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SAVANNAS ON THE ISLAND OF HAWAII[1]

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The purpose of this study was to investigate and attempt to characterize the vegetation of certain savannas on the Island of Hawaii with respect to similarity or uniqueness, and possible relationships to other tropical areas or mid-latitude continental regions. Since the area is an island, one might expect low species diversity, as well as considerable floristic similarity between sites.[2] Sites were selected for physiognomic similarity of the vegetation and differences in the physical environment in order to meet the goals noted.

Hawaii (Figure 1) is the largest, and geologically the youngest island in the archipelago, with half its area being relatively barren volcanic material. Elevations vary from sea level to Mauna Kea's altitude of 13,796 feet (4205 m). The northeast trade winds predominate, producing considerable variation in rainfall, ranging from over 200 inches (508 cm) on the windward side to less than 10 inches (25 cm) on the leeward. When traversing the island, one is struck by the variety of

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environmental zones, including rainforest, arid, alpine, and savanna. Savanna-like areas occur in most of the island's environmental zones, but especially in the drier leeward areas.

Methods

For this reconnaissance study, sites were selected in two altitudinal zones (Figures 1, 2 and 3). Care was taken to avoid ruderal areas by choosing sites at least 10 meters from roads. Research methods included using a meter-square sampling quadrat placed along various transects (Figure 4). Samples were taken at either 5-or-10 meter intervals, with internal spacing being consistent for individual transects. Presence of plant species was recorded in order to determine frequency along the transects within each site. Cover class and sociability were also recorded using class values similar to the Braun-Blanquet method.[3] Each species was initially assigned a number and a sample was collected for identification (see Table 1 for species list). The field work was conducted during the years 1975 and 1976.[4]

The Sites

Site one (Figures 1 and 2) was 1.5 miles (2.4 km) from the junction of the Saddle Road and the road to Mauna Kea. Physiognomically it appeared similar to many other savanna areas, being grassland with scattered trees. The site was located at an elevation of 7120 feet (2170 m), in the transition between Zone E low phase and Zone E high phase of the "Vegetation Zones

