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Feral Dogs of the Galápagos Islands: Impact and Control

Bruce D. Barnett and Robert L. Rudd

Organisms introduced onto insular ecosystems, after they have become established, frequently increase to destructive numbers. Several species of mammals introduced onto the Galapagos Islands illustrate this ecological axiom. For example, domestic dogs intentionally introduced now exist as three major types: domestic, free-ranging or pariah, and feral. Problems derived from their presence are most apparent on the islands of Santa Cruz and Isabela. Feral and pariah dogs are both scavengers and predators. While other introduced mammals (chiefly feral cattle and pigs) have served as prey, in recent years severe depredations on the unique endemic Galapagan fauna have been caused by the dogs. The chief targets have included land and marine iguanas, tortoises, and colonially nesting marine birds. To counter this problem, a coordinated eradication and study program on all dog populations has been underway since 1979, and an eradication program on Isla Isabela, begun in 1981, continues with marked success. Control rests primarily on carefully placed flesh baits poisoned with Compound 1080 (sodium monofluoroacetate). Field studies on distribution, demography, behavior, and disease transmission also began on Isla Isabela in 1981. Particularly notable is the high incidence of filarial heartworm in several species of mammals, including the local human residents. Dogs are important reservoirs of this parasite. Descriptions of the problems created by the dogs and speculations on the nature of selective return to the wild state are presented.

Zusammenfassung

Lebewesen, die in insulare Oekosysteme eingeführt werden, vermehren sich nach ihrer Etablierung oft in einem zerstörenden Ausmass. Einige der Säugetierarten, die auf den Galapagos Inseln eingeführt wurden, illustrieren dieses ökologische Axiom. So existieren zum Beispiel Hunde, die mit Absicht eingeführt wurden, heute in drei Hauptgruppen: als Haustiere, als streunende Tiere oder Parias, und als wilde Tiere. Probleme, die sich aus deren Gegenwart ergeben, zeigen sich deutlich auf den Inseln Santa Cruz und Isabela. Wilde und streunende Hunde sind sowohl Aasfresser

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wie auch Raubtiere. Während andere eingeführte Säugetiere (hauptsächlich wilde Rinder und Schweine) als Beute gedient haben, haben kürzlich ernsthafte Verwüstungen der einzigartigen endemischen Galapagos-Fauna stattgefunden. Die hauptsächlichsten Angriffe richteten sich gegen die Land- und Marine-Iguanas, Schildkröten und Seevögel, die in Kolonien nisten. Um diesem Problem zu begegnen, läuft seit dem Jahr 1979 ein koordiniertes Vernichtungs- und Studien-Programm in Bezug auf alle Hundepopulationen, und ein Vernichtungsprogramm auf der Isla Isabela, begonnen in 1981, dauert noch an mit sichtlichem Erfolg. Die Vernichtungskampagne bedient sich hauptsächlich sorgfältig platzierter Fleischköder, die mit dem Compount 1080 (Natrium-Monofluoroacetat) vergiftet sind. Untersuchungen am Platz betreffend Verbreitung, Demographie, Verhaltensweisen und Uebertragung von Krankheitsvektoren begannen auf der Isla Isabela in 1981. Besonders bemerkenswert ist das häufige Auftreten von filariformen Herzwurm in einigen Säugetierarten inklusive Menschen. Hunde sind wichtige Reservoirs dieses Parasiten. Im folgenden sind die Probleme beschrieben, die durch die Hunde hervorgerufen werden, und Mutmassungen angestellt über die Art einer selektiven Rückkehr zum Urzustand.

Introduction

The introduction of organisms from other areas can easily upset the delicate balance of natural island communities, especially when such organisms are not faced with the natural checks to their increase that are normally found in the home environment. Their rapid and successful establishment in such circumstances is likely, and is normally followed by an increase in their numbers at the expense of native flora and fauna. In contrast, island organisms, which have been isolated for a long period of time from more complex continental ecosystems, have become specialized to a simplified island environment and are often incapable of withstanding competition with, or predation by, introduced species. At the same time, other critical factors come into play. MacArthur and Wilson (1967) pointed out that because a given land area can support far fewer numbers of predators than prey, predators will be relatively rare, even on large islands; smaller islands may maintain a carrying capacity too low to support any permanent predator population. Also, the likelihood of dispersal of large, terrestrial predators to islands decreases as the dis-

tance from the mainland increases, and on islands that do not normally support large predators, natural selection has not favored the emergence of avoidance behavior in the endemic fauna.

A dangerous illustration of these concepts presently exists in the Galápagos Archipelago, where feral dogs seriously threaten populations of endemic fauna on the islands of Santa Cruz and Isabela (Fig. 1). Research on feral and domestic dog populations on Isabela, currently being conducted in conjunction with the Charles Darwin Research Station and the Galápagos National Park Service, should aid in understanding the establishment and impact of these kinds of introduced predators. Studies of the ecology and population biology of the dogs can provide a basis for the development of effective methods for their long-term control on these islands and in other areas where similar problems exist.

