

Mammals in Hawai'i

A Synopsis and Notational Bibliography

Second Edition

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lation appears to be an apt subject for study (see McClusky, Olivier, and others, 1974; and Edmonds, Noland, and others, 1976).

Further reports of interest and applicable to rabbit studies in Hawai'i are those of Gibb, Ward, and Ward (1978), Edmonds, Backholer, and Shepherd (1981), Jaksić and Soriguer (1981), and Skira, Brothers, and Copson (1982).

Rattus rattus. Roof rat.

ORIGINAL DESCRIPTION: *Mus rattus* Linnaeus, Systema Naturae, Ed. X, 1:61. 1758.

TYPE LOCALITY: Sweden.

NATIVE RANGE: Greater part of India, Ceylon, Himalayan foothills, Burma, southern China, Indo-China, Malay States, Sumatra, Java, Borneo, Celebes, Philippine Islands. Has spread with commerce to all tropical and temperate regions of the world; particularly well established in port and coastal areas (based on Ellerman and Morrison-Scott, 1951, p. 581).

RANGE IN HAWAII: Found on each of the eight main islands, also on Ford, Kāohikaipu, Mokuolo'e, Mokolii, and Moku'auia (all near O'ahu), and Sand and Eastern islands at Midway; may be the rat of Lehua, and possibly occurs on other small islands and islets.

The roof rat in Hawai'i is derived from European-type stocks, and these are referable to the subspecies *Rattus rattus rattus* (Johnson, pp. 26-27, in: Storer, 1962), which has been dispersed by human agency in a westerly direction to the Americas and into the Pacific. This form is distinct from the many known in Southeast Asia, some of which have invaded the Pacific in an easterly dispersal. A prominent characteristic of *R. r. rattus* is a series of three well-established color phenotypes, and although their genetic properties were described nearly 60 years ago (Feldman, 1926), the literature has been burdened with writings that treat the color variants themselves, or groups of them, as separate subspecies. The impropriety of this procedure is emphasized in some reports by the lumping of the original white-bellied wild-type rats ("*R. r. frugivorous*") with the gray-bellied mutant phenotype ("*R. r. alexandrinus*"), under this latter name. Further, all black individuals are called "*R. r. rattus*," whereas such rats consist of two phenotypically indistinguishable forms of quite different genetic origin. Tomich and Kami (1966) have reviewed the problem at length and have shown that Hawaiian populations are typical in having the expected hereditary pattern for coat color (see Figs. 9 and 10). Tomich (1968) discusses the distribution of the several color types on Hawai'i Island.

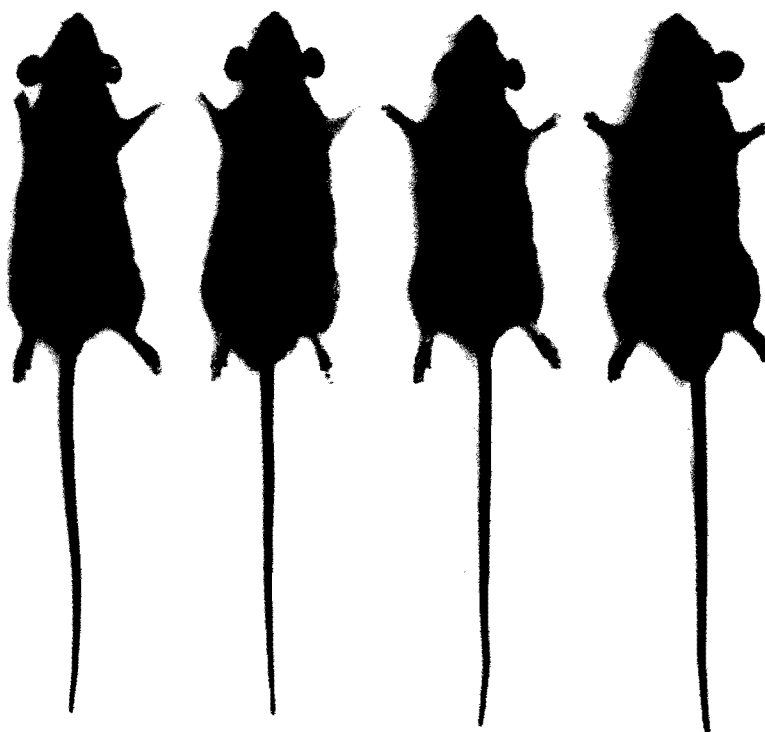


FIGURE 9.—Genetic color types of the roof rat (*Rattus rattus*), dorsal aspect. The outer specimens are mutants for identical black body color, but color in one is controlled by a dominant gene, while color in the other is expressed by a recessive gene pair. The inner specimens are both of the wild-type brown coloration. (Author's photo.)

Rattus rattus in Hawai'i is adapted especially to wooded gulches, sugar cane fields, and dry, wet, or even extremely wet forests. It retains, however, a classical commensal relationship with man, and frequents ornamental vegetation, stone walls, buildings, and other structures. But it obviously does not depend upon man for survival.

This species is locally common at lower and middle elevations, and is found sparsely distributed at higher altitudes, for example, about ranch cabins on cattle range in an open forest of *māmane* (*Sophora chrysophylla*) at Pu'u Kihe, 7,750 feet, on Mauna Kea. Extreme station of record is 9,800 feet, in the attic of the Crater Observatory (a heated building) at Haleakala National Park, Maui, where this rat occurs sporadically. Four specimens were obtained there for identification in July 1962, from Robert J. Badarocco, courtesy of the National Park Service.

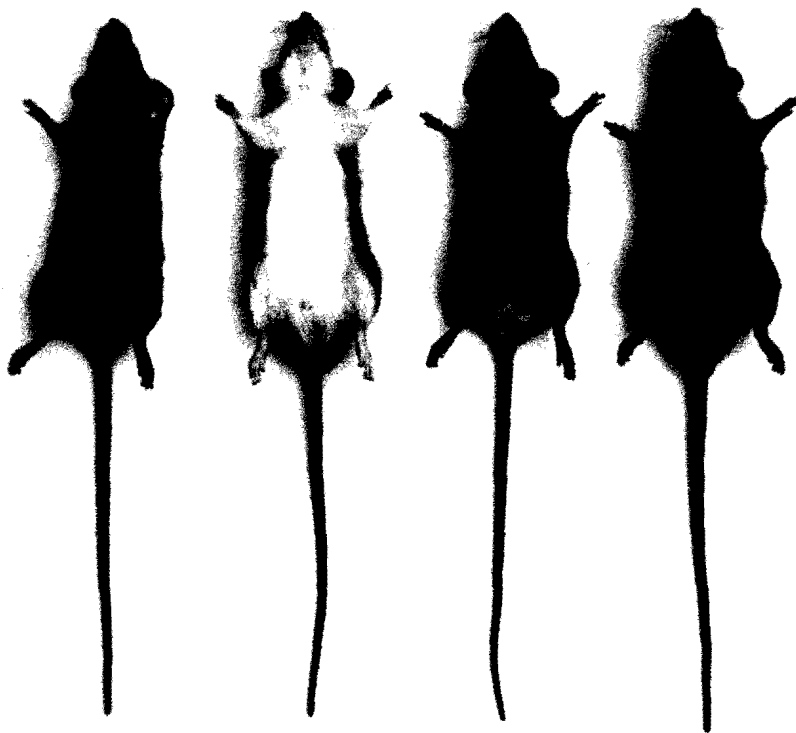


FIGURE 10.—Ventral aspect of rats in Figure 9. The two black rats have identical slate-gray belly color. The white-bellied rat is of the original wild type, but the specimen to its right expresses a mutation for gray that is similar in appearance to that in the black rats. (Author's photo.)

The roof rat has been noted specifically as a predator on native birds. The most striking and unfortunate example is that which resulted in extinction of the Laysan rail (*Porzanula palmeri*) in its last refuge at Midway Islands, and the extirpation of a population of the Laysan finch (*Telespyza cantans*) from this same area (Munro, 1945; P. H. Baldwin, 1945b). Atsatt (in: Munro, 1945, p. 50) identifies the rat positively as *Rattus rattus* when he states that, at both Sand and Eastern islands, "rats are *Rattus rattus alexandrinus*, (the gray or roof rat, the predominant variety, 80% of the whole), and *Rattus rattus rattus* (the black rat)." P. H. Baldwin (1945b, p. 348) reports that in its initial abundance soon after the introduction in 1944, population density on Eastern Island rose to 100 rats per acre (see also Anon., 1946b).

Richardson (1949, p. 228) found the roof rat on Moloka'i, and (1963) what may have been this species on Lehua, in critically important habitats of native

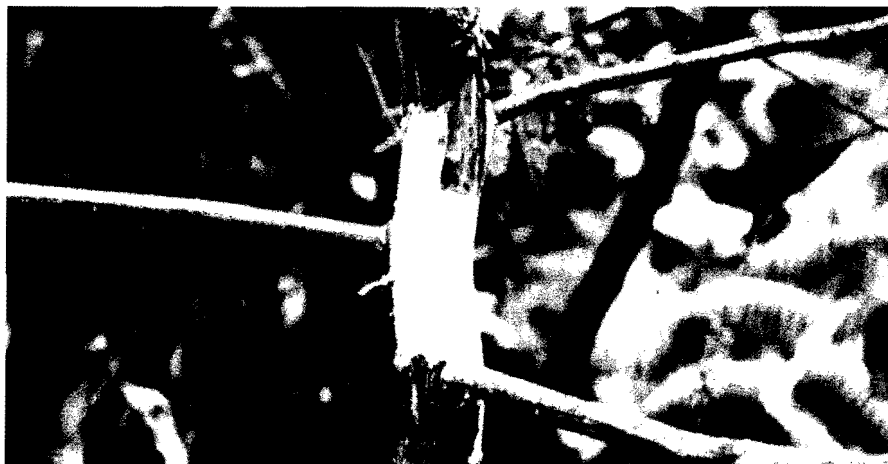


FIGURE 11.—Damage to young *koa* trees by the roof rat. Stems often are girdled, crippling the tree. (Paul Scowcroft photo.)

birds. Schwartz and Schwartz (1950a) report its predation on nestlings of the zebra dove (*Geopelia striata*) on Hawai'i. Korte (1963), Whitesell (1964), and Scowcroft and Sakai (1984) point out that the roof rat may be detrimental to regrowth of native *koa* by stripping bark from saplings.

The classical view of the roof rat as an invader of native ecosystems in the Pacific shortly after the voyages of Captain Cook has been seriously questioned, with both New Zealand and Hawai'i as prominent examples (Atkinson, 1972, 1977). See also Ralph, 1978. In reality, all evidence as derived from the historic record and the sequential decline of native bird species indicate that the period 1870 to 1890 may be a more likely era of final invasion. That the rat has entered even the most remote forests of Hawai'i, where it is the prominent rodent species, has been further documented in recent years (Conant, 1972; Tomich, 1981b).

Single species study and observation of the roof rat has produced an abundance of reference material since 1969. For Hawai'i, see Buxbaum (1973), van Riper (1974), Baker and Allen (1978), and Teraoka, Nagata, and Corn (1981). Additional reports, especially from New Zealand, are as follows: Best (1969, 1973), Daniel (1972), and Michener (1976).

***Rattus norvegicus*. Norway rat.**

ORIGINAL DESCRIPTION: *Mus norvegicus* Berkenhout, Outlines of the Natural History of Great Britain and Ireland 1:5. 1769.

TYPE LOCALITY: England.

NATIVE RANGE: Palearctic Asia, where it is common in the cooler countries, throughout China, Siberia; has spread with commerce and become cosmopolitan, but the metropolis of the species is in the north temperate zone rather than in the tropics (in part from Ellerman and Morrison-Scott, 1951, p. 588).

RANGE IN HAWAII: Recorded from Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i. May occur on the few smaller islands where permanent human settlements are present; known also from Ford Island in Pearl Harbor.

The Norway rat in Hawai'i is represented by stocks of probable European and American origin. These are remarkably uniform in basic characteristics wherever they occur, and are generally referable to *Rattus norvegicus norvegicus* (Johnson, p. 31, in: Storer, 1962). This rat is best adapted to city, village, and farm environments where foods from domestic or agricultural sources are plentiful. Such nutritional materials may be fundamentally essential, whereas mildness of climate is only secondarily necessary. Schiller (1956) reports survival of Norway rats in a severely cold climate under special conditions of food abundance.

In the mild Hawaiian climate this rat is sometimes locally common in and about lowland sugar cane fields, but is more likely to be absent from them altogether. It occupies also middle elevation planted forests, although it is the least numerous of the rats, and does not inhabit extensively the native forests or wide expanses of grassland. Many field habitats were abandoned in the two decades before 1970, and in Hāmākua District, on Hawai'i, for example, this rat is rarely found except in village and farmyard environments. Extreme known elevation is 5,800 feet, at Halepiula on Mauna Kea, where the rat is associated with water catchment and storage facilities in remnant forest range land. Soils unsuitable for burrowing, the absence of man-made structures, and scarcity of food and easily accessible water seem to restrict *Rattus norvegicus* from many wild habitats.

No rats of this species were trapped in a two-year period on a transect in wet to dry habitats from 3,000 to 10,000 feet elevation in Hawaii Volcanoes National Park; and in neighboring rain forest of Kīlauea Forest Reserve at 5,300 feet, a grid of traps on a 200-acre study area captured only four in the same period (Tomich, 1981a, 1981b). In another study at 20 to 120 feet elevation in Waipi'o Valley (Tomich, 1979), during a similarly intensive project in riparian woodland, just four *Rattus norvegicus* were trapped in nearly five years of operation.

Examples of reports outside Hawai'i and pertinent to the study of this rat are Calhoun (1962), Barnett (1963), Brooks and Barnes (1972), Yabe (1979a, 1979b), Pye and Bonner (1980), and Lattanzio and Chapman (1980).

Rattus exulans. Polynesian rat.

ORIGINAL DESCRIPTION: *Mus exulans* Peale, U. S. Exploring Expedition 8 (Mammalia and Ornithology):47. 1848.

TYPE LOCALITY: Tahiti, Society Islands.

NATIVE RANGE: Southeast Asia, from whence it has spread with man to the East Indies, Philippines, New Guinea, and to the Pacific islands, reaching in its farthest distribution New Zealand, Easter Island, and Hawai'i. Occurs extensively with *Rattus rattus* in these regions, but has not ventured deeply into the Asian continent (based on Ellerman and Morrison-Scott, 1951, p. 590).

RANGE IN HAWAII: Found on Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, Kaho'olawe, and Hawai'i. May occur on Ni'ihau, but is not specifically reported from there. Inhabits also Kure Atoll (at the northwestern end of the chain); Popo'i'a and Mokumanu (near O'ahu), and Ka'ula (off Ni'ihau).

Clapp and Wirtz (1975, p. 151) mention reports of rodents on Lisianski, which may have included *Rattus exulans*, but no rodents are presently on the island. Transect studies to 10,000 feet in Hawaii Volcanoes National Park (Tomich, 1965d, 1981a) place *R. exulans* at a maximum elevation of 4,900 feet on Mauna Loa, where a single specimen was caught in systematic trapping over a period of two years. King (1971) caught two rats assignable to *R. exulans* on the rim of the Haleakalā Crater, on Maui, among nesting petrels at 9,400 and 9,700 feet elevation, but did not retain the specimens from this maximum elevation range. Simons (1983) reports an additional six *R. exulans* in the same petrel colony during work conducted in 1979–1981. Again, museum specimens apparently were not retained, but it does seem assured that the Polynesian rat exists, at least sparingly, at this unusually high altitude.

Rattus exulans in Hawai'i is characteristically a lowland rodent, and this may be in part a result of its tropical and subtropical origins. However, its successful colonization of Green Island at Kure Atoll (28° 25' north), and Stewart Island, New Zealand (47° south), which is its southernmost station (Watson, 1956), suggests a reasonable adaptation to cooler climates. Hawaiian populations are noncommensal in the sense that they do not often occupy human dwellings, but flourish best on agricultural lands. This rat becomes most numerous in sugar cane fields and abandoned pineapple fields, but does well in adjacent wooded or grassy gulch and waste areas. It is usually uncommon in native or planted forests, and is often absent from them at elevations above 2,500 feet. Occurrence is rare in wide expanses of grassland. Only one has been caught in repeated trapping at Makahālau, at 3,800 feet on the Waimea Plain of Hawai'i.

The Polynesian rat is presumed to have come to Hawai'i with early colonizers from the central Pacific. Because it was not used for food in Hawai'i

as it was in New Zealand (Watson, 1956, p. 560), it would seem that the rat came as an immigrant rather than as an introduced species. However, the ancient Hawaiians did use miniature bows and arrows for sport hunting of the Polynesian rat (Stokes, 1917, p. 270; Malo, 1951, p. 233; Buck, 1957, p. 376) and may have purposely brought it in this connection.