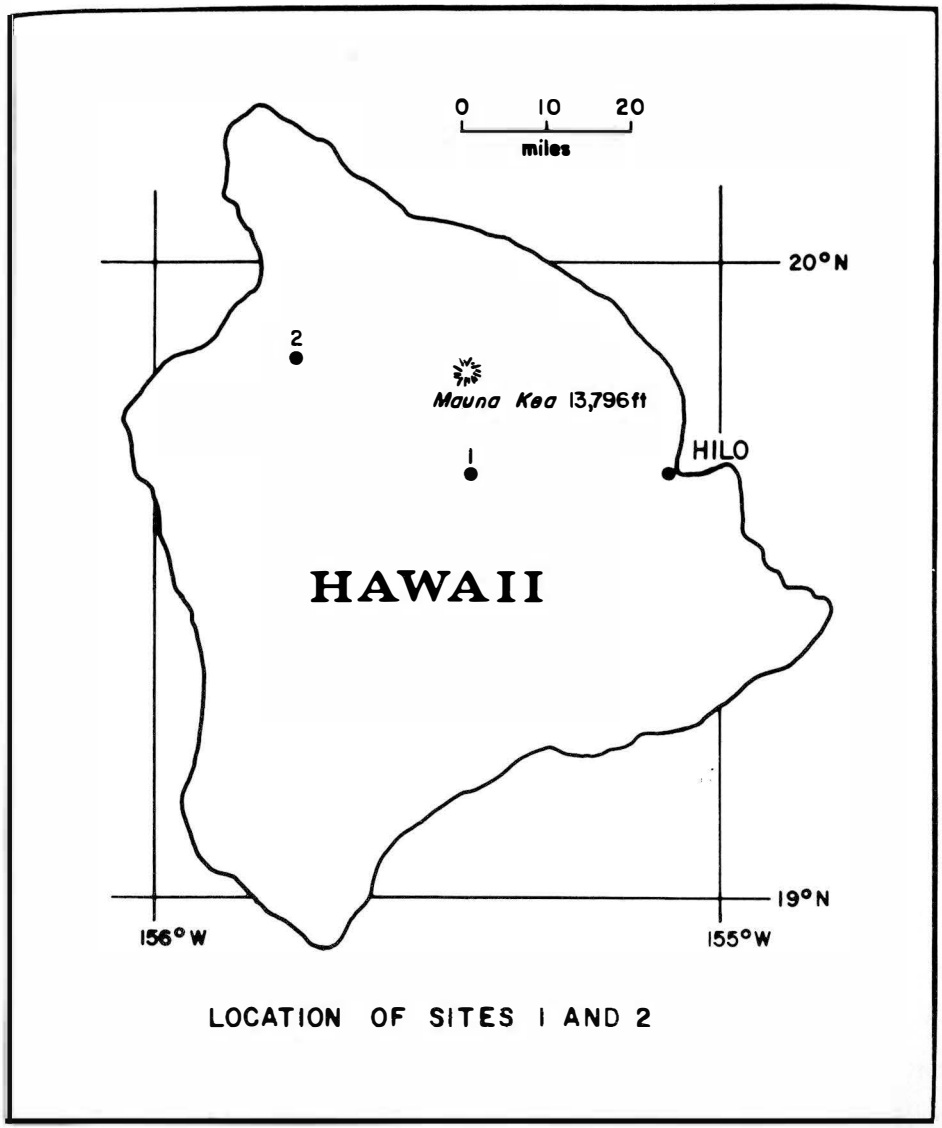

0 10 20
miles
20°N
2
Mauna Kea 13,796ft
1
HILO
HAWAII
19°N
156°W
155°W
LOCATION OF SITES 1 AND 2

Figure 1

of Hawaii" noted in the system by Ripperton and Hosaka.[5] This zone has frequent fog in addition to rainfall ranging from 20-40 inches (51-102 cm). The soils[6] were Inceptisols, in the "medial, isometric" family (annual average temperature from 47 to 59°F., 8-15°C), of the Kilohana series. Kilohana loamy fine sand was predominant on 12 to 20 percent slopes, grading into a type referred to as "reconnaissance cinder land" in surrounding areas. The soil was dark brown to very dark brown (10YR2/2 - 10YR4/3, using the Munsell Color system), mildly alkaline, with high permeability, slow runoff, and slight erosion. The area is now used predominantly as rangeland for cattle, but the presence of the inoperative Humuula Sheep Station (about 1 mile, 1.6 km, from the site) indicates that in the past sheep were grazed there.

With respect to vegetation (Table 1) the dominant tree, mamane (Sophor chrysophylla), was observed in varying conditions, from dead and nearly so to quite healthy. Hairy cats-ear (Hypochoeris radicata), a herbaceaous weed, was present in 93 percent of the samples, covering 5-10 percent of the quadrat area considered. Grasses of Agrostis sp. were present in 98 percent of the samples, with an average coverage of 35 percent of the quadrat area. Poa annua (annual bluegrass) was present in 100 percent of the samples on the east side of the road (covering 30 percent of the quadrat area), and in 19 percent of the samples on the west side (but with negligible coverage) where the soil was more sandy and rocky. The overall value was 46 percent of the samples. Other species of lesser importance were Taraxacum

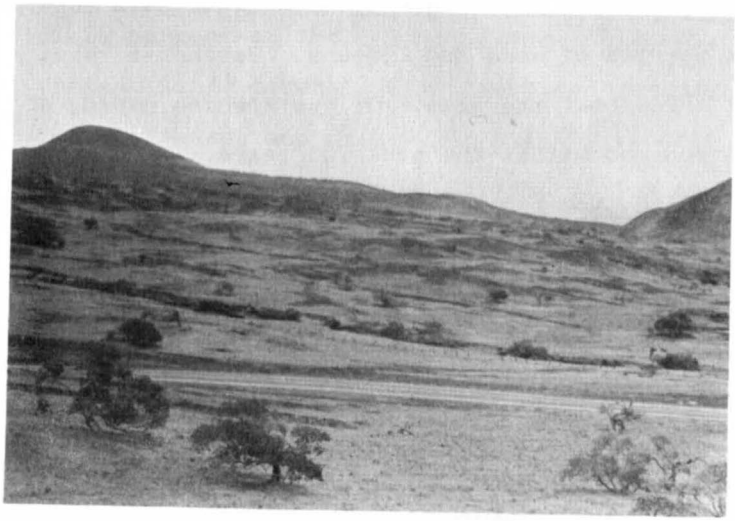


Figure 2

Photograph of Site 1. South Slope of Mauna Kea facing eastward. February 1976.

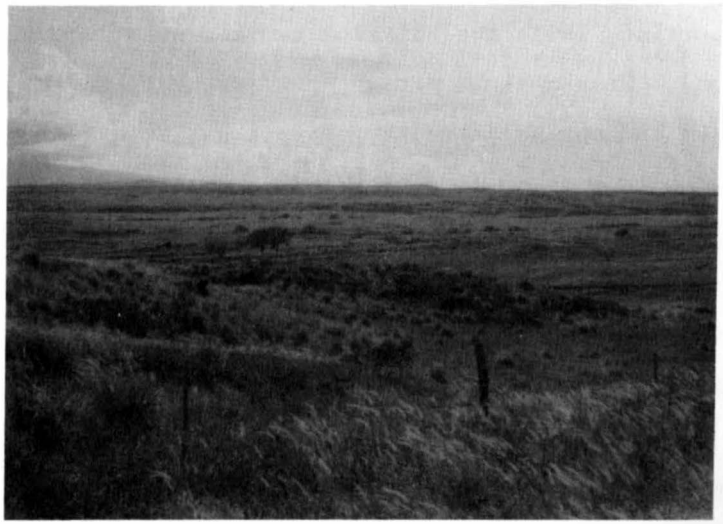


Figure 3

Photograph of Site 2. Facing southward, February 1976.