History

The introduction of domestic dogs to the Galápagos followed soon after the original colonization of the Archipelago. In 1832, José Villamil, a native of Louisiana, was granted permission by

the Ecuadorian government to found a colony on the islands as compensation for his service in that country's war of liberation. He chose to settle on the island of Floreana (Charles), several kilometers inland from Black's Beach. Ten years later he left Floreana and founded a colony at Wreck Bay, on the island of San Cristóbal (Chatham). Since that early period, feral dogs have existed continuously on both islands (Melville, 1856; Salvin, 1876; Slevin, 1931, 1959; Thornton, 1971) and have only recently been exterminated by poisoning and shooting.

Wild dogs were first reported on the island of Isabela (Albemarle) in 1868 by

a visiting British researcher (Salvin, 1876). The first permanent settlement on Isabela was founded by Antonio Gil in 1897, and when the Stanford Hopkins Expedition visited the village in 1898, they noted large-scale destruction of tortoise eggs by wild dogs along the nearby coast. By 1906 almost 200 people lived in the highland settlement of Santo Tomás. In the same year, passengers on the schooner "Academy" observed wild dogs in the grasslands above Santo Tomás and along the coast several miles from the Villamil community (Slevin, 1931, 1959). By 1913 the increasing number of feral dogs was described as a "terrible plague" on the cattle populations in the highlands.

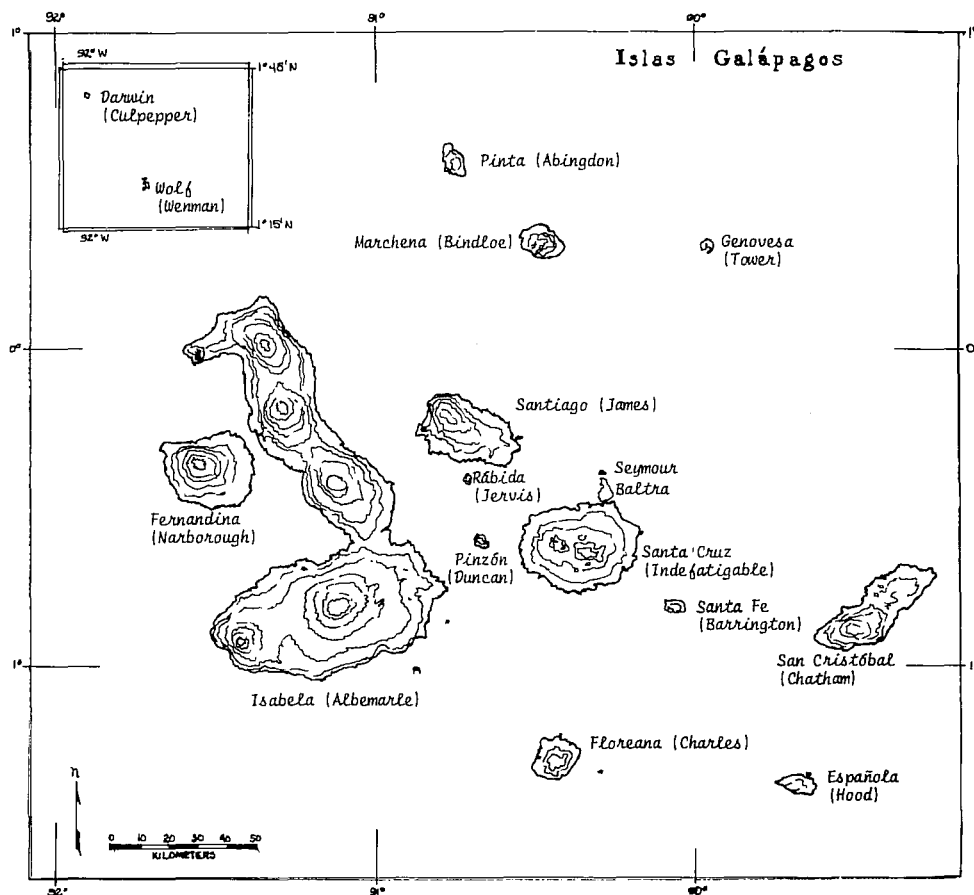


FIGURE 1 Map of the Galápagos Island. Historic English names are given parenthetically.

Wild dogs were first reported along the coast north of Sierra Negra in 1934 by a group of Americans studying marine iguanas in a small cove west of Elizabeth Bay (Robinson, 1936). Although it has been claimed that as many as 5,000 feral dogs may have inhabited southern Isabela in the past (Naveda, 1950), recent estimates indicate a total population of not more than 500 to 800 animals (Kruuk, 1979; Moore, 1981).