The islands have been occupied from possibly as early as the second century (Suggs, 1960). It would appear that the rat could have been in Hawai'i for 1,400 years or longer (Kirch, 1982). Rats are seldom recorded in the early literature of Hawai'i, although one was known from Cook's time, and is presumed to be *Rattus exulans*. The documentation is quite clear, for Cook (1785, Vol. 2, p. 228) said in describing the fauna of Kaua'i, where he made his first landing after cruising up from more southerly waters, "There were . . . some rats, resembling those seen at every island at which we had yet touched."

The Polynesian rat was thought to be rare in Hawai'i early in this century, if not extinct, and R. C. L. Perkins (1903, p. 466) assumed that it had been driven out by other rats. The first museum materials were collected only in 1913-1915 (Stone, 1917). Stone compared these with Peale's *Mus exulans* from Tahiti and *Mus vitiensis* from Fiji, and concluded that it was appropriate to erect the new species, *Rattus hawaiiensis*, to encompass the Hawaiian population. However, as early as 1897, Waite, according to Stone (1917, p. 259), had suggested that populations from the various Polynesian islands should belong to Peale's species (= *Rattus exulans*). G. S. Miller (1924) was of a similar opinion, but Tate (1935) chose to recognize several species groups. Ellerman (1947) examined specimens from most of the range of this rat, on islands and on the Asian mainland as well, and declared in support of Waite and Miller that all populations should be referred to *R. exulans*. Ellerman (1947) studied and listed a total of 12 subspecies, including (p. 64) *Rattus exulans hawaiiensis*, and was first to use this combination.

The common name Polynesian rat is fitting for *Rattus exulans* and is derived from the broad association of this rat with Polynesian cultures. The more inclusive term "Pacific Island rat" has also been used, but local populations have been called, for example, according to Hossack (1907) the "little Burmese rat" (in Southeast Asia), "*kiore*" (in New Zealand), which is equivalent to the Hawaiian '*iole*, and "Hawaiian rat" (in Hawai'i).

Questions still exist concerning degrees of relationship among the far-flung populations of the Polynesian rat, whether within a single archipelago or between widely separated islands. Marples (1955) discusses a segment of this problem, and Uchida (1964) reports a probable extension of the known range, to the southern Ryukyu Islands. However, on a visit to Hawai'i in July 1984, Dr. Tatsuo Yabe of Yokohama relayed the information (pers. comm.) that on close scrutiny the Uchida specimens, collected on Iriomote-jima, all

correspond to *Rattus rattus*, and that no authenticated records of *R. exulans* are known from the Ryukyu Islands.

An item of interest has been the supposedly large changes in population density, and decrease in previously known range in Hawai'i. Stokes (1917) hoped for discovery of colonies additional to that on Popoia, and Illingworth (1931) pointed out some 15 years later that goodly numbers of the rat did in fact live on parts of O'ahu. Svihla (1936) recorded *Rattus exulans* to be of probable general distribution in Hawai'i. Whether this rat suffered a great decline during the establishment and spread of later arriving species is not known. Supposition, rather than good observational evidence, seems to have been predominant during this period, and no one really knows what happened. A well-documented parallel exists in New Zealand where *Rattus exulans maorium* was known to be abundant over most of the country in early times (Best, 1898; Marples, 1954). It is now common only on the peripheral small islands, and may be absent altogether from North Island. Immigration and spread of *R. rattus* and *R. norvegicus* are implicated in this radical restriction of range (Watson, 1956).

If *Rattus exulans* in Hawai'i yielded to other rodent invaders, ecological readjustments have been made and a resurgence has taken place, because this rat is frequently the most abundant of any in lowland populations, for example, on Hawai'i (Tomich, 1961). Spencer (1938, p. 26) states that it comprises nearly 75 percent of Maui rats. In popularizing Stokes' report (1917) on this rat, Gill (1929) proposed that *R. exulans* is poor at gnawing. The fact remains that it is this species that often does most of the damage to standing sugar cane. At Kure Atoll the population was extremely dense in 1923 at the time of the Tanager Expedition, for Gregory (1924, p. 23) states that "thousands of a new form of the Pacific Island rat were found on Ocean [now Green] Island." High population peaks have recurred there in a similar fashion over the years and are of special interest as a populational feature of a small low island.

Other aspects of *Rattus exulans* may be mentioned here as possible aids to the need for laboratory study of this species. Anon. (1960c) reports laboratory reproduction in New Zealand, and a small breeding colony of O'ahu stock was maintained at the Experiment Station, Hawaiian Sugar Planters' Association, in Honolulu, for a number of years after 1956 (W. R. Smythe, pers. comm.). A ventral dermal gland was described in this species (Quay and Tomich, 1963) and it may be of significance to an understanding of its behavioral patterns. Rudd (1966) has found the same feature in Malaysian rats.

While *Rattus exulans* has not been demonstrated to be a direct threat to forest birds, it is a probable predator on Bulwer's petrel (*Bulweria bulwerii*) of Popoia, where Fisher and Baldwin (1946, p. 7) declared that this bird "has been practically wiped out by rats in the last few years." A report from Kure

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Atoll studies (Kepler, 1967) documents predation of the Polynesian rat on the Laysan albatross (*Diomedea immutabilis*) in which the rats literally eat the birds alive as they sit impassively on their nests. R. L. Walker reports (pers. comm.) from a March 1966 trip to Kure that *R. exulans* is a serious predator on burrow-nesting species including the wedge-tailed shearwater (*Puffinus pacificus*) and Bonin petrel (*Pterodroma hypoleuca*). There was no evidence of successful breeding by the petrel in later years of rat abundance following a 1961 low in rat numbers.

Studies of the Polynesian rat after 1969 have been numerous, and it is often the subject of single species studies in Hawai'i and other Pacific localities, where the information gained is useful to understanding this rat. Williams (1973) provides a thorough review, through 1971. Wirtz (1972, 1973) completed his work on Kure and found limitations of food resources important to the economy of *Rattus exulans* there (see also, Norman, 1975). Other island populations were examined by McCartney (1970), Bettsworth (1972), Mosby and Wodzicki (1972, 1973), Mosby, Wodzicki, and Shorland (1974), and Moller and Craig (1977), who add to information on basic biology, food habits, and ecological attributes. Continental populations are treated by Dwyer (1978), Koepl, Slade, and Turner (1979, 1981), and Brooks and Pe (1980); and Taylor (1975) may have reached a final explanation of what has driven the *kiore* of New Zealand from the main islands in these southern latitudes. Refinement of methods for captive rearing has led to increased use of *R. exulans* in controlled laboratory experiments (Egoscue, 1970; Wirtz, 1973; Garrison, 1974; and Davis, 1979).

Mus domesticus. European house mouse.

ORIGINAL DESCRIPTION: *Mus domesticus* Ruddy, An Essay Towards a Natural History of the County of Dublin . . . , Vol. 1. 1772.

TYPE LOCALITY: Dublin, Ireland.

NATIVE RANGE: Southern Denmark, in most of the rest of western Europe, and around the Mediterranean Sea (Ferris, Sage, and others, 1983). It has spread widely with commerce and become cosmopolitan as an introduced species. Highly adaptable to temperate latitudes, but occurs widely in the tropics.

RANGE IN HAWAII: Found on all major islands, except that specific record is lacking for Ni'ihau. Known also from Midway Islands and Ka'ula, Mokuolo'e, Mānana, Kekepa, and Kapapa (islets near O'ahu).

House mouse populations of Hawai'i are referable to *Mus domesticus*. This form, in its native range, is separated from the more northerly Linné's house mouse, *M. musculus* Linnaeus 1758, by a narrow hybrid zone crossing southern

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Feral dogs in Hawai'i are identified increasingly as predators on such native bird populations as the *nēnē* (State of Hawaii Department of Land and Natural Resources, 1974; Stone, Walker, and others, 1983), and on colonial sea birds (Byrd and Boynton, 1979; TenBruggencate, 1984a, 1984b, 1985). There is, however, additional evidence that the roof rat is a staple food of feral dogs on Hawai'i (Tomich, 1981a) and on Maui (C. H. Diong, pers. comm.), in that scats contain typically the matted fur and bones of this rat on both islands. A report from Alabama (Causey and Cude, 1980) showed that free-ranging dogs frequently pursued deer, but that foods were basically from smaller animals. Beck (1973) provides supplementary data. Another work, on the dingo in Australia, gives insights into movement patterns of that form of the dog (Whitehouse, 1977). Finally, the legendary "Pele's dog," or a relative of it on Mauna Loa at high elevation as if resident there for a period of years, was observed closely and photographed, but could not be captured or befriended (Engledow, 1961; Bryan, 1964; Mendonca, 1978).

The project begun in 1966 for phenotypic reconstitution of the Polynesian dog fared well at first, and results accrued quickly. In time, however, the stock lost vitality through inbreeding. Funds for staff and for upkeep of the dogs became insufficient to maintain accurate pedigree records, and the project was ultimately abandoned in 1980 (J. L. Throp and J. S. W. Marr, pers. comm., 1983). It is regrettable that the support for such a commendable endeavor could not have been firmer. The workers did succeed in producing animals that were probably reasonable likenesses of the ancient dog of Hawai'i (Fig. 43); one of them was sent as mascot for the *Hokule'a*, a replica of the Hawaiian double-hulled canoe that was sailed to Tahiti in 1976 using Polynesian methods of navigation (Haugen, 1976). Whipple (1977) and Throp (1978) describe aspects of this canine genetic adventure in some detail. A new attempt should be made, as ultimate success seems likely.

***Herpestes auropunctatus*.** Small Indian mongoose.

ORIGINAL DESCRIPTION: *Mangusta auropunctata* Hodgson, Journal of the Asiatic Society of Bengal 5:235. 1836.

TYPE LOCALITY: Nepal.

NATIVE RANGE: Northern Arabia eastward through Iraq, Iran, Afghanistan to Kashmir; India south to the central states, eastward to Nepal, Assam, and Burma; Hainan Island, Thailand, Indo-China, and the Malay Peninsula (adapted from Ellerman and Morrison-Scott, 1951, p. 295).

RANGE IN HAWAII: Occurs on O'ahu, Moloka'i, Maui, and Hawai'i; widespread and firmly established throughout these four islands; escaped from captivity about 1965 on Mokuolo'e (Coconut Island) in Kane'ohe Bay, O'ahu, and apparently established. Present also on Ford Island in Pearl Harbor.

In Hawai'i *Herpestes auro-punctatus* is called simply the mongoose, which is a practical name for a singular mammal having no near relatives in the Americas. We should be aware, nonetheless, of the opinion of Ellerman and Morrison-Scott (1951, p. 295) who designate this animal as the small Indian mongoose to distinguish it from similar species such as *H. edwardsi* (Geoffroy), the Indian gray mongoose, and *H. fuscus* Waterhouse, the Indian brown mongoose. Blanford (1891, p. 121) and Powell (1914) applied the same common name, small Indian mongoose, to this species. The specific name *auro-punctatus* mean, literally, "gold-spotted," and our species has also been called the gold-spotted mongoose. The plural is mongooses, a plain fact not always taken seriously in the local patois (Anon., 1963b). Walker and Hudson (1945) augment further the lighter side of the mongoose problem.

P. H. Baldwin, Schwartz, and Schwartz (1952, p. 336), who present the most comprehensive material for Hawai'i, have adequately treated systematics and explain fully the designation *Herpestes auro-punctatus auro-punctatus* as it applies to the West Indian and Hawaiian populations. This form ranges in northern India from Manipur to Orissa, and into Nepal, as one of five designated subspecies, and is thus locally available in Calcutta, from whence at least one lot of mongooses originated for transport to Jamaica. Related species of mongooses, their classification, and some structural characteristics have been treated by Pocock (1916, 1937, 1941), by Ellerman and Morrison-Scott (1951), and by Hinton and Dunn (1967).

Herpestes auro-punctatus in Hawai'i has been aggressive in its spread to all regions of each island occupied. P. H. Baldwin, Schwartz, and Schwartz (1952, pp. 341-342) neatly characterize its range by saying, "Mongooses live from sea level to approximately the highest elevations on Moloka'i (4970 feet), O'ahu (4025 feet), and Maui (10,025 feet). On Hawai'i, the range extends from sea level to the upper limit of vegetation near 10,000 feet and excludes only the barren summits of Mauna Loa and Mauna Kea which rise to 13,680 and 13,784 feet, respectively." However, these authors provide specific maximum elevational records of only 6,000 feet in Kīpahulu Valley on Maui; and 7,000 feet, evidently on Mauna Loa, Hawai'i. The mongoose is unlikely to be found much above these levels. Sign on the Mauna Loa Trail occurs to about 7,000 feet, as observed on numerous occasions during two years of the IBP program (Tomich, unpubl.). In a two-day transect study along the road from the Humu'ula Sheep Station at 6,700 feet to Halepōhaku at 9,200 feet on Mauna Kea, in 1969, mongooses were trapped only to a level of 7,200 feet. None ever reached the open pit refuse disposal site at Halepōhaku, according to residents of a construction camp there. On the eastern slope of Mauna Kea we trapped the mongoose with some regularity in wooded pasture lands of Kūka'iau Ranch to the Pu'u Kihe cabin at 7,750 feet. Extreme station of record was 7,800 feet

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in a small forestry planting just above the cabin at the Forest Reserve boundary (Haas, Wilson, and Tomich, 1972).

Greatest concentrations are in beach and lowland areas, but the species does well at middle and higher elevations at favorable locations. It is found, for example, at the Pōhakuloa military camp (6,700 ft), supported to some degree by the refuse dump. Carrion of feral sheep on the higher reaches of Mauna Kea apparently does not attract the mongoose to this cold habitat. The work of Kami (1964) suggests to me that scavenger beetles in cattle dung serve as an important food source and engender a commensal relationship between mongooses and cattle on the range. The Mokuolo'e population originated from escapes among animals brought there for use in food-fish toxins research, and finds adequate food on that small island.

The mongoose in Hawai'i originated from Indian stocks brought originally to Jamaica. Thus the account of this species begins properly in the Caribbean where rat problems were serious in sugar cane fields well before 1870. Espeut (1882) relates the first known introduction to Jamaica in 1872, and (p. 714) extolls the success of the venture, but, admitting damage to quail and other ground-nesting birds, he observes that, "snakes, lizards, crabs, toads and the grubs of many beetles and caterpillars have been destroyed. . . ." It is apparent that the mongoose in Jamaica was then acclaimed not only for rodent control but also for control of sugar cane insects and "pests" in general. Espeut's unbounded enthusiasm for this animal led him also to wonder why it was not taken to Australia and New Zealand to kill rabbits. Anon. (1883b) reviews the original introduction and indicates that further shipments had been made to Jamaica.

Possibly on the strength of Espeut's paper, Hawaiian sugar planters became interested in the mongoose as a predator on rodents in their fields (Anon., 1883a). This latter article recommends caution and also provides some earlier history, in these excerpts:

Whether it would be wise to introduce the animal to these Islands may be a question. It would be important first to learn more of the nature of the creature, for they might prove an evil. They certainly are as fond of poultry as of rats, and possibly have other undesirable qualities.

As long ago as 1816, Luman, in his article on the sugar cane, "Hortus Jamaicensis," vol. ii, p. 206, drew attention to the capabilities of the Mongoose as a rat catcher in the following words: "There is an East Indian animal called *mungoes* which bears a natural antipathy to rats; if this animal was introduced here [Jamaica] it might probably extirpate the whole race of these noxious vermin."

It appears, however, that until some twenty years ago, no attempt had been made to introduce the Mongoose into the island, and even then the results were unsatisfactory or fruitless.

The introduction and complete naturalization of an animal possessing such strong predatory habits and remarkable powers of reproduction as the Mongoose must have an important influence on all indigenous and introduced animals capable of being affected by it.

