; however, a mixture of tall and short herbs remained.

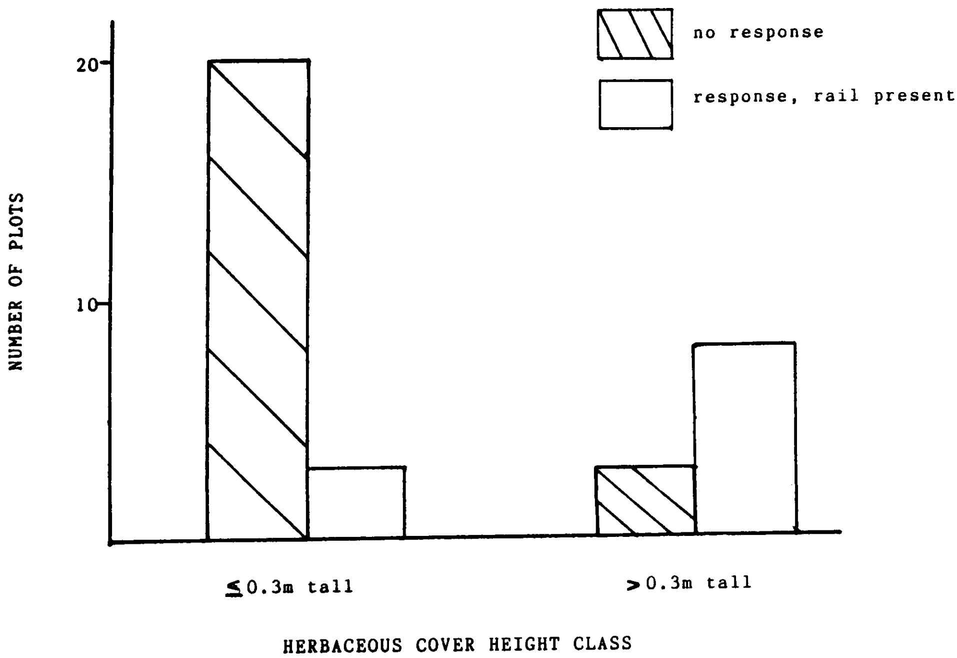

FIGURE 2. Comparison of Galápagos rail presence with herbaceous vegetation height class, Santiago Island, Galápagos, November 1986. There may be two-way interaction with the presence of a freshwater pool and height class. In this figure, only plots with a freshwater pool are included. Rail presence between the height classes was nonrandom (Fisher's exact probability test, $P = 0.001$), with a higher proportion occurring in the taller herb cover.

FERNANDINA

Rails were found at 800 m elevation on the south–southwest slope where grasses were abundant. They were not found on the southeast side of the rim (1,330 m), where tall grasses and sedges were also abundant (Table 1). T. de Roy (pers. comm.) found rails at about 800 m more frequently than at the rim's southeastern side during several trips to Fernandina. The number of rails appeared to be small, and they are perhaps scattered among suitable sites.

SANTIAGO

Rails were found only on the southern highlands of Santiago at an elevation of 550–650 m (Table 1). Rails were found at 11 playback areas; density of responding rails in sectors with rails was higher than on other islands (Table 2). Two of these plots had three or four rails responding during the playback period, respectively (Table 1). A total of 25 responding rails were recorded during the playbacks and while walking between transects.

Rails were found more often than expected in playback areas with a freshwater pool present than in playback areas without pools under the model of equal distribution among classes (Fisher's exact probability test, $P = 0.0004$). Similarly, rails were found more often than expected in playback areas with pools and greater than 25% tall herbaceous cover than in areas with pools and low herbaceous cover (Fisher's exact probability test, $P = 0.001$, Fig. 2). Many sites in the low herb class were extensively grazed and had 100% cover of herbs less than 30 cm tall. There may be a two-way interaction with the presence of a pool and vegetation height; however, this question was not possible to examine because of a small sample size (N = 11).