Within the last 100 years, there have been accounts of feral dogs on Santa Cruz as well, but little is known about the history of their introduction (Salvin, 1876; Heller, 1903; Beebe, 1923, 1924). Though their numbers are apparently not large (Naveda, 1950; Kruuk, 1979), their damage to island fauna has been severe (Anon., 1976).

Dogs of the Coast

At present, feral dogs occur along the coast of southern Isabela, from Elizabeth Bay on the Perry Isthmus to Punta Cristóbal. This portion of the island is characterized by extensive lava flows, which radiate from the numerous secondary cones that flank the major volcanoes of Sierra Negra and Cerro Azul (Fig. 2). These vast, basaltic lava fields support little animal life, and the dogs are confined to a narrow, 200-m strip of land along the coast, which also supports the many animals and birds that are associated with the marine environment. Some dogs also inhabit the Cartago Bay region on the eastern side of the isthmus, and the possibility of their continued northward migration toward Volcan Alcedo (on the northern part of the island) threatens resident populations of land iguanas (*Conolophus subcristatus*), giant tortoises (*Geochelone elephantopus*), and breeding colonies of flightless cormorants (*Nannopterum harrisi*) and blue-footed boobies (*Sula nebouxi*).

The dogs present a singular and surprisingly uniform appearance (Figs. 3 and 4). They are large canids, measuring 50 to 70 cm high at the shoulder and attaining a length of 100 cm from head to tail root, with conspicuously large ears. Most of the animals are short-haired, and white with brown or black spots. There may be a reason for this consistency in appearance: Homeotherms exposed to high daily temperatures can benefit by maintaining certain characteristics within the population that reduce the cost of temperature regulation. Traits such as short hair, light coat color, and large ears may aid the dogs in effectively dissipating excess heat. Alternatively, the dogs in this region might look alike on account of geographical isolation, which may have caused a reduction in phenotypic variation within the closed breeding group.

Placental scars in the uteri of 15 female dogs destroyed during the first months of an eradication campaign instituted by the Galápagos National Park Service indicate an average litter size of five young (S.D. = 0.89). If one assumes that approximately 400 dogs live along this coastline and that half of these are female, then, given a reproductive interval of 6 months for domestic canids, as many as 2,000 new individuals may be introduced into the population each year. This high influx of new animals, however, is probably counterbalanced by high natal and juvenile mortality, combined with a relatively short lifespan for adult dogs. In fact, preliminary age estimates reveal that most of the animals are young, few living past 5 years of age. Common infestation by *Dirofilaria immitis*, a nematode heartworm transmitted by the endemic *Aedes taeniorhynchus* mosquito, together with the general hardships that are part of life in this environment, may explain the absence of older dogs.

Analysis of 169 fecal samples and the contents of 12 stomachs from coastal dogs indicates a diet of marine iguana

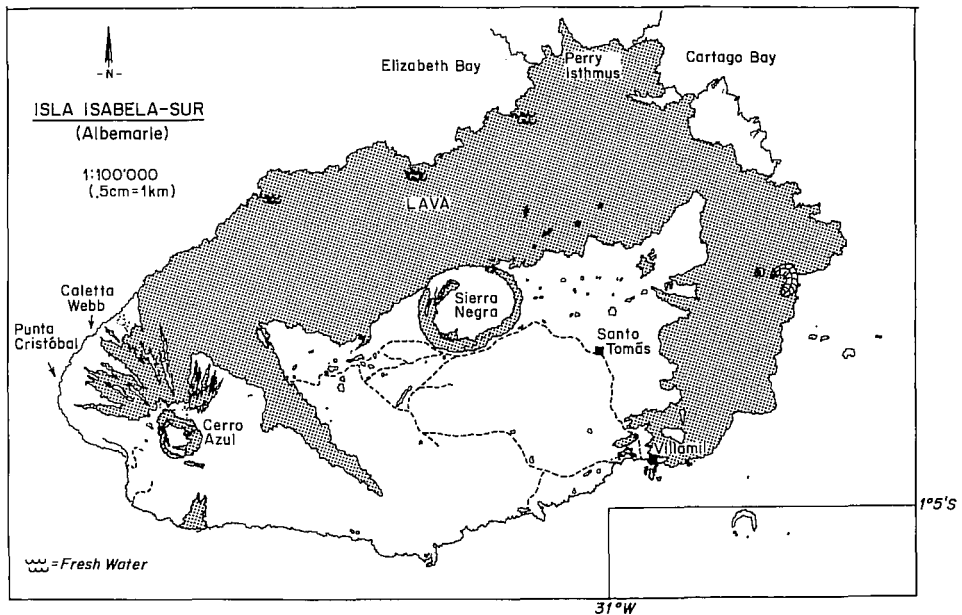


FIGURE 2 The southern portion of Isla Isabela, on which both an eradication and a coordinated field study program are in progress. Physical features and place names are mentioned in text.