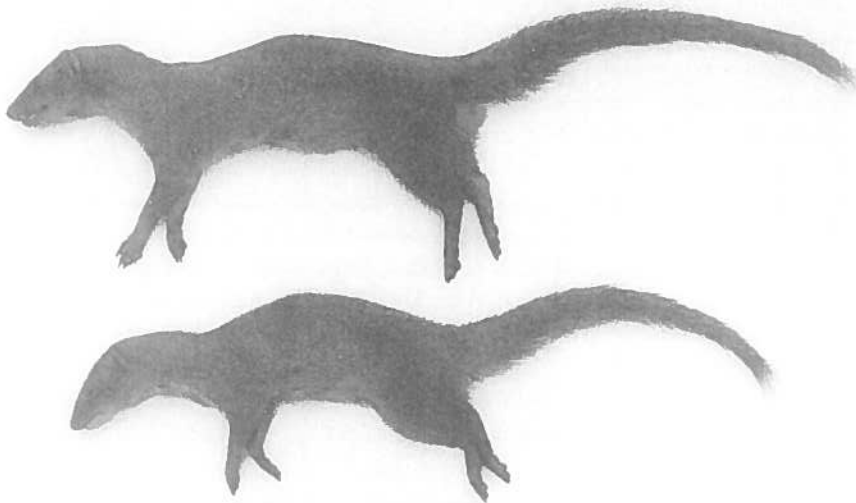


FIGURE 45.—Small Indian mongoose (*Herpestes auropunctatus*). Freshly killed male (above) and female (below). The small eye, slender body, and tapered tail are shown in these specimens. Adult males weigh 16 to 32 ounces (450 to 900 g) and females are smaller, at 11 to 18 ounces (300 to 500 g). (William S. Devick photo.)

Regardless of these admonitions, in the very same year 72 mongooses were brought to Hawai'i, on September 30, 1883, and released along the Hilo-Hāmākua coast of Hawai'i Island (E. H. Bryan, Jr., 1938b). Two years later another "large number" of these animals was procured for the Hāmākua plantations (Anon., 1885).

Offspring of these animals or subsequent introductions from the West Indies were established also on Maui, Moloka'i, and O'ahu. Details of this operation, if recorded, have not come to my attention. Some resistance was met in an attempt to bring the mongoose to Kaua'i, for Tinker (1938, p. 83) relates that a shipment of them reached the island, but was thrown overboard in the harbor before the mongooses could be released on land (original source not found).

In retrospect for Jamaica and the Caribbean region, the mongoose has not been accepted with favor. Eric (1896) recognized some true qualities of the species, and stated (p. 108), "However interesting the mongoose may be from a natural history point of view, the fact remains that it has over-run every part of Jamaica, has done, and is doing incalculable damage in every direction." Before 1900 extensive control programs were in operation (Anon., 1898). Some saw hope in natural biological control through parasitic infestations of ticks (Anon., 1897), a notion that was later refuted (Thompson, 1950), or the unlikely function of extensive cannibalism (Anon., 1902b).

Williams (1918) found the mongoose valuable only under special environmental conditions, when he thoroughly analyzed its food habits. Urich (1931) summarizes mongoose problems in Trinidad; and Meyers (1931) suggests complications for the West Indies in general from decimation of insectivorous vertebrates by the mongoose.

Spencer (1950) introduces a new era in the understanding of *Herpestes auropunctatus* in the West Indies, and is followed by Seaman (1952), Wolcott (1953), and by Pimentel (1955a, 1955b) whose interest lay in the species as a reservoir of rabies and leptospirosis. Tierkel and others (1952) deal specifically with rabies in Puerto Rican populations.

There is some parallel, in the chronology just recited, in the Hawaiian experience with this mongoose. Hinton and Dunn (1967) discuss the matter for the West Indies and for Hawai'i as well. After early glowing reports such as Anon. (1888), some writers turned against the animal (Anon., 1904a), although for what specific purpose does not seem to be known. Some control was practiced (Pemberton, 1923), but in general it seems that the mongoose was left alone. Later commentators, in contrast to those from the West Indies, left the question open, or rose in token defense (E. H. Bryan, Jr., 1938b; L. W. Walker, 1945b).

A central question for Hawai'i is whether the mongoose is a negative factor in relation to birds, both native and introduced, and whether it is of positive value in rodent control. This animal is thoroughly omnivorous, as is shown from sources presented earlier, but the suggestion that it eats sugar cane (G. M. Allen, 1911) is unfounded. Beccari and Rock (1921) charged that the mongoose ate fallen fruits of native fan palms (*Pritchardia*), possibly in excessive amounts. F. M. (1913), Pemberton (1925, 1933), La Rivers (1948), Kami (1964), and P. H. Baldwin, Schwartz, and Schwartz (1952) have contributed to the knowledge of food habits of the mongoose in Hawai'i; these last authors have exhaustively treated this subject, and have also considered at length the economics of mongoose populations. Specific cases of bird predation are reported by W. A. Bryan (1908) and by Ord (1964). Schwartz and Schwartz (1950b, 1951) found the mongoose an important predator on the ring-necked pheasant (*Phasianus colchicus*), but one of lesser importance on the California quail (*Callipepla californica*). Woodworth and Woodside (1953) were inconclusive as to whether poisoning of mongooses aided in pheasant production. P. H. Baldwin (1945a), Elder (1958), and R. L. Walker (1966) list the mongoose as a factor in decline of the Hawaiian goose. King and Gould (1967) suggest that the mongoose is responsible for depletion or extirpation of Newell's shearwater (*Puffinus newelli*) on O'ahu, Moloka'i, Maui, and Hawai'i. Pemberton (1925) and Kami (1964) observed similar high incidences of rodent remains in mongoose excreta from sugar cane fields near Honoka'a, on

Physiological parameters of cardiac output (Lin and Kobayashi, 1976) and of thermal factors (Nellis and McManus, 1974; Ebisu and Whittow, 1976) add to understanding of the mongoose in its adjustment to environmental conditions. Chromosome studies (Fredga, 1967; Cohen and Chandra, 1970; Mittal and Kaul, 1975) reveal a novel chromosome arrangement which may provide some insights into the characteristics of *Herpestes auropunctatus* as a species.

Felis catus. House cat (includes feral populations).

ORIGINAL DESCRIPTION: *Felis catus* Linnaeus, Systema Naturae, Ed. X, 1:41. 1758.

TYPE LOCALITY: Uppsala, Sweden.

NATIVE RANGE: Ancestral species occupy Europe, western Asia, and Africa.

RANGE IN HAWAII: Established in the wild on all eight main islands; has been present from time to time with man or in a feral state on others, for example, Tern Island at French Frigate Shoals (Anon., 1964k).

The domestic cat (Zeuner, 1963, pp. 387-400) has a relatively short history that is not well known. The European wild cat (*Felis silvestris* Schreber) appears to be the chief ancestor of common breeds, but also included are the African yellow cat (*F. libyca* Forster), and perhaps others. Ranges of these wild species are extensively overlapped. The first tamed cats are recorded from Egypt, about 3,800 years ago.

Felis catus is generally agreed to have been present in Hawai'i since the early days of European contact (R. C. L. Perkins, 1903, p. 394; W. A. Bryan, 1915, p. 293). It is likely that ships' cats would have made attractive prizes for the island natives and that shore populations became quickly established after Cook's time. Specific dates of early introductions have not been uncovered, nor is the history of spread to the wild recorded. Rothschild (1893) reports cats as common in Lāna'i and O'ahu forests in 1892, and R. C. L. Perkins (1903) indicates they were abundant on Lāna'i during one of his visits of that era. Nīihau had no feral cats in 1936 according to the observations of Franck (1937, p. 322), but Fisher (1951, p. 33) reported them as common about 1950. Franck (1937), however, states that on his 1936 visit to Kaho'olawe, cats were present and had evidently been abundant, for the lone island resident said, "I used to shoot six or seven cats a night and catch three or four in traps."

Feral cats are most common at the lower and middle elevations, but do go also high into the rugged mountains. A ranger at Haleakala on Maui said in 1963 that cats were occasional along the lower roads, near Headquarters (7,000 ft elev.), and in the crater at a similar elevation, apparently entering through Kaupō Gap. They seem not to be present frequently on the very high slopes of Mauna Kea and Mauna Loa, on Hawai'i, but do range, perhaps regularly, to at

least 5,600 feet in the saddle between these peaks, and to 7,000 feet on the east flank of Mauna Kea near Kahinahina.

Feral cats are notorious for their actual or alleged predation on birds. R. C. L. Perkins (1903, p. 394) reports a serious case involving apparently a variety of native forest species on Lāna'i, and Richardson and Woodside (1954) report another, involving the dark-rumped petrel (*Pterodroma phaeopygia*), at 9,000 to 10,000 feet on Mauna Kea. Other investigators (for example, Schwartz and Schwartz, 1950b) suspect the cat as a factor in bird predation.

Field data on food habits are few. L. Nichols, Jr. (pers. comm.) examined stomach contents of several feral cats on Lāna'i about 1958 and determined the principal diet as *Mus domesticus* and lizards (introduced Scincidae); also found were occasional scorpions, centipedes, and fledgling passerine birds. Near Kahinahina on Hawai'i, two stomachs each contained the remains of a skylark (*Alauda arvensis*).

Two cats I collected from semiarid rangeland near the Saddle Road Junction (2,500 ft elev.) in April 1964, also on Hawai'i, were living well off the land. The stomach of one contained the remains of a skylark. That of the other contained parts of two *M. domesticus*, crushed shells of two eggs (possibly skylark), and fragments of a hawk moth (*Sphingidae*) and of three other moths. In the colon were remains of two mice, of a skylark, and of one or more moths, from earlier feeding.

These few data illustrate an excellent adaptation of the house cat to living in the wild. Both the specimens examined were young adult females; one was pregnant and with slight fat deposits; the other was lactating heavily and in good condition. *M. domesticus* had been extraordinarily abundant in the region the previous late summer and seemed to have still been common. Rather frequent road kills of cats in that part of the island suggest a relatively dense population. In the field the cat-mouse relationship may be as firm as in the farmyard, but it is apparent that available small birds are also a substantial food source. Eating of lizards and arthropods demonstrates a versatility in feeding habits which may allow survival when rodents and birds are scarce.

The feral cat is without doubt of some significance in wild bird conservation and game bird propagation, but opportunities for its study have never been fully presented. A basic understanding of these areas of wildlife management should include intensive investigation of the feral house cat and an orderly program for disposing of unwanted pets that might otherwise be turned out to fend for themselves.

House cats in Hawai'i take readily to the wild and it is difficult to draw distinctions between feral animals living near human habitations and doorstep cats foraging away from home. Several times in trapping for the mongoose in the sugar cane and small farm belt we have caught cats. Some were meek,

The mule story continues into more modern times with a few notes on persistence of this form in commerce and as a curiosity. As recently as 1973 one sugar plantation maintained mules for transport of seed cane from less accessible fields (Anon., 1973a). A tourist-oriented mule ride service has been available for several years on Moloka'i and was reported as resuming after a year of shutdown (Anon., 1982c). Mules continue to be bred in Hawai'i, and a resident of Āhualoa Homesteads on Hawai'i rides a sporty animal with appaloosa markings.

Savory (1970) provides an illustrated review of the mule and its parentage; Chandley and others (1974) delve into the genetics of infertility in horse-donkey hybrids.

Sus scrofa. Pig (includes originally wild forms, domestic swine, and those reverted to the wild).

ORIGINAL DESCRIPTION: *Sus scrofa* Linnaeus, Systema Naturae, Ed. X, 1:49. 1758.

TYPE LOCALITY: Germany.

NATIVE RANGE: As a truly wild species (Eurasian wild boar) the pig has occupied all of Europe and northern Africa, Asia Minor, southern Asia, and north to Taiwan, Japan, and Korea. Its range is now much restricted and has been influenced by man through hunting as well as introduction (adapted from Ellerman and Morrison-Scott, 1951, p. 345).

RANGE IN HAWAII: Formerly present in the feral state on probably all eight major islands; briefly present also on Laysan. Found now only on Ni'ihau, Kaua'i, O'ahu, Moloka'i, Maui, and Hawai'i.

Reed (1959, pp. 1635-1636; 1960, pp. 138-141) discusses references to a supposed single ancestor of the domestic pig as the subspecies *Sus scrofa vittatus* Boie of southeastern Asia. These imply a much earlier domestication than is supported by archaeological evidence and suggest an improbable prehistoric transfer of these stocks to the Near East and Europe. This same author notes in modern populations of Western pigs a marked preadaptation for easy taming and suggests a reinvestigation of the possibility that pigs may have been domesticated at several times from different wild populations. He reports that Jarmo, in Iraqi Kurdistan and occupied about 8,500 years ago, is the oldest presently known site where domestic pig remains have been found (Reed, 1961, p. 33).

Pigs of Asian ancestry were introduced to Hawai'i during ancient times by the Polynesians, and served as an important source of food. They were also, according to Luomala (1960a, pp. 225-226), used in sorcery and had more prestige in religion than had the dog. Pork could be eaten only in the men's

house, and was taboo to women. Buck (1957) illustrates boar-tusk bracelets and provides other references to the pig in Hawaiian culture. These animals are presumed to have been rather small in size, and to have remained readily in domestication. Cook (1785, Vol. 2, p. 234) noted on Kaua'i in 1778 that pigs were in abundance and ran without restraint about the houses, and (Vol. 2, p. 543) of those traded for on Hawai'i in 1779, "we could seldom get any above fifty or sixty pounds weight." Ellis (1917, p. 23) observed in 1823 that the natives possessed among their original quadrupeds, "a small species of hogs, with long heads and small erect ears." These were sometimes found in the mountains and were the only ferocious animal of the islands. He noted further (p. 162) at Kapāpala, "Few of the Hawaiian females are without some favorite animal. It is usually a dog. Here, however, we observed a species of pet we had not seen before. It was a curly-tailed pig, about a year and a half old, three or four feet long, and apparently well fed. It belonged to two sisters of our host."

Cook brought English pigs on his first voyage to Hawai'i (Cook, 1785, Vol. 2, p. 217), and landed a boar and sow on Ni'ihau February 2, 1778. Many importations have followed. In the early 1820s at least a few pigs were exported to establish this animal in the colonies of the Pacific Northwest (Scouler, 1905, p. 166). Presumably all eight main islands of Hawai'i that supported Polynesian settlements also had pigs. Anon. (1902a) indicates wild pigs on Kaho'olawe before 1840, and these may have been in part of Polynesian stock. They disappeared at some unknown date, and probably had been gone long before 1913 when Forbes (1913a) visited the island. I have found no early reports of feral pigs on Ni'ihau, but Franck (1937, p. 322) found them there in 1936, and Fisher (1951, p. 33) found great numbers of them. The 1891 record of this species on Laysan (F. D. Walker, 1909) was likely of animals kept only for a short time, and though allowed to roam over the island, were presumably eventually slaughtered for food. Some may have been reared there, however, for Walker notes (p. 30) that the pigs were found foraging on an abundant "yam" (= *Boerhavia*, which has a fleshy root) and very little other food was required. No mention is made of their possible effect on nesting of sea birds. This activity may have been slight, or it may have been ignored. Pigs are not mentioned on Laysan by later writers.

Feral pigs have long been distributed in the upland forests and pastures of the six larger islands they inhabit, except on Maui where they were found as late as the 1960s only in the West Maui Mountains in the Kahakuloa area (J. S. Medeiros, pers. comm.), and in East Maui at Kīpahulu Valley (Warner, 1967). Hawai'i has the largest, most widely distributed populations.

The old Polynesian type of *Sus scrofa* has been absorbed or replaced by stocks of European origin. Warner (1959) and Nichols (1962d) are of the opinion



FIGURE 53.—Young male feral pig (*Sus scrofa*) in the mountains of Hawai'i Island. A long snout, coarse mane, straight tail, and black color are characteristic of these pigs. Mature boars usually weigh up to 150 pounds (70 kg), but much larger specimens are on record (Nichols, 1962c). (Lyman Nichols, Jr., photo.)

that the feral Hawaiian pig of today is typically like the Eurasian wild boar of Tennessee and California, which is intermixed with semidomestic strains of pigs. Hence, the island pigs are referable to the same subspecies, *Sus scrofa scrofa*. Young are usually black, but may have the wild-type longitudinal reddish striping in the juvenal pelage (Fig. 54). Adults are generally also black, but occasional spotting or white feet indicate persistence of domestic strain traits in some populations. Pullar (1953) observes similar conditions in Australian pigs.

In the middle of the nineteenth-century R. J. Hollingsworth (1853, p. 75) made the following recommendations in relation to efficient hog raising with selected breeds in Hawai'i:

Concerning location, I would advise those interested in this matter to allow their hogs to run at large, and if possible that run to comprise a ravine that abounds with wild apples, guavas, etc., as those fruits afford food for hogs one half the year at least, and as security against the swine going wild, accustom them to be herded at the sound of a horn, and entice them into a pen every night, by dealing out some luscious kind of food."

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FIGURE 54.—Feral piglet about 3 weeks old captured on open range near Waimea, Hawai'i. After several days of hand feeding, it foraged amiably about the garden. Object in the mouth is an earthworm rooted from the loose soil. Wild-type pelage stripings are evident. (Courtesy of Samuel Kaaekuahiwi, Jr.)