SAN CRISTOBAL

Only one rail was found on San Cristóbal, in the farming area of El Chino at 200 m elevation. Despite intensive and extensive searching, rails were not found in the higher elevations (Table 1). The herbaceous vegetation was characteristically low and heavily grazed by cattle and horses, especially near the numerous freshwater pools.

FLOREANA

Several areas appeared as suitable rail habitat on Floreana. Yet the Galápagos rail was not found despite seven days of searching (Table 1). At the base of several hills there were freshwater pools with tall, dense herbaceous vegetation. In all areas that appeared suitable there were numerous signs of feral pigs.

DISCUSSION

Rail density increased with elevation on Isabela and Santa Cruz, probably because of the greater moisture in the higher zones. This is supported by the findings on Fernandina where rails were found only in the more humid area of 800 m elevation rather than at the rim (1,330 m), which is above the cloud belt (Hamann, 1981). The apparent absence of rails away from the wet area at Pozo Colorado (Isabela) also indicates the propensity of the rails for mesic areas. Although they are scarce, the presence of rails at 200 m elevation on San Cristóbal and the absence or rarity of rails in the higher zone (550–600 m) is unlikely to be characteristic of their normal distribution and abundance. The upper zone of San Cristóbal, unlike much of Isabela and Santa Cruz, is almost exclusively private land and is used heavily as pasture for domestic cattle and horses. Although there are areas of pasture with herbaceous vegetation greater than 30 cm tall, they are scattered among a larger framework of short grazed herbs. The upper area of San Cristóbal receives heavy precipitation, and for a given altitude, receives more rain than Santa Cruz and Isabela (see Hamann, 1979b). It is the only island with permanent freshwater streams and has numerous small depressions that form freshwater pools. Itow & Weber (1974) found bogs only on San Cristóbal, Santiago, Santa Cruz, and southern Isabela, and commented that the bogs of San Cristóbal were (p. 46) "heavily disturbed by free ranging cattle." San Cristóbal probably once had a very large rail population. Few early explorations were made on San Cristóbal early in the 19th century, hence our knowledge of early distributions and abundance of birds is poorly known prior to habitat destruction by humans (Grant, 1986).

Santiago also presents a similar situation. During the census, rails were restricted to a few areas on the upper plateau. The total population of rails may number fewer than 100. Darwin (1896, p. 376) noted "great numbers of a very small water-rail" in the upper part of Santiago. It is easy to picture the highland region having had a large rail population. The number of goats is now very high, so why several areas still retain a dense herbaceous vegetation when neighboring areas are extensively grazed remains an enigma. It is interesting that the density of rails in playback areas where rails were recorded tended to be higher than in the other islands I censused. This may be due to excellent habitat (albeit restricted in size) or to a changed structure within the population due to the restricted opportunities for successful dispersal. A higher proportion of young birds may remain at their natal site.