(*Amblyrhynchus cristatus*) (35 percent), Galápagos penguin (*Spheniscus mendiculus*) (32 percent), juvenile sea lion (*Zalophus californicus*) and fur seal (*Arctocephalus australis*) (8 percent), Audubon shearwater (*Puffinus lherminieri*) (7 percent), pelican (*Pelicanus occidentalis*) and blue-footed booby (*Sula nebouxi*) (6 percent) and traces of dog, cat, and black rat (*Rattus rattus*) (2 percent). The predominance of small prey in the diet eliminates the need for large hunting packs—we have rarely observed groups of more than three individuals. Aggregations of up to 16 individuals have been seen on occasion though, usually near sources of fresh or brackish water. Although we have watched dogs apparently drinking seawater, it seems unlikely that they possess an excretory system efficient enough to salvage adequate amounts of fresh water. This drinking behavior may result from a deficiency in one or more minerals in the diet, but only further study of the dogs' physiology can answer this question with any degree of certainty.

A recent report on predation of marine iguanas by feral dogs (Kruuk and Snell, 1981) suggested that these predators annually consume 27 percent of the iguana population in the region of Caletta Webb alone (Fig. 5). This figure is based on the nutritive requirements of the dogs and their observed preference for larger iguanas. Two further sets of observations, the subsequent censusing of the iguana populations, which showed a predominance of small- and medium-sized individuals, and analysis of the prey remains left by the dogs and found in their feces, support Kruuk and Snell's original hypothesis. Ultimately, the removal of the larger, breeding members from the iguana populations will lead to a high mortality/production ratio and thus portend grave consequences for the iguanas on Isabela.

Galápagos penguins (*Spheniscus mendiculus*) have also become a preferred food item for the dogs in the past 2 years. The breeding range for this species is restricted to the northern coast of Isa-

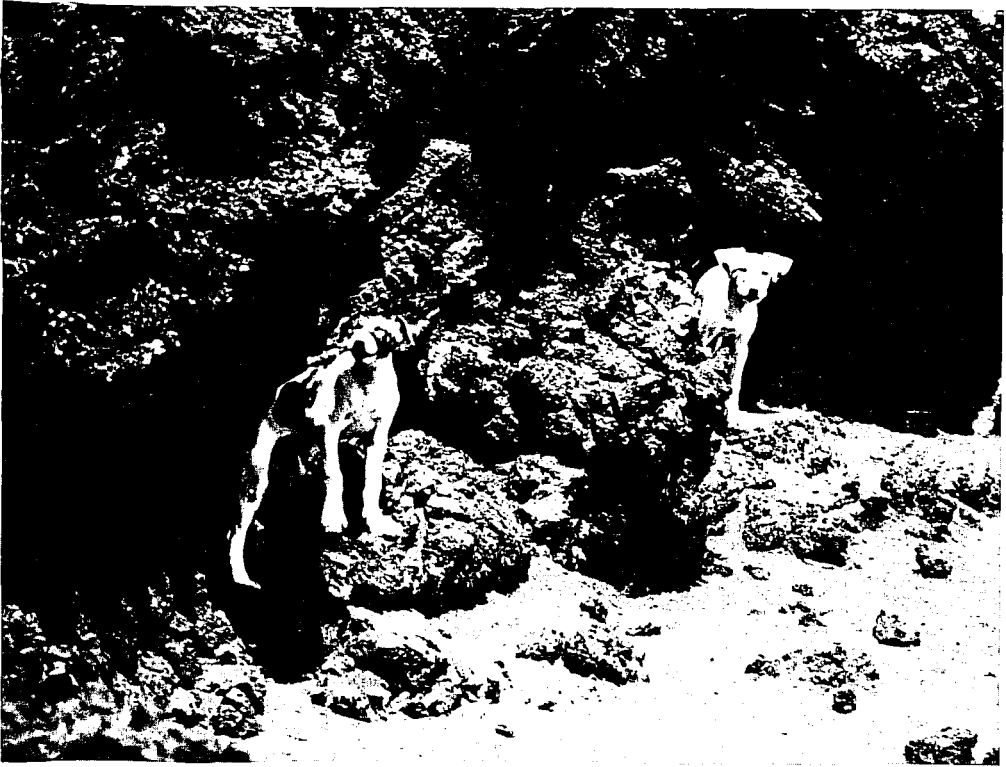


FIGURE 3 Pups on coast near Punta Cristóbal, Isla Isabela. Note refuges in lava recesses. (Photograph by Tui de R. Moore)

bela and the coast of Fernandina, where the cold waters of the Humboldt current flow through the Bolivar Strait (Houvenaghel, 1978). Penguin populations are extremely sensitive to intense predation pressure, and their continued existence in the Archipelago may therefore be threatened by this new dietary preference of the dogs.