Doubtless such practices led to escape of some of the selected stock and frequent admixture with the wild pig of early Hawai'i, or progeny of later introductions that had penetrated the heavy forests and other wilderness regions. C. S. Judd (1936) indicates that ranchmen in his time, or in some earlier era, purposely released imported boars of selected breeds on Mauna Kea to improve quality of the feral pigs.

On most ranches on Hawai'i, pigs are now managed to the extent that they are regularly hunted as food. Young males are often castrated and freed for later harvest, and sows are not usually taken. In hunting, the pigs may be shot, roped from horseback, or caught by hand with the aid of dogs. Feral pigs taken alive are frequently reared or fattened in pens.

Vollrath (1947) reviews methods in commercial pork production. Domestic pigs are generally confined in piggeries remote from the wild populations. I have observed, however, as in Puna District, Hawai'i, in 1964, that relatively tame wild-type pigs are sometimes loosely mingled with inferior domestic types in some farmyards where the animals are permitted to run loose in the adjacent forest.

Feral pigs, in spite of their obvious quality of providing a substantial source of food (and no Hawaiian feast is complete without a pig, or several of them, roasted in the *imu*), have been considered a pest when numerous in specific

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FIGURE 55.—Excited feral boar on Hawai'i Island. The mane is bristled and the tusks are bared; alerted pigs audibly gnash their tusks when apprising danger, and this behavior serves to hone the edges of these teeth (Lyman Nichols, Jr., photo.)

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forest regions. Watersheds, forests, and range are damaged when pigs root excessively and disturb the forest floor and its plant cover, or the perennial sods of pasture lands. The following reports from the Territorial Board of Commissioners of Forestry and Agriculture indicate the problem as recognized some 60 years ago:

The central forest of O'ahu is riddled with wild pigs which are removing the undergrowth and it is most desirable that the new appropriation be extended to cover this pest as well as the goats. Already, with contributed funds we have begun to tackle this difficult work by constructing a pig hunters' cabin on the Koolau Range in the Ewa Forest Reserve. [Report for 1925, p. 21.]

The damage done by wild pigs continues, especially on the Koolau Range on O'ahu. These are not being exterminated rapidly because of the remoteness of their haunts and the difficulties which hunters experience in reaching their range. [Report for 1929, p. 22.]

McEldowney (1930) speaks further on the same issue. With increased human population on O'ahu, pigs have receded in numbers and today they are not easily found. L. W. Bryan (1937c) reviews the history and status of pigs on Hawai'i, and Tower (1926), Tillett (1937), Vitousek (1941), and Nichols (1962e) present stirring episodes from the rugged sport of hunting pigs on O'ahu and Hawai'i.

In modern game management *Sus scrofa* figures prominently, particularly on Hawai'i, and specific attention has been given it. A research project begun in 1958 (Warner, 1959) was carried on until 1964, with the assembling of a wide variety of useful data (Nichols, 1961a, 1962d, 1963, 1964a). These progress reports show that a firm foundation has been laid for the understanding of the pig as a game animal closely associated with the economic interests of landowners. Hanson and Karstad (1959) present comparative data on feral swine in the southern states, and Henry (1968) reports on their estrous cycle and gestation period.

With substantial progress in control of feral goats on some National Park lands and the court-ordered elimination of feral sheep from habitat of endangered native birds on Mauna Kea in the 1970s, the feral pig has emerged as the most prominent agent of ecological perturbation, of wet forests in particular.

Recognition of the pig as a destructive factor in Kīpahulu Valley (incorporated into Haleakala National Park in 1969, largely as a gift of The Nature Conservancy) came at first gradually (Banko and Wilson, 1968), but less than ten years later pig damage in the open lower valley assumed emergency proportions (Lamoureux and Stemmermann, 1976). With firm evidence that strawberry guava (*Psidium cattleianum*), a shade-tolerant alien tree, was invading the forest through transport by pigs, plans were formulated for intensive investigation (Smith and Diong, 1977), and these plans have since been carried forward with the management recommendation (C. W. Smith, Editor, 1982) for protection of the whole valley by eradication efforts and the

formation of a buffer zone. The pig and strawberry guava headed a list of undesirable alien species. See also Jacobi (1976), Diong (1980), Yoshinaga (1980), and Gagné (1982) for methods of trapping pigs; alien vegetation and pigs; and effects of pigs on bog plants. Several sources indicate that pigs are now widely spread in wet uplands of West Maui.

Meanwhile, research on the pig at the state level has continued, with a final report issued for Hawai'i Island (Giffin, 1978). Other work on this island includes that of Cooray and Mueller-Dombois (1981). At Hawaii Volcanoes National Park, major studies of the feral pig continue in the formulation and execution of management plans (Katahira, 1980; Higashino and Stone, 1982). This work emphasizes fencing of pigs from key areas and is proving to be a feasible management program which can be expanded. See also Warshauer, Jacobi, and others (1983), and Brower (1985).

A conference entirely on the subject of feral pigs was held in August 1980, at Hawaii Volcanoes National Park. It suffices to say that research on control and management of pigs is at an exciting level. Programs appear now to be limited only by available funds and manpower. In keeping with objectives of this book it is impossible to provide more detail. Attention is fixed on management of the feral pig in continental United States (Pine and Gerdes, 1973; Barrett, 1978; Wood and Barrett, 1979; Barrett and Pine, 1980; Singer and others, 1981). Reports from elsewhere include Diong, 1973; Hone and O'Grady, 1980; Hone, O'Grady, and Pedersen, 1980; and Andrzejewski and Jezierski, 1978. Challies (1975) relates pigs to a New Zealand island biota. Aspects of techniques and biology are treated by Henry (1969), Andrzejewski (1974), Covacevich (1976), and Baber and Coblenz (1982). Hunting of pigs in Hawai'i is still a favored activity as indicated by Takimoto (1974). Regular reports on the status of the pig as a game mammal are issued, as exemplified by Telfer (1982), Bachman (1982), and Saito (1983) relative to hunting within state game management areas.

Axis axis. Axis deer.

ORIGINAL DESCRIPTION: *Cervus axis* Erxleben, Systema Regni Animalis, p. 312. 1777.

TYPE LOCALITY: Banks of the Ganges River, India.

NATIVE RANGE: Ceylon and Peninsular India, northward to Kumaon, Nepal, Sikkim, Bengal (Ellerman and Morrison-Scott, 1951, p. 360).

RANGE IN HAWAII: Principally on Lāna'i and Moloka'i; one remnant population on O'ahu; introduced on Maui in 1960.

The axis deer in Hawai'i is a true wild species that has descended from an original stock of eight animals brought to Moloka'i in 1868. There are two

subspecies of axis deer, the nominate *Axis axis axis* (Erxleben) of the Indian mainland, and *Axis axis ceylonensis* (Fischer), found only on the island of Ceylon (= Sri Lanka). It is probable that Hawaiian populations are derived from the Indian form. The axis deer is usually designated as *Axis*, a genus distinct from that of the elk (*Cervus*), but its affinities with the elk are plainly evident in behaviorism, in antler form, and in the fact that upper canine teeth are sometimes present. Nichols (1960a, p. 5) reports this observation from Hawaiian specimens: "Fawns are born with a small pair of upper canines implanted in the maxilla; these are usually shed before the animal reaches one year of age, but may occasionally be found remaining in the cartilage of the upper jaw of adults." Graf and Nichols (1966, pp. 652-653) expound fully on this matter.

The original deer arrived in Honolulu in December 1867 on the trader *Loch Na Garr* out of Hong Kong, as a gift to Kamehameha V. Three bucks and four does had survived the voyage and a male fawn was born aboard ship during the layover in Honolulu harbor. The deer were transshipped in the King's yacht to his private lands on Moloka'i in January 1868, where they established the first herd. At some later date several were returned to O'ahu and released, and in 1920 a group of 12 was introduced to Lāna'i. Various authors have referred to these events (Tinker, 1938, pp. 120-121; Lennox, 1950; Nichols, 1962a, p. 90), but the bases for their statements are not all known to me. Cooke (1949, pp. 64-67) is perhaps the best single source of information, inasmuch as he includes quotes of newspaper articles researched by the Archives of Hawai'i. It appears that the deer were shipped from India via Hong Kong through consular connections and that Dr. William Hillebrand (1821-1886), the eminent physician-botanist, had made arrangements for obtaining them when in Calcutta. Hillebrand, in spite of his concern for the threat by feral cattle to integrity of native forests, was instrumental in the importation of many alien plants and animals (Degener, 1932-1980, Bk. 5, p. D) and the axis deer was quite possibly among them. Another version of the event, as related by Tinker (1938, p. 120), but undocumented and unlikely in view of the several newspaper articles quoted by Cooke, places the deer as a gift from the Hawaiian Consul to Japan, and originating from the Imperial deer park of Japan.

On O'ahu a herd was present on Diamond Head prior to 1898, but had died out sometime thereafter. The Moanalua Valley herd began about 1910 from escapes, and increased to about a thousand head in 1938, but deer were very scarce there by 1950. R. J. Kramer (pers. comm.) estimated in 1962 that there were about 25 in the valley, in *kiawe* (*Prosopis*) thickets above Salt Lake. Pressures from land development, poaching, and stray dogs have kept this herd small and may have annihilated it.

The herd on Moloka'i increased to an estimated 1,000 within 20 years (Anon., 1947a) and in about 30 years became a pest in its relatively protected status on



FIGURE 56.—A group of alert axis deer (*Axis axis*), on the island of Lāna'i. The young male in the foreground has spike antlers. The spotted pelage is present in adults as well as in the fawns. Thickets of the introduced *kiauwe* (*Prosopis*) provide excellent food and cover. (Lyman Nichols, Jr., photo.)

private lands. Sabin (1934), for all the discrepancies in other facets of his article, may be on good authority when he states, concerning these same deer (p. 40), "At the end of the century they had become so numerous that experienced hunters were engaged to dispose of a considerable proportion. These hunters were from California, remained in the islands about a year, killing nearly 3000 deer." Cooke (1949, p. 67) gives the number as 3,500 to 4,000 deer killed, and Graf and Nichols (1966, p. 634) specify the years as 1900 to 1901.

The Lāna'i herd, since 1959, and a large portion of the Moloka'i herd, since 1956, have been under management of the State Division of Fish and Game, agreements having been made with the landholders for public hunting at the discretion of the Division (Nichols, 1962b).

Management studies of these populations were begun in 1956. William Graf worked on Moloka'i deer for more than a year and Lyman Nichols, Jr., worked principally on Lāna'i for three years. The high quality of these well-organized investigations has been revealed through a preliminary summary report (Nichols, 1960a), and one detailed paper (Graf and Nichols, 1966).

The future of the axis deer as an important game species seems assured on Moloka'i and Lāna'i (Nichols, 1964e) as it has adapted easily to these environments. Public hunting was permitted on Lāna'i beginning in 1954, and on

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FIGURE 57.—Mature male axis deer on Lānaʻi. Only males bear antlers, which may reach a length of more than 35 inches (88 cm). A large buck weighs about 200 pounds (90 kg); a doe weighs about 120 pounds (50 kg). (Lyman Nichols, Jr., photo.)

Molokaʻi in 1959. Nichols (1961b) describes in popular style a Molokaʻi hunting expedition.

Because of demand for increased hunting domain, as early as 1950 efforts were made to introduce axis deer onto other islands (Lennox, 1950). These initial attempts were opposed principally by botanists, agriculturists, and ranchers (exemplified by Lyon, 1950), and no deer were then shipped. The problem was then further examined (Graf, 1958, 1959a) and in 1960, on the basis of the management assurances that the deer would not penetrate native



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forests, fed largely on introduced plants, were free of dangerous parasites and disease, and that their populations would be controlled by hunting, axis deer were released by legislative mandate on Maui. Nichols (1962a, 1962c) briefly discusses this event and related problems. The deer on Maui did not immediately increase and further importations of breeding stock were considered but not carried out.

Later attempts were made several times to legally extend the range of *Axis axis* to the island of Hawai'i, with the closest bid for success in 1963. The 1950 proposal (Anon., 1950) had brought immediate response (H. S. Baldwin, 1950a, 1950b), followed by later articles also in the *Hilo Tribune-Herald*, from outside the Territory on June 20 and 21, a rebuttal from the Board of Agriculture and Forestry on June 22, and an announcement on June 30 that the Board would defer action on shipment of deer.

To illustrate the political complexity and emotional effect of proposals that would establish deer at new localities in Hawai'i, there follows a chronology of selections from more than 25 newspaper articles that appeared in the 1963 incident. This affair ended in a court order to permanently ban state-supported introduction of deer to the island of Hawai'i (Anon., 1964g). Arguments pro and con were essentially the same in 1963 as in 1950.

A bill was submitted to the 1963 Hawaii Legislature to appropriate money for capture and transport of deer (Hughes, 1963a). The bill was brought to public attention by H. S. Baldwin (1963), and other newspaper articles followed (for example, Anon., 1963d). Hughes (1963b) prepared a feature article in which many statements of those opposing the introduction were questioned and refuted. When the bill was passed and release of funds was imminent (Anon., 1964a), a new tide of opposition arose. Game management officials prepared and distributed an objective evaluation of the problem in support of the proposal (Anon., 1964b). Arguments against the proposal tended to be unsound or biologically unrealistic, were seemingly prompted by desires to preserve selfish interests, or suggested a ridiculous alternative (Anon., 1964c, 1964d, 1964e; Brand, 1964). However, two substantial objections to introduction of the deer were voiced from areas unrelated to economics (H. S. Baldwin, 1964; Anon., 1964f). Those citizens promoting deer introduction had the staunch support of the game biologists, as indicated, but felt that their plans (Kaya, 1963) were swept aside by the newspapers (Parker, 1964).

The proposal resurfaced in 1968 after a period of quiet, when the last legal barrier to introduction had been overturned (Anon., 1968a). In October 1969 arrangements were made for transfer of seven deer, as a first lot held in pre-shipment quarantine on Lāna'i, in spite of continued opposition from ranchers, scientists, and a growing environmental movement. The governor finally was convinced to oppose the plan and ordered a delay of shipment on

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October 15. No immediate alternative action was taken. A skimming of numerous news articles of the time includes Anon., 1969a, b, c, and d. From that point the matter seethed for a while. Two other items of this currency are Titcomb 1969a and 1969b, followed by summary articles stretching into 1974 (American Society of Mammalogists, 1972; Hawaii Audubon Society, 1972a, 1972b, 1974). The matter was being argued out by the Animal Species Advisory Commission in its advisory capacity to the State (Anon., 1970) and the matter fell also under the virtually impossible requirement for an acceptable Environmental Impact Statement (Anon., 1972b; Benson, 1972). The issue withered after 1973 as the environmental movement of the time gained stature. Meantime, dogs broke into the pen of deer, by then gracefully aging on Lāna'i, killing or scattering them (Anon., 1973b; Tune, 1974).

The major herd of axis deer is on Lāna'i, with the 1981-1982 population estimated at 2,800. Legal hunting accounted for 393 deer in the 1981 season. On Moloka'i there were about 500 deer, with no open season for the second consecutive year because of low numbers. A trend for increase was evident. The axis deer on Maui occupies privately controlled lands and is not censused with regularity by state game managers. Some extension of range is noted in the dryland exotic forest of the Kīhei region, between Makena and 'Ulupalakua (Ueoka, 1982).

Comparative studies of many aspects of populations in Hawai'i and in India or Sri Lanka would be of value. Graf and Nichols (1966, pp. 640-644) have observed that antler lengths in Hawaiian deer are possibly as great as those in India and that the local deer may have even heavier and wider antlers than those in India. These authors report a maximum beam length of 37 inches, while the record head for India is slightly more than 39 inches (Martin, 1913). Blood factors in Indian specimens were studied by Naik and Others (1964) and these could be of importance to an understanding of the Hawaiian deer.

Significant additional writings, largely on deer in the native range of India, are those of Schaller (1967), Pillai and Hingorani (1970), Sharatchandra and Gadgil (1980), Johnsingh (1981), and Dinerstein and Dublin (1982).

Odocoileus hemionus. Mule deer.

ORIGINAL DESCRIPTION: *Cervus hemionus* Rafinesque, American Monthly Magazine 1:436. 1817.

TYPE LOCALITY: Mouth of the Big Sioux River, South Dakota, United States of America.

NATIVE RANGE: Western North America from about the 60th parallel in Canada and southern Alaska to central Mexico, and generally west of the 100th meridian.



FIGURE 58.—Adult female mule deer (*Odocoileus hemionus*) in the verdant forest of Kaua'i. This species was introduced in 1961, from western Oregon, and became quickly established. (Gerald E. Swedberg photo.)