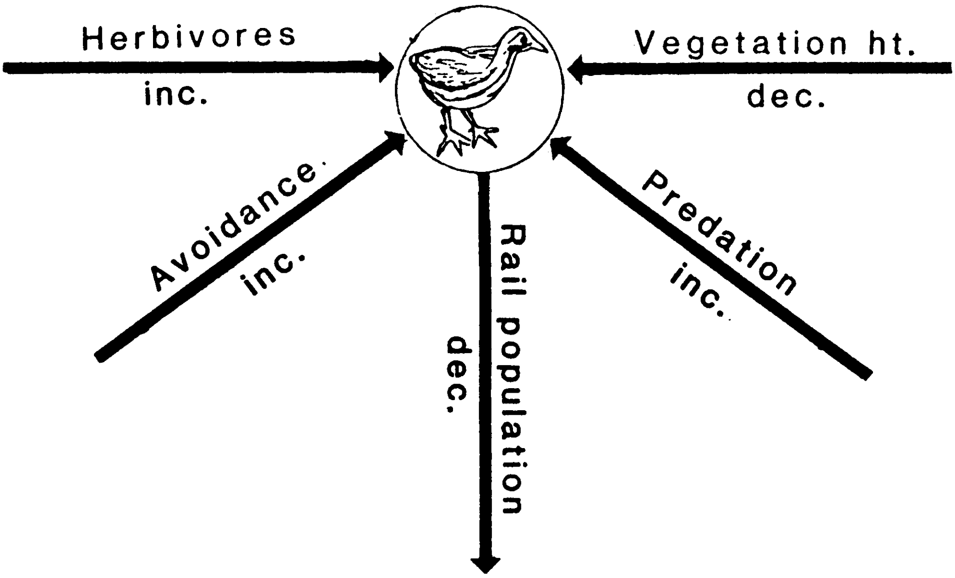

FIGURE 3. Herbivore–predator model. As the number of herbivores increases, there is likely to be an increase in the patchiness of low and tall herbs, with an overall decrease in the proportion of tall herbs. This model predicts that as areas of tall cover decrease and the cover height patchiness increases, the rail population will decline by increased predation and a decline of suitable habitat.

The rail was rare or extirpated on Floreana. There appeared to be suitable habitat for it. The plateau area of the highlands is no greater than 360 m elevation, and rainfall there appears to be lower than on the other islands censused (Hamann, 1979b). Thus it is likely that there has never been a large population of rails. Feral mammals, which have had a long history on Floreana (Darwin, 1896; F. Cruz, pers. comm.), may be responsible for the present status of the Floreana rail population. Although the rail may be present, F. Cruz (pers. comm.) has not seen this species on Floreana since 1983. The drought during 1985 was severe, perhaps restricting this species to fewer sites, thereby increasing the possibility of extirpation. Floreana has the largest number of recent vertebrate extinctions (see Steadman, 1986), which is probably a result of the early history of feral mammals.

Grazing by goats on Pinta appeared to reduce the population of rails (see Franklin et al., 1979). With the reduction of goats in the early 1970s, the rails appear to have recovered (see Franklin et al., 1979). During 1978, rails were very common (P. Grant, pers. comm.). However, the population is vulnerable to declines as long as goats remain.

Rails appear to avoid areas with herbaceous ground cover of short herbs. Avoidance is likely to be augmented by selective pressures by indigenous (e.g., barn owl, *Tyto alba* (de Groot, 1983)) and introduced predators (e.g., feral pigs (Coblentz & Baber, 1984)). When the density of herbivores increases, the herbaceous vegetation would probably become more patchy, with an increase in areas with low herbs. Predation may be facilitated in such an environment. Rail populations may decline if areas of low herb cover are avoided and may also decline by an increase in predation in patchy areas (Fig. 3).

MANAGEMENT RECOMMENDATIONS

It is clear that several rail populations are threatened. If the populations of rails on Santiago and San Cristóbal remain small, early extinction (as Floreana may have experienced) is more likely due to natural disturbances, inbreeding (see Schonewald-Cox et al., 1983), and population changes of predators/herbivores. Optimally, the goat and pig populations need to be eliminated on Santiago. Due to the large size of the highland region and humid conditions, Santiago could potentially provide a reserve for this species. The problem on San Cristóbal is more difficult. Acquisition of areas of the plateau region and exclusion of herbivores would be necessary. The size and shape of the reserve must minimize the area exposed to grazed areas, thus minimizing the influence of predators. Domestic animals must not be permitted to roam free on Floreana. Wild pigs were once eliminated (F. Cruz, pers. comm.); however, they have been reintroduced from domestic stock. The area of Cerro Narranjo and other wet areas that form at the base of several hills would be the best sites for fencing if herbivores cannot be excluded from the park. The few remaining goats on Pinta must be eliminated to reduce the major threat to that population.

Protecting areas from herbivores would also promote plant conservation. Restoring natural vegetation and protecting existing areas should concurrently help the rail populations. Thus, joint conservation efforts are needed. I strongly suggest a plan of action to restore the plant communities of Santiago, the only uninhabited island with a large highland region. Eradication of introduced herbivores on the important island of Santiago would be a major ecological success story.

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