Dogs of Cerro Azul

Cerro Azul, the Galápagos' second tallest volcano (1689 m), is situated on the western side of southern Isabela. The prevailing southeasterly winds and fog coming in from the sea are forced rapidly upwards and are thereby quickly cooled. More rain falls on the lower elevations of the volcano's southern slope than in any other southerly exposed coastal area on the islands. A mesophytic, deciduous, steppe forest predominates along the coast which slowly opens up until, at an alti-

tude of about 250 m, it is replaced by open meadows or "pampas." Above 1,000 m the vegetation becomes xerophytic, becoming desert-like on the caldera rim (Hamann, 1981). Between 100 and 200 feral dogs live on the open pampas, which cover all but the north and northwest slopes.

The majority of the Cerro Azul dogs look quite like the coastal animals. Most are short-haired and white with brown or black spots, but longer-haired and darker-colored individuals are more common than along the coast (Fig. 6). Also, few of the highland dogs possess the noticeably large ears, perhaps because selection for heat-dissipating characters may not be a strong factor in a region with a considerably cooler climate.

Counts of placental scars in the uteri of six females revealed an average litter size of six (S.D. = 0.75). Adult dogs appear to have a longer lifespan than those of the coastal region, some reaching



FIGURE 4 Juvenile female from the "coastal" population at Caletta Webb. (Photograph by Tui de R. Moore)

an age of 8 to 9 years. One reason for the more common occurrence of older animals may be that the *Aedes taeniorhynchus* mosquito is less abundant at higher altitudes, explaining why far fewer cases of *D. immitis* infestation were discovered within this population.

Cerro Azul also supports approximately 2,000 feral cattle, and these serve as a major food source for the dogs (Fig. 7), comprising 50 percent of their diet, the remainder of which includes coleopterans (14 percent), orthopterans (11 percent), grasses and ferns (8 percent), dog (6 percent), and traces of cat, ground finch (*Geospiza fuliginosa*), and black rat (8 percent). Though the cattle appear to be the main staple of the dogs' diet, surprisingly few successful kills have actually been witnessed. Harassment seems to be

the usual method of attack; this "strategy" requires a smaller expenditure of energy and a reduced risk of injury to the attacker. In this kind of attack, sufficient damage may be sustained by the prey such that it later dies of its wounds. In light of the large number of cattle in the area, this approach would ensure an adequate food supply and allow the dogs to obtain most of their nourishment by scavenging the remains of their dead victims. Another explanation for the same strategy is possible, and involves modifications in the behavior and/or morphology of canids that have been subjected to the process of domestication. Domestication refers to changes in genetic characteristics by selective breeding practices applied to a given population of animals. Dogs, which have

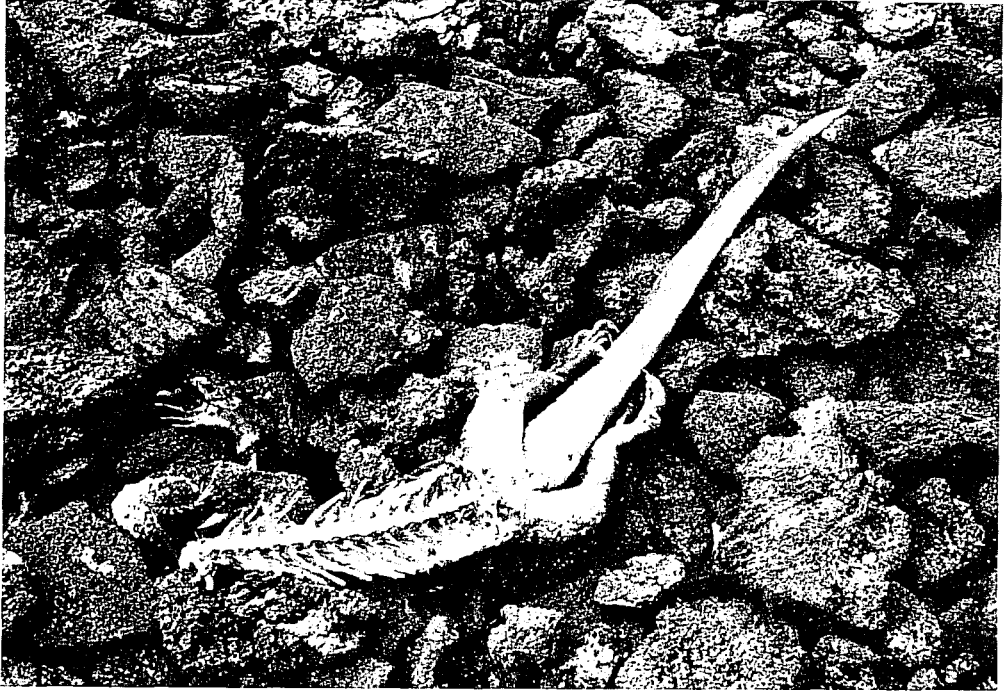


FIGURE 5 Marine iguana freshly killed and partially eaten by dogs at Punta Cristóbal, Isla Isabela. (Photograph by Tui de R. Moore)



FIGURE 6 Adult male dog from the "highland" population of Cerro Azul, Isla Isabela. (Photograph by Tui de R. Moore)

a history of almost 16,000 years of domestication (Brisbin, 1974, 1976), display morphological and behavioral traits that actually reduce their predatory abilities but increase their effectiveness as scavengers. Changes in tooth structure, for example, have resulted in modified molars in domestic canids—from the sharp-cusped, carnassial teeth used for ripping and tearing by their wild ancestors, to a more smooth-cusped form, so that they have come to resemble teeth used for grinding by more herbivorous species. The inhibition of a killing bite, observed in certain domestic breeds (Fox, 1978), may also influence the feeding strategy of the Cerro Azul dogs.