RANGE IN HAWAII: Island of Kaua'i. Has been imported rarely in the past to other islands, but not liberated.

Odocoileus hemionus is called by two common names stemming from the notion prior to the work of Cowan (1936) that two species were represented: black-tailed deer (*O. columbianus*) of the North Pacific coast, and mule deer of the South Pacific coast and interior. Indeed, the two presently recognized subspecies often called black-tailed deer are, as Cowan reiterates (in: W. P. Taylor, 1956, p. 339), an incipient species having in common structural and behavioral characteristics that differ from those of the other subspecies of mule deer. Because we are dealing now with a single variable entity, mule deer should be the name of choice for the entire species, as used by E. R. Hall (1965, p. 15). Translated literally, the specific epithet *hemionus* means mule (half donkey), and can be referred to the large ears possessed by all forms of *O. hemionus*, although some observers note that the tail of the interior forms suggests in miniature the tail of a mule.

The stocks of mule deer in Hawai'i are from wild fawns captured in the coastal region of Oregon, and are definitely referable to *Odocoileus hemionus columbianus*. Swedberg (1963, 1967) has recorded introduction of these deer to

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FIGURE 59.—Two-year old buck mule deer on Kaua'i, June 13, 1962. Antlers are in velvet and still growing. The hardened antlers are shed each winter after the breeding season. A large male will weigh 140 pounds (60 kg) and females weigh about 80 pounds (33 kg). (Gerald E. Swedberg photo.)

Kaua'i. They were pen-reared for nearly a year in Oregon before shipment to Hawai'i. A group of ten was turned out on Polihale Ridge of the Pu'u Ka Pele Game Management Area, Kaua'i, on June 19, 1961. A second release of ten occurred at the same site on June 12, 1962. Fifteen additional deer were released on April 13, 1966. There were nine males and 26 females in these three shipments. The chosen range lies at the western end of the island in moderately dry native and introduced forest (30 to 50 inches of rainfall per year), at an elevation of some 2,000 to 3,000 feet.

There is some evidence that *Odocoileus hemionus* was occasionally brought to Hawai'i in the previous century. Clark (1939) relates a fanciful story concerning Captain Alexander Adams who commanded voyages in and out of Hawai'i in the early 1800s. Two "plain North American deer" may have been brought by Adams from the Pacific Northwest about 1816 in the brig *Forester*, one of the early ships owned in Hawai'i. Corney (1896, pp. 40-41) probably records the start of this voyage of the *Forester* from Hawai'i in 1815, when he says, "Mr. Biggot, the supercargo, took command, and got one Adams to navigate and some islanders to work the ship. He then sailed from Karakakooa [Kealakekua] Bay for the coast of California." In February 1817 (p. 71), the *Forester*, then renamed *Kaahumanu*, was being fitted out for Canton at Lahaina, Maui, with Alexander Adams in command. Wilson (1922) provides the original data for this importation of deer, as written by James Macrae in 1825.

Tinker (1938, p. 120) notes a "200-pound buck" brought from Oregon in 1857 aboard the brig *Advance*, by Captain Collins, but there is no known record of mule deer being released permanently into the wild except for the much later introductions to Kaua'i.

The population became readily established, and limited hunting was first projected for 1968 (Swedberg, 1964b). Particular attention was paid to aspects of this growing herd and some ecological data on the invasion of a new habitat have accrued from these observations. However, the mule deer of coastal Oregon has not been a spectacular success as a game animal in Hawai'i, much to the comfort of those who would protect native plant life from introduced herbivores. It does not frequently make the news. A hunting season was actually opened for the first time in 1969, but few deer were taken (Anon., 1971a). The animal was then expanding its range and numbers were estimated at 600. Hunting the mule deer on Kaua'i has become a popular sport, but the success ratio is low at about two deer per 100 hunting trips. Of 21 taken in 1981 under a bucks-only rule, all were in excellent physical condition. The deer consume largely introduced plants in their present range, although they eat readily native species such as *koa* (*Acacia*) and *pilo* (*Coprosma*) where these are available. The population of 300 to 350 animals (1981) remains stable, and although it has a high potential for increase, illegal kills of does and extra-seasonal take of bucks probably explain lack of herd growth (Telfer, 1982). Management information is available, but specific research on this deer in Hawai'i is of low priority.

The mule deer is well known in its native range, and the following reports treat many aspects of it: Dixon (1934), Leopold and others (1951), Linsdale and Tomich (1953), Taber and Dasmann (1956), W. P. Taylor (1956). Newer studies from the continental range are those of Wallmo (1981) on the aggregate populations, of Bandy, Cowan, and Wood (1970), Cowan and Raddi (1972), Mierau (1972), Westrom, Nelson, and Connolly (1976), and Freddy and Bowden (1983) on aspects of biology; and of Miller (1970), Müller-Schwarze (1971, 1972), Truett (1977), and Volkman, Zemanek, and Müller-Schwarze (1978) on behavior.

***Antilocapra americana*. Pronghorn.**

ORIGINAL DESCRIPTION: *Antilope americana* Ord, in: Guthrie, A New Geographical, Historical and Commercial Grammar, Philadelphia, Ed. II, 2:292, 308. 1815.

TYPE LOCALITY: Plains and highlands of the Missouri River, United States of America.

NATIVE RANGE: Formerly western North America, including southern

(Anon., 1964h). These animals were confined and were used in connection with the Peace Corps program (Schriver, 1964). With the birth of a calf from the surviving pair in April 1965, a nucleus herd was established in the valley. Williams (1968) reports that two of four in the valley in January 1968 were being shipped to Kaua'i.

O'ahu buffalo were maintained through the years by the Ing brothers, who operated a nursery at Kāne'ōhe. Plans were made to sell their five remaining animals late in 1964 when the pasture was assigned to another use (Anon., 1964i). While repairing the fence on November 16, Henry Ing was attacked and injured by an angry bull (Anon., 1964j). The five buffalo were sold and shipped to a private zoo in California on December 4 (Morse, 1964). The buffalo did not drop immediately from the scene on O'ahu, and an elderly taro grower continued to plow his paddies with one at Waiāhole (Morse, 1965).

A token population of a dozen or more animals was retained in Hawai'i after 1975 as somewhat of a curiosity from former times. A Kohala High School project, of up to ten animals, including the Waipi'o Valley herd, has been instructive (Anon., 1972a; Clark, 1975).

In 1983 J. S. W. Marr (pers. comm.) reported, as director of the Honolulu Zoo, six owned by that institution, three of which were on loan to the University of Hawai'i for research purposes. The herd at Kohala High School was dispersed in 1977-1978 when assistance in their care by owners of a private feedlot was no longer provided. Two of the buffalo were transferred to the Pana'ewa Zoo at Hilo, three to the Maui Zoo, and others were sold to private agencies with the proceeds donated to the school scholarship fund (David Fuertes, pers. comm.). The statewide population appears, then, to be fewer than 15. Currently, world attention is focused on the water buffalo for its long history of association with man as a source of power, milk, meat, and fuel, with suggestions that it could be more widely employed in the rural tropics (Tullock and Grassia, 1981; Norman, 1982).

Bos taurus. Domestic cattle (includes managed and feral populations).

ORIGINAL DESCRIPTION: *Bos taurus* Linnaeus, Systema Naturae, Ed. X, 1:71. 1758.

TYPE LOCALITY: Uppsala, Sweden.

NATIVE RANGE: The wild progenitor of domestic cattle once occupied forested regions of Europe, North Africa, and southwestern Asia, but is now extinct.

RANGE IN HAWAII: Feral cattle were historically abundant on Kaua'i, O'ahu, Moloka'i, Maui, and Hawai'i. They also ranged freely on Lāna'i, apparently under loose control; finally extirpated from O'ahu in 1962; now present only on Kaua'i, Moloka'i, and Hawai'i, in generally inaccessible forest or lava regions.

The urus or wild ox, *Bos primigenius* Bojanus, is the accepted ancestor of all the common breeds of domestic cattle, including the humped zebu and its derivatives. The urus persisted as a wild species in Europe until its extinction in 1627, but was never tamed. It has been referred to as the aurochs, but this name is more properly applied to the European bison, *Bison bonasus* Linnaeus. Through selective breeding, a strain of cattle that is phenotypically similar to known descriptions of the urus has been reconstituted in Germany (Zeuner, 1963, pp. 201-211). Early domestic cattle in the Near East, North Africa, and southeastern Europe date back at various sites to 6,000 and as much as nearly 10,000 years ago (Reed, 1961, p. 34; Wendorf, Close, and Schild, 1985).

Captain George Vancouver brought the first cattle to Hawai'i on his second voyage, in 1793. Circumstances surrounding this importation are of interest, and their record is available from the seafarer's journals (Vancouver, 1798, Vol. 2, pp. 120, 127, 147). Vancouver had intended to bring the cattle directly to Kamehameha I at Kealakekua Bay, Hawai'i, but he dropped anchor first at Kawaihae on February 16.

Calms and adverse winds impeded sailing and the cattle were extremely weak. In the emergency, a cow and bull were put ashore near Kawaihae on the 19th. The cow died in the canoe en route to shore, and the bull lived only a few days. Vancouver's five remaining cows were landed in Kamehameha's canoes at Kealakekua Bay on February 22, "in a healthy state though in low condition." Loss of the last bull was a disappointment to Vancouver, but he was heartened because two of the cows seemed to be in calf.

On his third voyage, in 1794 (1798, Vol. 3, p. 11), Vancouver was more fortunate with his cargo of cattle, most of which was landed at Kealakekua on January 15. "These consisted of a young bull calf nearly full grown, two fine cows, and two very fine bull calves, all in high condition." The animals left there in the previous year had thrived; one cow had produced a heifer, and Vancouver states, "I had little doubt, by this second importation, of having at length effected the very desirable object of establishing in this island a breed of these valuable animals." Vancouver had sailed to Hawai'i as a midshipman under Cook in 1778 and 1779 (B. Judd, 1929, p. 81) and was greatly dedicated to Cook's cause of stocking the islands with various domestic animals. He asked (p. 53) for a ten-year taboo on the slaughter of cattle, sheep, "and other European animals," and this Kamehameha granted, with some reservations.

Vancouver tarried along the west coast of Hawai'i before finally leaving that island, and on February 28, referring to the Waimea Plain that stretched above him, he wrote (p. 64):

In this valley is a great tract of luxuriant, natural pasture, whither all the cattle and sheep imported by me were to be driven, there to roam unrestrained, to "increase and multiply"

far from the sight of strangers, and consequently less likely to tempt the inhabitants to violate the sacred promise they had made; the observance of which, for the time stipulated in their interdiction, cannot fail to render the extirpation of these animals a task not easily to be accomplished.

These were prophetic words, indeed, and Vancouver departed from Hawaii on March 4, 1794, satisfied that his project would succeed. The original cattle were from Mission San Carlos, near Monterey, California. The 1794 importation came from "New Albion," possibly more specifically, the lower Columbia River region. Thus two separate sources are known for the nucleus cattle herd of Hawaii.

Anon. (1938b), in quoting from the writings of Delano (1817), captain of the American trader *Perseverance* (B. Judd, 1929, p. 18), indicates that cattle on Hawaii had multiplied considerably by 1801, and were being used for beef. Also, one of the original bulls landed by Vancouver in 1794 was reported to have been brought to Maui in 1806, as the first of any cattle to be shipped from Hawaii to another island.

Corney (1896, p. 109) noted in 1818 on Hawaii:

The cattle go about wild, and are not allowed to be shot without permission from King Kamehameha. Mr. Manning the Spaniard [i.e., Don Marin], keeps a large herd of tame cattle, and makes excellent butter and cheese . . . and they are penned up regularly, but allowed to go out in the morning.

Ellis (1917, p. 301) in describing Joseph Goodrich's first trip to Mauna Kea, in the summer of 1823, stated: "Leaving Towaihae . . . he had walked to Waimea, on the skirts of which he encamped with Mr. Parker, who was employed in the shooting of wild cattle." This person was John Palmer Parker, who later founded the Parker Ranch. And further, in relation to these same cattle (p. 303):

Although there are immense herds of them . . . the only advantage they derive is by employing persons, principally foreigners, to shoot them, salt the meat in the mountains, and bring it down to the shore for the purpose of provisioning native vessels.

Speaking of conditions on Maui in 1825, Andrew Bloxam (Bernice P. Bishop Museum, 1925, p. 27) stated: "There are some cows on the southern part of the island kept for breeding, and also a few horses, but none in the neighborhood of Lahaina." This suggests that cattle, as well as horses, may have populated Maui at a slower rate than they populated Hawaii. Wyllie (1850, p. 51), in reference to Hawaii, notes, perhaps erroneously, that "few cattle were killed until after 1830; they were killed mostly for their hides; they were greatly thinned off, and being so much harassed, retreated farther up the mountain."

Certainly, there was an early diversified use of cattle, and the king's rules must have been quite flexible in their application, in part because of rapid increase in the herds.

Vancouver's New Albion cattle were vaguely described only as black. Exact

descriptions of these and other early imported stock seem to be unavailable, although there is occasional reference to the longhorn type. Brookshier (1945, p. 17) credits Don Marin, who arrived in Hawai'i in 1791, with bringing the first longhorn cattle to O'ahu from Mexico. Date and information source are unspecified. L. H. Miller (1900-1903, p. 39) observed on a visit to the Kūka'iau Ranch, on windward Hawai'i: "The old native cattle are often very long horned, one old bullock head here extends to six feet and some inches." Gregory (1924, p. 32) also indicates, with the accession of "two mounted heads of Hawaiian long-horned cattle" to the Bishop Museum collections in 1923, that Spanish-type cattle were present. On August 12, 1963, I examined such materials as were available in a storage gallery of the museum. One specimen is the mounted head of a large red bull with excellent horns extending $73\frac{3}{8}$ inches between their tips. A skull with similar typical lateral-extending horns has a span of $70\frac{3}{8}$ inches. These two have no apparent accession numbers, but they may be those received in 1923, if they are actually of Hawaiian origin. A third specimen (Acc. #5121, dated June 20, 1957) comprises a partial skull with intact curved horns, and is from a large bull of a different lineage. These horns measure 39 inches between their tips, and the longer one is 32 inches from base to tip. Meek (1851) suggests a wide range of origins for Hawaiian cattle as early as 1850, to include other Pacific islands and Australia, but the source of the information is lacking.

Bird (1964, p. 138) describes roving stock of Hāmākua District in 1873 thus: "The cattle are a hideous breed—all bones, hide and horns." These and later strains must have varied greatly in form and color through the years and were extracted from the several beef and dairy breeds introduced into the islands. Occasional outstanding and powerful bulls have been noted (Hobbs, 1939). The last bull taken from the Maulua section of Kūka'iau Ranch, in 1942, was described by Robert R. Martin (pers. comm.) as large, ferocious, and black. The mounted head is displayed in the ranch village social hall. Its strongly curved horns measure each 16 inches long and span a respectable $29\frac{1}{4}$ inches. Surviving feral cattle are presently described as a scrub type. Carlson (1957) and Carlson and Bryan (1959) show a spectacular photograph of a spotted cow fleeing through a Kona District forest (see also Fig. 63).

Progress in breeding of the domestic cattle in Hawai'i has been continuous (as exemplified by Anon., 1886) and herds are generally now of highly selected purebred or crossbred stock. Henke (1929) reports on the industry to that period, and includes numerous historical references. Towne and Wentworth (1955) suggest a brisk trade in cattle as early as 1811, to supply settlements on the northern Pacific coast of America. Anon. (Editor, 1826) reports the curing of beef in 1825 (presumably by salting it) by operators in remote Hawaiian forests. Hides were also an item of trade, as was tallow, and these products



FIGURE 63.—Feral cow (*Bos taurus*) bolting from the camera in the wet forest of Hawai'i Island. These cattle are wary and difficult to approach. This scrub specimen of Hereford extraction is typical of present-day feral cattle in Hawai'i. (Norman K. Carlson photo.)

were usually sought more than the cured beef. Wilkes (1845) observed cattle in the interior of Hawai'i in 1840. Anon. (1859) describes a hunt in that year on Mauna Kea. Bird (1964, p. 210) noted in 1873 while visiting Humu'ula,

Mauna Kea, and the forests which skirt its base, are the resort of thousands of wild cattle, and there are many men nearly as wild, who live half savage lives in the woods, gaining their living by lassoing and shooting these animals for their skins. . . . [The cattle] usually keep near the mountain top in the daytime for fear of the hunters, and come down at night to feed. About 11,000 were shot and lassoed last year.

Bullock hunting figured prominently in the tragic death of David Douglas (1799–1834), the intrepid Scottish botanical explorer and mountain climber whose body was found above the present village of Laupāhoehoe in a pit trap, trampled by a captured bullock (Goodrich and Diell, 1839; Harvey, 1947, pp. 232–237). Mysterious circumstances surrounding the incident suggest foul play by the hunter who worked the trap, but the death was never adequately explained (Harvey, 1947, pp. 251–253). Traces of the traps may still be seen at the site, at 6,000 feet elevation, known as Kaluakauka (the Doctor's Pit). Wilkes (1845, pp. 203–204) sketched the layout of these traps on his 1840 visit there. In 1934 a stone monument and bronze plaque were erected at the site in Douglas' memory by the Burns Club of Hilo (L. W. Bryan, 1934, pp. 28–30), and a grove of Douglas fir (*Pseudotsuga*) is planted there. The story of this tragedy is occasionally recounted in the news media, as exemplified by J. Bryan (1964).

Cattle were used as draft animals, as Wyllie (1850, p. 53) further reports:

Oxen—these noble animals were used by the missionaries, about 1825–26. Many excellent teams are now in daily use in the city. . . . Several plantations kept from ten to fifteen yoke of good working oxen. Good yokes and good teamsters are much wanted to complete well trained and experienced teams.

Oxen continued to be commonly used until an unspecified date (Anon., 1938b), but probably into the period (at least on Kaua'i) of a well-developed sugar industry in the 1880s. Anon. (1903d) reports for the Territory in 1900, 38 working bullocks, which indicates by that time their nearly complete replacement by horses and mules, although ox teams were still employed at Molokai Ranch, Moloka'i, as late as 1908 (Cooke, 1949, p. 85). William F. Mendes of Honoka'a relates (pers. comm., 1983) that as a boy in the 1920s he drove oxen for his father's business of cutting and hauling firewood to sugar plantation camps of the Hāmākua coast on Hawai'i, out of the Āhualoa Homesteads.

The first tannery in Hawai'i was opened in Honolulu in 1904 (Anon., 1904c, 1905). Cattle for the O'ahu markets, in the absence of refrigerator ships, have by tradition been shipped alive from the outer islands for slaughter. The colorful operation of loading cattle onto the inter-island steamers by driving them into the surf, towing them out, and slinging them aboard, has attracted much attention (Anon., 1903c). This method has been only recently completely outmoded by the mobility of truck transport and adequate docking facilities, but it remained in use at least until 1947 (Clarke, 1947).

Reynolds (1850) summarizes early conditions in the keeping of livestock in Hawai'i. With the abundance of cattle, problems soon arose in relation to their control. Johnson (1850) discusses the matter of fencing, and R. J. Baker (1944) notes regulations imposed for Honolulu in 1850. An early description of the effects of cattle on the eastern Waimea Plain and in the Hāmākua forests is thus vividly presented (Anon., 1856):

It is in the memory of many foreigners now living there, when the whole of these plains were covered with a thick wood, to the very edge of the slope. Where now hardly a tree is to be seen for miles, we were informed by an old resident, that twenty-five years ago he lost himself with his team in the woods. . . . The clearing of the land has been almost entirely effected by cattle. The few head brought by Vancouver in 1793 increased so rapidly, that early in the present century thousands of them were killed for their hides. At this moment they swarm in the thick jungle that covers the windward or eastern slope toward Hamakua. They are now gradually destroying this, and thousands of old dead trees both standing and lying prostrate, form the present boundary of these woods, and exhibit the mode in which the destruction is effected; for whilst the old trees die of age, no young ones are seen taking their places, as during the last thirty or forty years, the cattle have eaten or trodden them down.

Hillebrand (1856, p. 36) cast a warning about the consequences of continued overpopulation of cattle and pleaded for moderation, when he said:

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J. Bryan

The small area of our islands is too valuable to be devoted to cattle rearing. Allow them to multiply for all the legitimate purposes of the dairy, home consumption and supplying of shipping. . . . If we rear them for the sake of their hides and tallow, I imagine the expense of producing them is too great. We forfeit by it the vital sources of our soil.

There appears to have been little interest or action toward the extirpation of feral cattle, even late in the second half of the nineteenth-century. During this period we suppose a gradual usurpation of former forest lands for sugar cane, pineapples, and cattle ranching. Many miles of stone fences, wherever stone was available, outline boundaries of old paddocks. Some are effective stock barriers today. Some purposely include low ports for the passage of pigs, as I have observed in the Puna District, on Hawai'i. On the upper slopes of Mauna Kea, pasture limits were not easily defined, and the cattle ranged as high as the plant cover extended. In 1889 a survey party availed itself of the presence of cattle to supplement their rations (E. D. Baldwin, 1889), and the cattle were probably abundant enough that such poaching was overlooked.

The largest and most persistent cattle problem was on Hawai'i, and much of the discussion centers on this island. C. S. Judd was a proponent of forest protection and has presented a summary account of action taken (C. S. Judd, 1936). He states:

The first steps toward the protection of the *mamane* forests on Mauna Kea slopes were taken in 1907 when adjacent ranchers built fences at the upper limits of their pastures to keep their tame cattle from joining bands of wild cattle higher up on the mountain slopes.

The first proclamation making the mountain a forest reserve was signed by the governor on June 5, 1909, and embraced 66,600 acres of practically all government land.

In early writings, C. S. Judd (1918, p. 129) asked for the curbing of unowned cattle, and stated: "If this one element of damage were removed once and forever, a great deal will have been accomplished for forest protection in Hawai'i." Later (1927a) he called for extensive research in forestry and noted an apt remark made by Albert Koebele in 1900. Judd was so impressed by the ecological disturbances wrought by cattle that he (C. S. Judd, 1927b) labeled the time from 1815 to 1921 as the "cattle period in Hawaiian forestry." This suggests that workable control measures were in effect about 1920, although Anon. (1919a) made an additional strong plea for them. Lyon (1919, p. 300) states, in reference to loss of O'ahu forests: "Cattle have been the greatest factor in pushing the forests back to their present narrow limits, and at certain vital points cattle are still allowed to penetrate the remaining forests."

Fencing of the forests on Hawai'i was followed by stock removal. L. W. Byran (1937b) reports that the last cattle were taken from the fenced reserves on Mauna Kea about 1931, and refers (p. 9) to what was probably the remnant herd in the lower wet Maulua section that was extirpated in 1942 when the last bull and 11 other head were trapped by Kūka'iau Ranch men (p. 143). The same



FIGURE 64.—Feral bull retreating through the rain forest of South Kona District, Hawai'i. Principal vegetation is the tree fern (*Cibotium*) and the 'ōhi'a tree (*Metrosideros*). Feral cattle are small; bulls may weigh perhaps 1,000 pounds (450 kg) and cows about 600 pounds (275 kg). (Norman K. Carlson photo.)

author pointed to the last stand of feral cattle as the "southeast slopes of Mauna Loa above the 5,000 foot contour," where about 200 head were estimated then to remain.

Some stray cattle of Hereford and possibly Shorthorn derivation were still known on Kaua'i in the 1960s, according to game division personnel. These animals were in the forests of the Pu'u Ka Pele and Kōke'e areas and were mostly unbranded ranch stock that could not be effectively controlled by ordinary range practices. Cattle were formerly present and hunted in the region of Hipalau, on that island (H. P. Judd, 1939a).

Although feral cattle are generally recognized as a reservoir of tuberculosis, because these herds do not mingle with domestic stock no statewide program is in effect to extirpate them. Strict attention has been paid, however, to the problem on O'ahu. The Biennial Report of the Hawaii Department of Agriculture and Conservation, 1960-61, reports (p. 30) that cattle tuberculosis there was nearly under control, and that, "in the premises quarantine on Oahu, 25 cattle were trapped out of the wild mountainous terrain and sent directly to slaughter." Dr. Ernest H. Willers, State Veterinarian, stated (pers.

comm.) on May 23, 1962, that this herd had finally been removed and that O'ahu was free of feral cattle.

Moloka'i was once inhabited by feral cattle, but the last of these were shot out in the years 1938-1940, from the vicinity of Pu'u Kolekole (Noah K. Pekelo, Jr., pers. comm.). Cooke (1949, pp. 45-52) records facets of cattle rearing, tallow production, and range abuse on Moloka'i, and describes the practice in which a captured feral bullock was tied to a tame "pin-ox" that eventually led the wild animal down to ranch headquarters. Kaho'olawe was used, with marginal success, as a cattle station after 1918 (E. H. Bryan, Jr., 1931), but abandoned, for feral animals seem not to have existed there in 1931. Uncontrolled cattle were known on Maui until about 1930, in the Kula Forest Reserve, particularly in Pu'u Ke'okea and Polipoli areas (J. S. Medeiros, pers. comm.). These cattle were finally extirpated under incentive permits granted to hunters who killed specified numbers of goats.

On Hawai'i there may have been as many as 2,000 head of stray or feral cattle in the 1960s. In July 1962, L. Nichols, Jr., noted (pers. comm.) abundant sign in the Puna Forest Reserve above the Kalapana-'Opihikao area, and in the same region R. E. Bachman reported (pers. comm.) additional frequent sign of cattle in January 1966. In November 1965, Norman Nichols kindly made a brief inquiry among ranchers of west Hawai'i and reported (pers. comm.) that McCandless Ranch was aware of some 1,500 feral head on their lands; Yee Hop Ranch, 200; Dillingham Ranch at Honomalino, about 200. These were all in South Kona District on the flank of Mauna Loa. Small bands were thought to exist on other remote ranches, and some cattle may well have occupied also portions of the adjacent forest reserves. Adequate data were not available for plotting exact range and abundance of these animals. A report of the Territorial Board of Agriculture and Forestry (Anon., 1958e) indicates that control measures were then being applied in limited fashion in the Kona districts. L. W. Bryan (1937b, p. 9) found the animals living in a rough lava-strewn area, over which a horse or man makes slow progress. Once the cattle started to run they were difficult to catch, even with dogs. He found also that, "except in dry weather, these animals are usually in good condition and the meat is well worth packing out."

In spite of the potential hazard of tuberculosis, practices on some ranches have included a loose management of these scrub cattle, in which they were caught, males castrated, and selective marketing done. Feral cattle are, of course, owned by the ranch they occupy.

However interesting stray cattle may be from an ecological viewpoint, it is certain that Hawai'i has seen more than enough of the results of their presence. A strong program should be activated for eliminating these animals from public

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lands, and cattlemen should support any reasonable program proposed for the elimination of their own feral herds.

Few studies have been made on the process of change in flora and lands under the pressure of cattle, although one thorough report relates reproduction of *koa* (*Acacia koa*) to grazing (Baldwin and Fagerlund, 1943). Cuddihy (1984) expanded this early study to include the soils and entire vegetation of the same ecosystem on the mid-slope of Mauna Loa. Swezey (1919) found insects to be a factor in *koa* seed production. It is most unfortunate that sample areas of native flora could not have been protected by fences, from the earliest times. It is heartening to know that a system of reserves, as proposed by Warner (1961), was initiated in 1970, although some researchers then gave little credence to the practical aspects of even this simple expedient (Degener and Degener, 1961). By 1984 the State Natural Area Reserve System included about 20 reserves.

As of 1983 feral cattle are still generally entrenched as indicated in earlier years. New herds were reported on Moloka'i in 1972 (Pekelo, 1973), and they occupied a strip of upland forest and ranch land about ten miles long. Another modern day episode concerning feral cattle is taking place in the uplands of south Mauna Loa. A stock of abandoned cattle had thrived on Kahuku Ranch in a pocket below the cliffs at South Point, in the vicinity of the old site of Wai'ahukini. When this land changed hands in 1969, Freddie Rice, then Kahuku manager, obtained a contract to remove all cattle from the area. He found some surprisingly wild-type stock. Selecting a dozen cows and one bull that was particularly attractive, he released them in the higher range land of Kahuku Ranch where safari type expeditions were projected for photography and some hunting, to include use of the bison and mouflon sheep brought to the ranch in 1968. In 1971 the original feral bull was replaced by one of Texas longhorn stock introduced from Verdugo Ranch in California. However, the project was left gradually to its own devices when Rice moved on to another job (Frederick H. Rice, Jr., pers. comm.).

The cattle have thrived at the mountain site and remain isolated from managed ranch stock. A cursory ranch survey in September 1983 censused 34 head in the release area, and an unknown number were thought to be present on the vast slope of Mauna Loa extending above South Kona (Gilbert Medeiros, pers. comm.). Kahuku Ranch has no plans for control or management of the herd. This raises some question about the future of these lands and adjacent reserve lands, and the natural biota they support.

The colorful story of cattle in early ranch days is related by Brennan (1974) in his report on the Parker Ranch. Halloran (1972) issued a summary of cattle types in Hawai'i before selective breeding of refined beef animals was well

established. Rouse (1973) places modern and older Hawaiian cattle in perspective by including examples and data in his world survey. Finch and Western (1977) provide information on ecology of cattle in some currently primitive societies. The flavor of the Old West persists in occasional flurries of cattle rustling, as noted by Rood (1974). Rustling is, of course, a serious crime, with heavy penalties levied against the culprits.

Cattle ranging free on small islands are not usual in Hawai'i, but examples from New Zealand are of interest (Taylor, Bell, and Wilson, 1970; and Dilks and Wilson, 1979).

Capra hircus. Domestic goat (includes wild, domestic, and feral forms).

ORIGINAL DESCRIPTION: *Capra hircus* Linnaeus, Systema Naturae, Ed. X, 1:68. 1758.

TYPE LOCALITY: Sweden.

NATIVE RANGE: Wild forms (subspecies) occur on the Greek Islands, in the Caucasus, southern Turkmenia in Russian Turkestan, Asia Minor, Iraq, Iran, to Baluchistan and western Sind, India (adapted from Ellerman and Morrison-Scott, 1951, p. 405).

RANGE IN HAWAII: Goats are now present and at least sparsely distributed on all main islands except Ni'ihau and Lāna'i. Populations not under satisfactory control exist on limited areas of Kaua'i, Maui, Hawai'i, Kaho'olawe, and perhaps Moloka'i.

The familiar domestic goat (Reed, 1959, p. 1634; 1960, pp. 130-134) probably arose about 8,500 years ago in southwestern Asia, from a presently extant ancestor, *Capra hircus aegagrus* Erxleben, and is not distantly removed from this wild form. Twisted horns of certain domestic and feral strains, as distinguished from the scimitar-shaped horns of wild goats, have seemingly developed through selection for this mutation. None of the various wild ibexes (*Capra* spp.) has been domesticated, and hence make no contribution to breeds of domestic *C. hircus*. The goat in Hawai'i is properly referred to at the subspecific level as *Capra hircus hircus*.

Feral goats in Hawai'i are readily tamed and many of those staked out among the plantation villages were captured as kids. Thus there is often no distinction between feral and domestic forms, although selected strains usually are kept from mixture with stocks of feral origin. The feral goats are generally black, black and brown, or brown, suggesting possible natural selection for these darker colors. White flank patches are sometimes present. Some flocks, as on Hualālai, are made up largely of spotted, pale-shaded, or silver animals. Hair is often short, although a beard and full mane give some animals a shaggy appearance. Typical curved horns that swing upward and backward, as well as



FIGURE 65.—Feral billy goat (*Capra hircus*) in the rocky uplands of Lānaʻi. This is a robust specimen with horns and color pattern typical of this population. Nichols (1961c) reports horns spreading to more than 26 inches (66 cm). An illustration in E. P. Walker (1966, p. 1474) shows an almost identical color pattern, but scimitar-shaped horns, in a wild goat (also *Capra hircus*) from Crete. Hawaiian feral goats weigh about 50 to 90 pounds (23 to 41 kg) for females, and 80 to 120 pounds (33 to 50 kg) for males. (Lyman Nichols, Jr., photo.)

those flattened and twisted outward, are present in Hawaiian populations. Yocom (1964) describes goats in specific areas on Maui and Hawaiʻi, and Graf (1959b, 1963) briefly considers the factors of isolation and habitat in relation to pelage, horn form, and hoof wear on Molokaʻi and Lānaʻi.

Captain Cook left goats on Niʻihau during his first voyage to Hawaiʻi, on February 2, 1778. He remarks as follows (Cook, 1785, Vol. 2, p. 217):

On the return of the boat, I went myself with the pinnace and launch up to the point . . . taking with me a ram-goat and two ewes . . . and the seeds of melons, pumpkins, and onions; being very desirous of benefiting these poor people, by furnishing them with some additional articles of food.

Thus were the fruits of an advanced civilization first thrust upon the native Hawaiians.