FIGURE 7 Feral (criollo or original Spanish) cattle, the chief sustenance of the "highland" dog population on Cerro Azul. (Photograph by Tui de R. Moore)

The hunting of large prey could explain the larger observed group sizes among the highland populations ($\bar{X} = 4$). Dogs from larger packs were commonly seen to break off into smaller groups for a time, only to later rejoin the same or another pack. While some domestic breeds exhibit a modification of behavior that prevents the establishment and maintenance of stable social relationships in closed-group situations, other breeds demonstrate a high tolerance to additions or removals from the pack (Fox, 1971). The fluid social structure observed in Cerro Azul populations could reflect similar domestic modifications of ancestral behavior patterns.

In the Cerro Azul highlands, then, we have a unique situation: a feral predator regulating the numbers of introduced herbivores. An even more critical aspect of this situation is that, because of their potential for moving down to the coast and thus endangering endemic island fau-

na, these dogs are being included in the eradication program of the National Park Service. The unfortunate result of this policy will be an unchecked growth of the cattle population, and 2,000 large herbivores can be very destructive to the flora of the pampas. These cattle have already transformed large areas into virtual shortgrass deserts by cropping a large portion of the native vegetation and endangering much of the remainder by destroying the natural watershed of the lower slopes.

Sierra Negra and the Origins of Feral Populations

Extending southward, forming a col that separates the volcanoes of Cerro Azul and Sierra Negra, is a narrow band of lava known as "El Quemado," or "the Burnt Forest" (see Fig. 2). It is composed of broken slabs of volcanic ejecta, with projecting knobs and ridges and abra-

sive, cutting edges that form huge barricades, making travel over them slow, painful, and dangerous. Also, the volcanic flow here occurred so recently that very little vegetation has colonized the hardened lava, and soil is practically nonexistent. Constant exposure to the hot, equatorial sun often drives temperatures to 35°C (95°F) and, though it is not more than 2.5 km wide at its narrowest point of crossing, the rugged topography and forbidding climate of the flow act as an effective barrier to the unchecked movement of terrestrial animal populations on Isabela. To the east lies the large southern slope of Sierra Negra, and the small settlements of Santo Tomás and Villamil lie in the shadow of the volcano. It is the domestic dogs associated with these communities that most likely serve as the origin of the feral dog populations on the island.

Thirty percent of the 70 families in Villamil own dogs. The sex and age distributions of this dog population are presented in Table 1. The highly skewed sex ratio in favor of male animals (3:1) is the result of the selection by local residents for superior performance as working and hunting animals. A small, but constant number of female dogs is maintained to compensate for a high mortality rate by continued production of a limited number of new individuals. Even though most of the dogs in this village are provided food by their owners, it is not uncommon to see animals combing the beachfront, taking an occasional lava lizard (*Tropidurus albemarlensis*), rat, or Sally Lightfoot crab (*Grapsus grapsus*) to supplement their diet.

In the smaller, more dispersed, highland district of Santo Tomás, 90 percent of the 42 resident families own dogs; un-

TABLE 1 Sex and Age Distributions of Domestic Dogs on Isabela

Island Santo Tomas	No. in age group		Total
	Male	Female	
0-6 months	20	10	30
6-12 months	17	8	25
1-2 years	11	7	18
2-3 years	14	7	21
3-4 years	10	4	14
4-5 years	13	5	18
5-6 years	3	0	3
6-7 years	0	0	0
over 7 years	2	0	2

Villamil	No. in age group		Total
	Male	Female	
0-6 months	7	3	10
6-12 months	8	3	11
1-2 years	5	1	6
2-3 years	3	1	4
3-4 years	0	1	1
4-5 years	2	1	3
5-6 years	2	0	2
6-7 years	0	0	0
over 7 years	3	1	4

like Villamil, where more than two dogs per household is rare, homes in this agricultural community support an average of four animals. A 2:1 sex ratio, favoring males, is apparent in this population as well, and females are similarly valued only for their reproductive contribution. Few of these village dogs live longer than 5 years. Juvenile mortality is high, with dog owners often controlling the size and composition of surviving litters. By choosing the fittest males to maintain effective hunting packs and the fittest females for breeding, these villagers are practicing a form of selection that illustrates man's role as a domesticator, determining the future genetic composition of the dog population and, by selection for males, reducing total population size.