Although the original goats had increased to six within one year, all were

killed in a dispute over their possession between rival chiefs of Ni'ihau and Kaua'i (Cook, 1785, Vol. 3, p. 95). Cook must have left other goats on Hawai'i early in the winter of 1778-1779 when his party was lavishly entertained and provisioned for several weeks at Kealakekua Bay. It was only on his return to the bay for emergency repair of a mast that disorders arose and resulted in Cook's death. The small matter of landing of livestock could easily have been omitted from the record under these circumstances.

George Vancouver was among Cook's officers and later returned several times to Hawai'i in command of his own vessel while extending the Pacific explorations. On the first of these visits, in 1792, Vancouver (1798, Vol. 1, p. 156) notes that Tianna [Kaiana], one of the chiefs at Kealakekua, already had several goats and that he did not present this chief with others. At Kawaihae the captain observed in 1793 (Vol. 2, p. 115) that another chief, Kahomotoo [probably Keeaumoku], "had taken the greatest care of the goats I had presented him with on a former occasion."

It appears, then, that goats were well known in Hawai'i by 1793, and must soon after have become common. Marques (1905), in a summary article, reports them as abundant by 1850, and apparently widely distributed in the wild. Goats may have been an item of trade for many years for their skins, and A. S. Baker (1916) reports evidence that they were systematically trapped even in remote places at some unknown time before 1916.

The poor quality of feral-type goats as milk producers is indicated by Thurston (1920), who advised the importation of selected breeds for milking. His scheme was unsuccessful, we may surmise, because of a probable lack of interest in the feeding and care of highly bred domestic stocks by the ordinary person who was to have benefited from it.

Problems of goats in excess numbers were most prominent on Hawai'i, and were closely interwoven with other livestock problems. There was little active concern about them before 1910, but the record of progress after that time is clear, as outlined in reports of the Territorial Board of Commissioners of Forestry and Agriculture. In the 1913 report is the statement (p. 53), "Through the co-operation of corporations and individuals much, of course, has been and is being done, in fencing, in protection, and in some cases in forest planting." Specific mention of goats was made in the 1922 report (p. 24):

An investigation and special report was made and forwarded to the Governor during the past year on the wild goat menace throughout the Territory. The basis for this report, in addition to general observations, was the participation, in June, 1922, in a two-day goat drive chiefly by boy scouts on the government leased lands of Puuanahulu and Puuwaawaa, Hawai'i, which resulted in extermination of 7000 wild goats. The conclusions reached in this report are that the unchecked wild goat population constitutes a menace to forest and grazing interests in the Territory, especially on Hawaii and Maui, that the most feasible way to control this pest is to conduct extensive drives and follow them up by extermination by

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expert hunters, that the land owners and Territory should cooperate in this work, and that \$20,000 should be appropriated as the government's share in the undertaking.

By 1929 there was further advancement, as is reported for that year (p. 22):

Warfare on the goats must be continued on Hawaii where the inaccessible lava flows provide retreats and breeding places. The situation is well in hand on the other islands where wild goats have become a rarity in most sections.

In 1931 (p. 38) a summary of populations in the islands indicated only 150 goats on O'ahu, but 75,000 on Hawai'i (apparently from L. W. Bryan, 1930). C. S. Judd (1936) indicated that goats on Mauna Kea were not of particular importance, as were the sheep, but had moved over there from Mauna Loa during the dry season of 1925 (apparently from L. W. Bryan, 1927). However, goats remained common in the vicinity of Mauna Kea (Nichols, 1964d). L. W. Bryan (1939) reports on the Ka'u fence, which would seem to have been a barrier erected on the southeast flank of Mauna Loa primarily to keep goats of the lava uplands from invading the lower forests. Sheep and cattle are not reported as ever having been abundant in this region.

Although goats were, and are, significant as a factor in forest and range deterioration, if not in the extinction of some specialized plant forms, they have been controlled on the smaller islands through unrestricted hunting. H. P. Judd (1939b) reports on the decimation of O'ahu goats probably well before 1920, and they are scarce there today. Goats had been present on Ni'ihau in the early 1900s (H. P. Judd, 1938b), but were annihilated from there about 1910 (Forbes, 1913b) as reported by H. P. J. (1930, p. 193) when "the contract of clearing goats off Ni'ihau was given to a Hawaiian hunter, and in a few years the last goat was brought in." At this time (1930) goats were few on Lana'i, and were thought to have been eradicated from Kaho'olawe, although C. S. Judd (1916) had estimated 5,000 on the latter island in 1906. Von Tempski (1928) and MacPhee (1931) indicate a large population on Kaho'olawe in or about 1918 when effort was made to reclaim the island for cattle raising. The 1966 population was estimated at more than 2,000 (Comdr. C. Zirzow, U.S.N., pers. comm. to R. J. Kramer).

Goats persisted as a managed game animal on Lana'i only through regulated hunting (Anon., 1955b; Medeiros, 1964a), and on Kaho'olawe they lived unattended by humans for many years. Kaua'i goats occupy some rugged and remote areas (M. Miller, 1937), but are carefully managed as a game species (Swedberg, 1964a, 1965), with hunting permitted only at specified times. East Moloka'i forests, however, still supported uncontrolled numbers of goats as late as 1964 (L. Nichols, Jr., pers. comm.)

Goats have presented the greatest problems of control on Hawai'i, and lesser ones on Maui. Trouble has occurred especially within the national parks where alien animals are undesirable in any numbers, in keeping with a firm purpose



FIGURE 66.—A goat drive on the rugged coastal slope of Hawaii Volcanoes National Park, island of Hawai'i. This is ideal goat habitat and a chronic problem area. Animals of this region are usually solid black, but white flank patches, spotting, and pale shading can be seen. (National Park Service photo.)

of the parks system to encourage and preserve only the native fauna and flora. A wise companion policy which restricts the parks from public hunting, unfortunately, left the parks with an overabundance of goats, and a difficult dilemma. Geerdes (1964) summarized these conditions for the park on Hawai'i, since 1921. Lamb (1938) considered the problem alleviated at that time, following a program of drives and fencing. Yocom (1964, 1967) in a brief ecological study of the populations in both the Hawai'i and Maui parks, suggested fencing as a final solution to the goat problem. Repeated drives in Hawaii Volcanoes National Park (Anon., 1965d) did little more than skim the surplus animals from the landscape. Feral goats may be an important factor in the ecology of the Hawaiian goose (P. H. Baldwin, 1947b), in the parks and elsewhere.

The goat appears to be a permanent member of the Hawaiian fauna because of its usefulness as a game animal (Nichols, 1961c). Graf (1957) suggests that this species be hybridized with one or several of the ibexes (*Capra* sp.), in order to improve its quality as game. No actual program was ever set up for this. The goat deserves more attention than has been given it, and it should be intensively studied from the aspects of characteristics, adaptive qualities, management, and control. Turbott (1948), Riney and Caughley (1959), and

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Atkinson (1964) have presented results of studies in New Zealand that should be of interest to investigators in Hawai'i.

With a firm resolve about 1972 to face the problem squarely, and with funding to accomplish it, the U. S. National Park Service has effectively eliminated the goat from Hawaii Volcanoes National Park. Considerable political urging was needed, but the results are in. The 1984 estimated number of goats is fewer than 30, and these employ all the wiles of the species for survival, including retreat to deep lava caves when pursued.

As late as 1970, park policy, in its applications, had favored a sustained yield program dictated by local hunting interests (Smith, 1971). The basic plan for goat eradication, however, was laid (Baker and Reeser, 1972) and soon thereafter put into practice. The fencing of manageable units of land was a key element, and this allowed for drives and final clearing of stragglers with the aid of especially schooled dogs, imported with a trainer from New Zealand (Altonn, 1972). By 1975 the massive herds were eliminated. In the eastern coastal Kalapana Extension of the park, regeneration of several native plants is well advanced (Williams, 1980). The assessment of Mueller-Dombois (1980) for the whole lowland area is also encouraging in the face of almost total devastation wrought by goats over many generations of uncontrolled habitation. Plants such as the native bean, *Canavalia kauensis*, a previously undescribed species, showed a remarkable recovery when protected from goats. A comprehensive resource management plan for Hawaii Volcanoes was adopted as a basic measure to prevent recurrence of such catastrophies as were caused by an abundance of goats (United States Department of the Interior, 1978). Effects of goats on the more resilient, yet plastic, *Acacia koa* of the park uplands is reported by Spatz and Mueller-Dombois (1973). Constant surveillance of park lands and strict maintenance of fences must be practiced in order to keep goats of adjacent ranch lands from repopulating the protected park area. Katahira and Stone (1982) report on current status of goat management and prospects for the future. Some promise is seen in release of radio-collared goats which join other goats and reveal their location.

The problem of goat damage and goat numbers at Haleakala National Park on Maui is a different one in several respects. Unfortunately, it missed the wave of the 1970s for alleviation and now becomes even more costly. The goat-infested terrain is rugged and at generally high elevation. Kjargaard (1982) brings the matter into sharp focus, noting that goats have escaped into rain forest not normally occupied, but that combined strategies should "turn the corner on the goat problem." Some private contracting and volunteer work groups are assisting the Park Service effort (Hawaii Audubon Society, 1982). Jacobi (1980) reports the plight of the *māmane* tree (*Sophora chrysophylla*) of the Haleakalā Crater, attacked here not by sheep, but by goats.

Meanwhile, the goat remains a much-sought game animal. It may have been exterminated on Lānaʻi in deference to the more desirable mouflon and axis deer on that island. None was observed in the 1981 game survey (Ueoka, 1982). On Kauaʻi, access to portions of Waimea Canyon was closed as a measure for maintaining a sustained yield of goats, and a general closed season was being considered. At the same time, the cliff areas of the Nāpali Coast of the island showed marked increase in goat numbers, to include the Hanakāpīʻai-Hanakoa region encompassing the Honoʻonāpali Natural Area Reserve. Although hunting is urged as a means of controlling the goat population in this critically important reserve, because of heavy hiker traffic along the coastal trail, firearms have been forbidden. Archery hunting is recommended to continue indefinitely. Rare endemic plants such as species of *Hibiscus*, *Brighamia*, *Lepidium*, and *Munroidendron* are recognized in the region, where "heavy use of forest vegetation" is observed. The Nāpali Coast population was estimated at 1,650 goats as of June 30, 1982 (Telfer, 1982), but with substantial reductions after initiation of bow hunting (Telfer, 1984).

Background information on the goat is valuable for understanding the animal (Payne, 1969; Noddle, 1974; Schaller, 1977). Research on biology of the feral goat in Hawaiʻi has seldom gained support, but work from other regions is useful to application here (Rudge, 1969, 1970a, 1970b, 1972; Williams and Rudge, 1969; Rudge and Smit, 1970; de Vries and Black, 1943; Watts and Conley, 1984). The papers of Dawson, Denny, and others (1975), Coblenz (1976), Kolz and Johnson (1980), and O'Brien (1982) provide more specialized information. Baldwin (1978) adds an acceptable note, and Hughes (1981) details an example of commercial production, with selected breeds of farm goats, in these modern times.

Ovis aries. Domestic sheep (includes domestic and feral stocks).

ORIGINAL DESCRIPTION: *Ovis aries* Linnaeus, Systema Naturae, Ed. X, 1:70. 1758.

TYPE LOCALITY: Sweden.

NATIVE RANGE: Domestic sheep were derived from wild sheep of central and western Eurasia. Few wild populations remain.

RANGE IN HAWAII: Firmly established on Hawaiʻi, principally on Māuna Kea and Hualālai. Altitudinal distribution on Hawaiʻi has been mainly from about 2,000 feet, as near Puʻuwaʻawaʻa, to more than 13,000 feet among the bare cinder cones of Mauna Kea summit region. Descended to sea level in the Kaʻū District, Hawaiʻi, when it was present there, and on Kahoʻolawe, which was the only other island occupied by feral sheep.

Ancestry of the domestic sheep has been defined by several incongruous



FIGURE 67.—Feral sheep (*Ovis aries*) in the lava wastelands on Mauna Kea, Hawai'i. Only the males are horned. Colors range from black to reddish brown to white. The wool is often soiled and ragged. Adults weigh 60 to 150 pounds (27 to 70 kg). (Lyman Nichols, Jr., photo.)

hypotheses involving unknown basic species, as explained by Reed (1959, p. 1635). One classification considers all Eurasian sheep, with the exception of a remote eastern Siberian race of the bighorn, *Ovis canadensis* Shaw, as subspecies of the argali, *Ovis ammon* Linnaeus. Such a view restricts the lineage of *O. aries* to the several forms of this one species. The domestic sheep and mouflon are included among these subspecies as *O. ammon aries* and *O. ammon musimon*, respectively, as listed by Uloth (1961). However, Hatt (1959, pp. 75–76) distinguishes between a domestic *O. aries* and a wild *O. orientalis* Gmelin in Iraq, and Perkins (1964) points to this second species, the red sheep, as a prominent ancestor of the domestic forms. He places domestication of sheep at nearly 11,000 years ago because of the presence in abundance of remains of young *Ovis orientalis* in the Shanidar deposits of Iraq, demonstrating human control of the sheep population. Other probable forebears of domestic sheep remain in the wild state, along with *O. orientalis*, but only as generally dwindling, small, and intermixed populations. Zeuner (1963, pp. 153–198) discusses sheep at length.

Feral sheep on Hawai'i are often referred to as Merinos, but other breeds are undoubtedly infused into this population. Kaho'olawe sheep differed in some respects from those of Hawai'i, particularly in the absence of black or



FIGURE 68.—Feral rams with unusually long horns, in bunch-grass habitat on Mauna-Kea. These sheep are derived at least in part from Merino ancestors. The strongly spiraled horns may reach a length of 34 inches (86 cm) (Nichols, 1964g). (Ronald L. Walker photo.)

brown in the wool color (R. J. Kramer, pers. comm.). Munro (1947) discusses sheep on Hawai'i, Lāna'i, and Ni'ihau, and implies that differences in their characteristics arose through isolation.

Domestic sheep are relatively adaptable to a feral existence, provided they are not exposed to wild predators. Feral populations are actually established only on islands where no large native carnivores are present. Examples outside Hawai'i are reported by Boyd and others (1964), Wilson and Orwin (1964), and Wodzicki (1961), and form useful comparisons with Hawaiian populations. The first introduction of sheep to Hawai'i is attributed (Wyllie, 1850, p. 45) to Captain James Colnett, who is said to have landed a ram and two ewes on Kaua'i in April 1791. B. Judd (1929, p. 51) refers to Wyllie's statement and reports the ship as the *Argonaut*, a merchantman that had come from the Pacific coast of North America.

Vancouver documented his importations more completely and precisely. He put a ram, two ewes, and a lamb born in passage from California, ashore at Kawaihae on Hawai'i, February 14, 1793 (Vancouver, 1798, Vol. 2, p. 115), in the care of Kahomotoo (Keeaumoku), a chief whom he had met and presented with goats on the 1792 stopover. He then proceeded to Kealahou and sent ashore his remaining sheep (Vol. 2, p. 127), a ram and two ewes.

On this third visit to the islands (Vol. 3, p. 11) Vancouver landed two each of rams and ewes at Kealahou on January 19, 1794, as a gift to Kamehameha I. In coasting northwest after leaving the island of Hawai'i, he remarked (p. 70)

on March 5, "I had reserved some sheep for establishing the breed in each of the islands." But as they waited off Moloka'i, an expected chief did not appear, the day being taboo, and they sailed on without leaving the sheep as intended. It is not clear if others of the six remaining animals were left on O'ahu or other islands visited. However, sheep became firmly established as a result of these early importations and were accorded royal protection, as were the cattle.

Sheep raising did not thrive quickly (Meek and others, 1853), but some animals must have wandered early and were able to survive at least for a time, for Ellis (1917, p. 304) reports that Joseph Goodrich stated, after his second trip to Mauna Kea, most likely in 1825, "Very near to the summit, upon one of the peaks, I found eight or ten dead sheep; they probably fled up there to seek refuge from the wild dogs." Kenway (1851, p. 72) envisioned the drier unforested western portion of the Waimea Plain as a sheep run. If cattle had used this area in earlier years, as Vancouver intended they should, they were in Kenway's time already driven from it by the bullock hunters:

The outer plain of Waimea, extending to the base of Mauna Kea and sloping toward the sea, a hitherto unused and useless tract . . . is a fine example, and on this land alone, a profitable and interesting population [of sheep] might be brought to exist, break the dismal silence and redeem the idle wilderness.

The Parker Ranch Humu'ula Sheep Station was formally established in 1876, although the site was occupied well before 1873 for ranching purposes (Bird, 1964). Stray and feral dogs reputedly hindered sheep farming in early times, and continue to harass the residual domestic flocks as well as the managed feral populations. This aspect is discussed under *Canis familiaris*. Dogs have likely been a selective factor in the development of wildness in feral strains of sheep, but its effect has not been quantified.