The unavailability of firearms to the inhabitants of Santo Tomás necessitates the use of dogs as an aid in hunting game. It is not unusual for a dog to be injured during a hunt; since it is then of no further use to its owner, the animal is normally abandoned. Also, some dogs stray from the hunting party and, if they are unable to find their way home, they become forced to fend for themselves. It is these free-ranging individuals that occupy an intermediate stage between the truly domestic and truly feral populations.

It is important to distinguish clearly between truly feral and free-ranging dogs. A feral population is produced when domestic animals escape to a habitat that is similar to that of their wild ancestors and thereby come under the influence of natural selection. This process requires many generations for complete removal of the constraints imposed by artificial selection, but the process is rarely as clear-cut as one might suppose. If evolution is a continuous process which moves almost imperceptibly from one stage to another, consideration of some intermediate construct to

aid in developing a conceptual framework for understanding this process is necessary. Brisbin (1977) labels animals in this free-ranging stage as "pariahs" and defines such populations in terms of those selective forces that act to determine their future genetic composition. The genetic composition in pariah populations is determined by breeding patterns that are influenced by, but not controlled by, the domesticator. This patterning is apparently the case among dogs lost or abandoned during hunting forays from Santo Tomás. Animals leading a pariah-type lifestyle assume a cautious, yet not quite fearful attitude toward man. A breakdown in the regimentation of social order may occur territorially; intragroup aggression decreases and there is a marked tendency to rely on scavenging more than on true predation to obtain food (Brisbin, 1977). By studying the differences in these behavioral patterns, it may be possible to gauge a given population's current position along the continuum of evolution from the domestic to the feral condition. Observed behavioral patterns may in turn provide insight into the historical pattern of dispersal of dogs throughout Isabela.

The dogs of Sierra Negra provide an example of differences in feeding habits between free-ranging (pariah) and truly feral canids. Most of their food is obtained by scavenging the remains of animals caught in snares placed by the hunting parties from Santo Tomás. These hunters may set up to 20 traps along any given animal trail, then return 1 to 2 weeks later to collect their catch. Many of the animals caught in these traps during the first days after they are set are no longer salvageable by the time that the hunters return, and they are therefore abandoned. Consequently, there is always a supply of surplus meat to support scavenging dogs. Analysis of dog feces in the area shows that 70 percent of their diet consists of feral cattle, pigs, and burros, and signs of dog activity are

plentiful around most trap-killed carcasses. These dogs, therefore, are still somewhat dependent on man for a constant food supply and, because the majority of them are either recently derived from village populations or may associate with village dogs in a breeding or other social context, their behavior can be characterized as that of a free-ranging or pariah population.

In contrast, dogs that have moved westward across the El Quemado lava flow and have come to inhabit the slopes of Cerro Azul practice a direct but rudimentary form of predation on the feral cattle populations of the area. They too ultimately rely on a form of scavenging to obtain their food. The difference between this strategy and that of the pariah animals resides in the fact that these dogs are themselves providing the carcasses, thereby precluding any dependence on humans for food. The likelihood of contact with village or pariah populations is also reduced by the presence of a significant geographical barrier, which further removes the dogs from the indirect influence of man.

The dogs of Isabela's northern coast are even more isolated from populations on Sierra Negra and Santo Tomás by the large and formidable lava fields that bisect the island on an east-west axis. These animals derive their sustenance by active predation on the endemic fauna of the coastal region and, by virtue of this behavior and their breeding patterns, may truly be regarded as feral.

The current investigation into the relative amount of phenotypic variation within these respective populations may further elucidate aspects of the discussion presented above and reveal a decrease in such variation with increasing distance from the source (or domestic) population. By this type of analysis, it may become possible to trace the history of feral dogs on Isabela and subsequently to apply similar techniques to the study

of these problems on other islands.

Control

The Galápagos National Park Service, in cooperation with the Charles Darwin Research Station and the Frankfurt Zoological Society, has recently embarked on a campaign to eradicate populations of feral dogs on the islands of Santa Cruz and Isabela. The most effective method employed to date involves the use of sodium monofluoroacetate (Compound 1080). This substance was originally developed for controlling rodent populations, but it has been found to be differentially toxic to canids at doses as low as 0.05 mg/kg. And, while 1080 is highly toxic, it is undetectable in flesh baits. The lag period that follows ingestion before manifest effects appear minimizes the potential for bait shyness and association. The suggested use of Compound 1080 is controversial and in many countries is greatly restricted. The risk to nontarget species must be considered as well when any pesticide is used, and a detailed knowledge of the target animal's behavior and ecology is a prerequisite to safe and effective application of the substance (Rudd, 1964).

On the islands, poison baits, obtained by killing a small number of feral cattle, are placed at various locations within the dogs' known range. By exploiting the domestic trait of predilection for scavenging, a surprising degree of success in controlling populations has been achieved. Baits are well hidden to prevent removal and ingestion by the Galápagos hawks and short-eared owls that also inhabit the region. These avian predators, however, are 200 times more resistant to the poison than the dogs: a dosage of approximately 10 mg/kg is necessary before the compound becomes lethal. Since a single bait (1 kg) only contains enough poison to ensure the desired effect on canids (0.1 mg/kg), hawks and owls would

have to consume at least 100 such baits to incur any significant toxic effects. On the other hand, cats (0.2 mg/kg) and rats (2.1 to 3.1 mg/kg) are more susceptible to the substance, but their eradication would be a desirable, if unintended, consequence.

Any effective control program must consider all phases of the target animal's ecology, and although removing feral dog populations is one important aspect of the current effort, action must also be taken to limit the future introduction, establishment, and growth of such populations. In the case of dogs on Isabela, steps must be taken to curb reproduction in domestic populations and prevent their dispersal from areas of human habitation. In one sense, the residents of the island's two settlements already practice a form of reproductive control with their dogs by regulating the number and sex of the surviving young. However, the huge surplus of male animals all but guarantees the impregnation of the fewer females and thus maintains a steady production of new individuals. Therefore, a program directed at reducing the number of potent males in the population could effectively decrease the rate of reproduction to manageable levels. Surgical vasectomy of male dogs is one technique of contraception which avoids the problem of sexually interested males and unreceptive females that is associated with ovariectomy and ovariohysterectomy, and is preferable to orchidectomy (castration), which ultimately results in the diminution of male secondary sexual characteristics (Hopkins *et al.*, 1976). The latter method would be particularly undesirable in instances where males are valued for their aggressiveness. Surgical procedures, however, are time-consuming and expensive, and would be impractical in the present situation. But the recent development of a chemical vasectomizing agent offers considerable potential for providing a fast, low-cost,

safe, and effective means of reducing fertility in domestic dog populations (Pineda, 1978). This compound (chlorhexidine digluconate) has been extensively studied for its safety and effectiveness for various applications as an antiseptic in both humans and animals. In the epididymis of the male testis, it acts as a sclerosing agent, which causes a proliferation of scar tissue in the epididymal tissue and eventual blockage of sperm passage through the tubule (Pineda *et al.*, 1977). There appear to be no qualitative changes in the seminiferous tubules or interstitial tissue after treatment, and hormone production is not impaired. Transient scrotal swelling may occur, but testicular palpation of test animals has shown no accompanying pain. This method of sterilization of large numbers of male dogs may reduce the number of pregnant females sufficiently to restrict total population growth. Moreover, if dominant males are rendered sterile without affecting their social dominance or aggressiveness, these dominants might prevent matings by their intact subordinates.

Future Research

Current control procedures have drastically reduced the size of feral dog populations along southern Isabela's northern coast and in the highlands of Cerro Azul and Sierra Negra. Where just 1 year ago an estimated 300 to 500 dogs roamed the coastal region, threatening the survival of marine iguanas, penguins, sea lions, and many species of seabirds, today less than 100 dogs remain. Efforts are also underway to remove the last individuals from the slopes of Cerro Azul. The effective reduction of these populations by the eradication program makes further studies at this time both impractical and difficult. The population sizes of introduced and endemic prey species are, however, being closely monitored to assess the impact of the remaining

feral dogs, and research is continuing into the relative amounts of phenotypic variation within the affected feral populations, through studies on the skull morphology and physical characteristics of the animals destroyed to date. Further, domestic dogs, endemic pinnipeds, and humans are being used as the subjects of an investigation into the epizootiology of canine heartworm. Radio tracking studies on these domestic animals and on the free-ranging dogs of Sierra Negra can be expected to produce information regarding their movements, activity patterns, social organization, and predatory habits. The testing of alternative contraceptive methods, including the use of the chemical sterilant chlorhexidine digluconate, is also planned for the coming year.

The study of feral dogs in the Galápagos islands presents opportunities for both basic and applied research and assumes particular relevance at a time when we are only beginning to understand and to compare general ecological patterns on earth. A well-planned, coordinated effort to control sympatric populations of feral animals in the Galápagos is badly needed. Dogs, cats, rats, pigs, burros, goats, cattle and, recently, guinea pigs and poultry have been introduced to the Archipelago and now present serious problems on all but a few of the Islands. The removal of only one of these species can actually benefit the survival and success of another by reducing competition for food or, as in the case of the dogs and cattle of Cerro Azul, eliminating the predation by one species on another. Understanding the complex ecological relationships among introduced populations and between them and the endemic fauna constitutes the first step toward developing sound and effective methods of control (Hutchins *et al.*, 1982). By studying these problems in relatively simple ecosystems like islands, we may be able to gain some insight into the general issue of the complex interac-

tions between humans and their modified environments.

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