Lāna'i was another early site for sheep raising, as was Ni'ihau (Anon., 1893). Although nearly 100,000 domestic sheep were tallied for the Territory of Hawaii in 1903 (Report of the Territorial Board of Commissioners of Agriculture and Forestry for 1909, p. 138), this industry has almost disappeared. Dr. Estel Cobb of the University of Hawaii informed me in 1962 (pers. comm.) that some 10,000 sheep then remained, principally on Ni'ihau and on Hawai'i, but with small flocks scattered throughout the islands. The Humu'ula operation became a classic in Hawaiian ranching and is the source of many descriptive articles, exemplified by Anon. (1902d, 1906). Plans for closing out the station as a sheep farm in 1964 (Anon., 1963e) were carried out. Economic reasons, including competition in both the lamb and wool markets, costly replacement of equipment, poaching, and predation by dogs and by pigs (on lambs), forced this action.

Ecological disturbances caused by feral sheep on public lands were long overshadowed by cattle problems, and have not so frequently come to public



FIGURE 69.—Highlined *māmane* trees in heavily depleted sheep range on Mauna Kea. The browse line is at 54 inches (1.8 m). (Jon G. Giffin photo.)



FIGURE 70.—One-acre sheep enclosure at Pu'u Kōle, Mauna Kea, established in 1963. Substantial recovery of vegetation is apparent in this photo, after 16 years, in 1979. A grove of unprotected trees at the far right died out during the experiment. (Jon G. Giffin photo.)

attention. Feral sheep were also more restricted in range and less plentiful than cattle, until cattle were brought under reasonable control. The principal concentration of sheep has been in the forest of *māmane* (*Sophora chrysophylla*) at the middle and upper levels of Mauna Kea. When cattle were restricted from this area, sheep continued to thrive in large numbers and to further derange the soils and vegetation.

Serious effort to control sheep on Mauna Kea was under way by 1934 (L. W. Bryan, 1935), but the same author reported three years later (1937a) an estimated 40,000 sheep still present. In a summary paper (1947) he estimated that nearly 71,500 sheep had been slaughtered on Hawai'i in the period from 1921 to 1946. By 1949 there was concern that the population structure had been disrupted on Mauna Kea, and that the numbers of sheep were dwindling (L. W. Bryan, 1950). A closed season was declared in 1949. The sheep recovered and under a management plan became a popular game animal. Anon. (1955a, 1955b) report a favorable season that year; Collins (1957) demonstrated the quality of hunting afforded by the feral sheep in that period, and Nichols (1964g) reports further on this subject. Management practices included the building of roads to permit hunters access to remote areas of sheep concentration. Nichols (1964f) described construction of enclosures for the evaluation of browsing and its effect on growth and reproduction of *māmane* in this region.

The Mauna Kea sheep population has demonstrated cyclic aspects observable in annual census figures. Following the low of 1949 of perhaps 500 animals, mostly rams, by 1958 there were some 3,000 in all, and a peak number of about 4,000 in 1960. Ewes now consistently outnumber rams. A population reduction to about 1,100 in 1962, in spite of less liberal hunting regulations, may be attributable to a natural decline in the reproductive rate, as shown in population tables (Bachman, 1963).

The downward trend leveled off (Nichols, 1964c), and a 1963 recommendation for a desirable herd size of 1,300 to 1,500 may have been realistic in relation to the necessity for re-establishment of natural *māmane* seedlings at higher altitudes. Under such a plan, gradual increase of sheep could be permitted to follow increments of available forage. Some areas of traditional sparseness of sheep were reserved for archery hunting (Nichols, 1961b; Kosaka, 1965).

The future of feral sheep, however, became seriously threatened in the 1970s as ecological problems intensified relative to its habit of consuming the dominant forest species of its principal habitat on Mauna Kea, the *māmane* tree. This plant is a nutritious legume likened to alfalfa as a food for herbivorous mammals. Three endemic passerine birds depend for sustenance on this tree in Mauna Kea habitats, and the *palila* (*Loxioides bailleui*) occupies no other range

except the native forest on the upper slopes of the mountain. Survival of the *palila* as a species depends on survival and health of the *māmane* forest. Its principal foods are seeds from green pods of *māmane* and insects associated with this and the *naio* tree. Van Riper (1980a, 1980b) has provided the most recent and most detailed documentation of these facts. The ultimate cause of decline of the *palila* is related to decline of the forest. Scowcroft (1976a, 1976b, 1978, 1981, 1983), meanwhile, has researched the problem of the mechanism of forest decline. All avenues have led back to the root cause—too many sheep over too long a period.

Legislation of the period produced firmly set laws for the protection of native wildlife, under the federal Endangered Species Act of 1973 and the Hawaii Endangered Species Act of 1975. The *palila* was listed by federal statute as an endangered species in 1967. As such, the bird was entitled to the preparation of a "Recovery Plan," a document which surfaced in due time (United States Fish and Wildlife Service, 1978).

A highly professional-quality management plan for the sheep (Giffin, 1976) was a valuable contribution to the solution of the sheep/*palila* controversy in that no basis could be found to justify continued presence of sheep other than the desire of hunters to have them there. The issue was clouded somewhat by accelerated development of astronomy facilities on Mauna Kea and the time-consuming formulation of a master plan for the state lands of the entire upper mountain (State of Hawaii Department of Land and Natural Resources, 1977). As a policy document the Mauna Kea Plan presented an ambivalent position by providing for ample sheep hunting and at the same time declaring for protection of the endangered *palila* and its life-supporting *māmane* habitat. Mull (1977) wrote an analysis of these incongruities.

The federal Endangered Species Act includes provision for a citizens' suit to enforce protection when an agency fails to do so (Section 9). As early as June 22, 1976, the Hawaii Chapter of the Sierra Club threatened to sue the state when "business as usual" management practices persisted on Mauna Kea, in further jeopardy of the *palila* (Anon., 1977). When another 18 months passed with no perceptible action by the State, the Sierra Club (1978) filed a lawsuit in the Federal Court of Honolulu. A decision rendered on June 6, 1979, held that the proposal for restricting sheep to a portion of the *māmane* forest was an ineffective solution and ordered all feral sheep and goats removed (Kobayashi, 1979). In an oddly timed decision, game officials closed the sheep, goat, and pig seasons for the period August 4–September 20 "because of the low population of game mammals on the mountain."

An intransigent state administration did "nothing," as the judge phrased it, in the next 11 months toward meeting a court-ordered July 31, 1981 deadline for clearing the sheep from Mauna Kea to promote interests of the *palila*

(Kobayashi, 1980). In a sequel article, Woo (1980) reports that the administration finally relented. Hunting would begin June 7, 1980, and continue indefinitely on succeeding weekends. Sakai (1980a) reports that some 780 sheep and 75 goats remained on Mauna Kea at the start of the eradication. Various tactics were used, including hunting by the wildlife staff from helicopters. When numbers dwindled the animals were considered for practical purposes to have been eradicated on July 31, 1981, satisfying the legal constraints (State of Hawaii, Department of Land and Natural Resources, 1981b). After 20 years, the position taken by Warner (1960, 1961) had been vindicated. It is not presently clear that repopulation is not in progress from stock living usually on ranch lands below the aging and deteriorated boundary fence, although precautions against repopulation have been outlined (Bachman, 1984). Juvik and Juvik (1984) provide a measured overview of the entire problem.

Farming of domestic sheep has been at a low ebb for a number of years, but a resurgence is evident as local markets for lamb, mutton, wool, and skins have strengthened. Examples of new herds of prized domestic breeds are reported for Maui (Tanji, 1978) and Hawai'i (Sakai, 1980b). To date none of these is being run in the vicinity of Mauna Kea.

Ovis musimon. Mouflon.

ORIGINAL DESCRIPTION: *Aegoceras musimon* Pallas, Zoogeographica Rosso-Asiatica 1:230. 1811.

TYPE LOCALITY: Sardinia.

NATIVE RANGE: Islands of Sardinia and Corsica. Introduced variously into southern, central, and eastern Europe; also into Texas in the United States.

RANGE IN HAWAII: Recently established on western Lāna'i, and on Hawai'i, on Mauna Loa and among the feral sheep of Mauna Kea. Introduced to Kaua'i but failed to survive.

The mouflon is usually considered a true species of wild sheep, but some European writers (Uloth, 1961; Pfeffer, 1967) treat it as a subspecies of the argali of Asia, *Ovis ammon* (Linnaeus). The mouflon has been widely distributed through Europe by man, from its original range on the two Mediterranean islands. In the United States it thrives in zoological gardens and on private game range in Texas (De Vos, Manville, and Van Gelder, 1956, p. 169). Origin of Hawaiian populations is unknown, other than from several specific zoos and private animal collections on the United States mainland, and from the Honolulu Zoo. It is a vigorous stock and seems to be typical of the species.

First release of mouflon in Hawai'i was on Lāna'i, on July 30, 1954 (Medeiros, 1954). This and subsequent releases on that island included 28 animals (R. L. Walker, 1959b). This sheep is well adapted to the rugged ridge

and gully lands sloping from the central plateau of Lāna'i westward to the sea. The population increased rapidly and when it reached about 200 sheep in 1964 (Medeiros, 1964b), a first season for the taking of 40 rams was declared (Anon., 1964p).

Mouflon were considered for addition to the fauna of Kaua'i, and four were released in 1958 (R. L. Walker, 1959b). These disappeared and no further stock was released there. Establishment of the species on Hawai'i is related to the mouflon-feral sheep interbreeding program, and is discussed in the following section.

As of 1984 populations of mouflon are managed for regular public hunting on Lāna'i and on Mauna Kea. A release in the Kahuku Ranch on the south rift of Mauna Loa appears to be established on these private lands, with an estimated population of several hundred, largely in alpine scrub habitat at 4,000 to 6,000 feet elevation (C. H. Bredhoff, Jr., pers. comm.).

The species is well distributed throughout the Lāna'i game management area with a 1981 population of nearly 900. Of 61 hunters, 41 percent were successful in bagging a permitted ram during that season. It was judged that as many as 41 rams could be taken in subsequent years without altering the favorable known 1:2 ram to ewe ratio (Ueoka, 1982).

In 1980 the mouflon assumed a new prominence as it was not included in the court ruling for removal of feral sheep and goats from Mauna Kea. Thus it is in the wings as the surviving hope of hunters for a viable stock of big game on the mountain. The unfortunate prognosis is that the mouflon, now standing at perhaps 500 animals, presents many of the undesirable features of feral sheep in the *māmane-naio* forest. Predictably, in a matter of time it will threaten the *palila* just as the feral sheep did (Scott, Mountainspring, and others, 1984). It is probably well said that what Mauna Kea needs now is an opportunity for rest and recovery, not more sheep.

As a sequel to feral sheep studies, Giffin (1980) has produced an excellent evaluation of the mouflon. Besides providing a detailed background of the species in native range and as introduced to other parts of the world, this report covers its biology on Mauna Kea and implications for management. The following paragraph paraphrases Giffin's work.

Mouflon occupy primarily the eastern slope of Mauna Kea where 78 were released between 1962 and 1966 in the vicinity of Kahinahina. Spread to new areas has been slow and there was a tendency for segregation from feral sheep. Few of these intermingled with the mouflon. It is probable that standing water is not utilized, rather that moisture is obtained from green plants and dew. The population rose to an estimated 525 by 1979, even after annual harvests beginning in 1975. These sheep range into ranch lands below the game management boundary, utilizing breaks in the fence for passage. About 40

WAI

MOUFLON



FIGURE 71.—Male mouflon (*Ovis montanus*) used in the project for hybridization with feral sheep at Pōhakuloa, on Hawai'i. Hybrid and pure mouflon have been released among the feral sheep of Mauna Kea. Adult mouflon rams weigh as much as 160 pounds (73 kg) and ewes attain perhaps 90 pounds (40 kg). (Lyman Nichols, Jr., photo.)

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percent of sheep counted in surveys were on ranch lands. Mouflon travel generally in small groups, but as many as 140 were observed in one herd, representing up to three fourths of the animals of the local region. Monitoring of exclosures established in 1963 shows that mouflon are carrying on the suppression of native vegetation much as did the feral sheep, in particular at the critical upper tree line where the forest is heavily depleted, to include stripping of bark from *māmane* trees.

Giffin (1980) makes good use of the world literature and includes an extensive bibliography of the mouflon. The papers of Kilham (1972) and Uloth (1976) are additions to this stock of information. McEldowney (1976) prepared an exhaustive bibliography useful to all aspects of concern about Mauna Kea. Powell (1985) reviews the plight of the native silversword (*Argyroxiphium*), another victim of browsing livestock on the mountain.

Ovis musimon x Ovis aries. Mouflon—domestic sheep hybrid.

Hybrids between these two forms are well known and are completely interfertile. This tends to support the assertion that these sheep are not distinct species. Borland (1964) lists the chromosome number of the domestic sheep as 54 and that of the mouflon is the same (Kurt Benirschke, pers. comm.).

In order to carry out a program to increase the quality of big game in Hawai'i (Nichols, 1962b), the hybridization of penned mouflon and feral sheep began with the importation of mouflon to Pōhakuloa, Hawai'i, in 1957 (R. L. Walker, 1959a, 1960; Uloth, 1959). The intended result of this breeding project was a sheep that was 7/8 mouflon, to be achieved by a series of selective matings, as proposed and outlined by Graf (1957). Desired features of such an animal were a superior trophy head, wildness, and a tendency to congregate only in small scattered bands. This last character has a special significance to management because previous range damage resulted not only from overpopulation of feral sheep, but also from their habit of gathering into large flocks and thoroughly denuding one area before moving on to another.

By June 1961, there were 36 feral ewes confined in small breeding pens, and more than 70 were held in a 300-acre paddock for breeding. A total of 40 first- and second-generation offspring had been produced (Report of the State of Hawaii Department of Agriculture and Conservation, 1961, p. 103). The program, however, was discontinued in 1963 for a variety of reasons and a principal stock of pure mouflons was released in November at the Kahinahina pens, at about 8,000 feet elevation on the east flank of Mauna Kea. Hybrids had been freed mainly at Pu'u Lā'au, also in the high sheep range, at 7,400 feet on the west flank. Observations revealed that mouflon rams released singly associated with bands of feral sheep, but when several mouflon were in the same area these maintained the habit of gathering into small bands of their own



FIGURE 72.—Young male F_1 hybrid between a mouflon ram and a feral sheep ewe (*Ovis musimon* \times *O. aries*). Characteristics intermediate between those of the parents are shown by body conformation, horn form, pelage, and tail length. (Ronald L. Walker photo.)

species. Nonetheless, hybridization did occur readily in the wild, and crossbred animals tended to flock with the feral sheep. Management techniques, to include heavy reduction of feral rams by selective hunting, were suggested as a means of increasing the rate of introgression of mouflon genes into the Mauna Kea flocks (these data from Bachman, 1964). Nichols (1964c) reports a census taken in that year. Some thought should be given to preserving a line of the original feral sheep uncontaminated by mouflon characteristics. This unique form has been possibly 150 years in development and is worthy of genetic, serologic, and other evaluation, in captivity if not in the wild.

Giffin (1980) summarizes briefly some data on interactions of the mouflon and feral sheep on Mauna Kea. Ninety-nine pen-reared hybrids were released at Pu'u Lā'au on the western side of the mountain in June–July 1962, and 12 mouflon rams were released there in August 1962 and October 1963. At Kahinahina on the eastern flank 30 ram and 48 ewe mouflon, and no hybrids, were freed between November 1963 and February 1966. It is here, on the east side, where the population of mouflon emerged, with feral sheep making lesser



FIGURE 73.—Bark stripped from *māmāne* trees of the mouflon range, Mauna Kea, Hawai'i. Damaged areas are outlined in black. Habits of mouflon are similar to those of feral sheep. (Paul G. Scowcroft photo.)

use of the area. A few sheep of either species sometimes associated with herds of the other, but gatherings of single species were the rule. Hybrids in this area were noted to run with either group.

Giffin cites an example (Roberts, 1932) in which free-ranging domestic sheep and mouflon on a small island produced no crossbred lambs until all mouflon, except two rams, were removed. In the following season 28 hybrids appeared in the herd. Thus, it may be that in the absence of mouflon ewes in the Pu'u Lā'au region, production of additional crossbred lambs was commonplace after 1963. Giffin (1980) remarks that crossbred lambs produced during the time of his study were thought to be progeny of hybrid adults. These data suggest that a gradual segregation was taking place between the two forms of sheep under conditions in the wild rather than a melding of their characteristics.

The eradication program included removal of obviously hybrid animals and no mouflon stock was known to remain on the western flank of Mauna Kea at the end of that program.