officinale (49 percent frequency with negligible coverage), and various species of moss and lichens. Patches of bare earth were present throughout the area. Of the species noted, at least 2/3 were introduced within the past 200 years.

Site two (Figures 1 and 3) was on the lower slopes north of the Hualalai mountain area, 3.2 miles (5.2 km) up the slope from Waikoloa. Physiognomically it also appeared similar to other savanna areas. It was at an elevation of 1520 feet (463 m), in the upper portions of Zone A and in Zone B of Ripperton and Hosaka.[7] The average annual rainfall is approximately 20 inches (51 cm). The soils included both Aridisols and Inceptisols, with the former order being dominant in the sample area. The Aridisols were in the "medial isohyperthermic" family (average temperatures of more than 72°F, 22°C), of the Waikaloa series. (Essentially the Kawaihae series soil was on the lower warmer portions while the Waikaloa series was at a cooler higher elevation). The Kawaihae series soil was dark reddish brown (2.5YR2/4) and the Waikaloa series soil was essentially the same color but with a color code of 5YR2/2. Both soils ranged from neutral to mildly alkaline and had moderate permeability and medium runoff with moderate erosion hazard. The Kawaihae soils were stony with a thin, very fine sandy loam to a depth of about 2 inches (5 cm).

The predominant tree in site two was kiawe (mesquite, algaroba, Prosopis pallida). Fountain fingergrass (Pennisetum setaceum) was present in 100 percent of the samples, covering

an average of 35 percent of the quadrat area. Sida sp. (Lei ilima) was present in 73 percent of the samples covering 5 percent of the quadrat area, and Emilia sonchifolia (floras point-brush, red pualele) was present in 93 percent of the samples, also covering 5 percent of the quadrat area. Other species included Rhynchelytrum repens (Natal redtop; 53 percent presence frequency), Plantago lanceolata (narrow-leaved plantain; 73 percent presence frequency), Sonchus oleraceus (sow thistle, pualele; 13 percent presence frequency), Opuntia megacantha (prickly pear cactus; 7 percent presence frequency). Small patches of bare earth were present throughout the area. Coprosoma sp. (pilo) and Indigofera suffruticosa (Indigo) were not present within the site, but were found nearby. Again, at least 2/3 of the species noted were introduced during the past 200 years.

Discussion

The low number of endemics and the high incidence of introduced species, especially with a notable presence of forage species, indicate that both areas have probably been broadcast seeded for pasture and perhaps partially cleared of brush. Authors such as Ripperton and Hosaka refer to these sites as "woodland" ("dry woodland" in Carlquist) in general discussions, but at present, they are grasslands with scattered trees, or what is generally known as savannas. Savannas have been of considerable interest to many researchers, and discussions have been made for various areas.[8]

It would appear that since the areas studied are on

an island, (an isolated area that is usually low in native species diversity) there should be considerable floristic resemblance from one savanna-type area to another (if they are natural).[9] However, reconnaissance studies show considerable variation, with the majority of species (2/3 or more) being introduced within the past 200 years. It has been noted that "An island vegetation is delicately balanced, a slight disturbance of equilibrium often leads to its partial or complete destruction...Many of the introduced trees, grasses, and herbs found their new habitat so ideal that they became dominant in many locations andalmost completely forced out the native species."[10] It is reasonable to state that there has been considerable disturbance of the vegetation in the areas that presently fit into the savanna category. Furthermore, one can suggest that most of the savanna-like areas of Hawaii are really pastures with scattered trees. In fact, many areas on the Island of Hawaii are pastures and rangelands with varying degrees of improvement, and several have been studied in detail by the University of Hawaii Agricultural Experiment Station, especially permanent pasture zones.[11] Sites included in this study have not been extensively researched because they are drier, have less productive potential, and fit into the realm of rangeland. Nevertheless there is some speculation that even these sites had more trees in former times. T.S. Newman suggests that the destruction of natural vegetation was begun by the native Hawaiians, and was continued by agriculture and introduced animals.[12] The

Soil Survey of the Territory of Hawaii[13] indicates that very little land was cleared by natives and that most of the vegetation destruction has occurred since the arrival of Americans and Europeans in the late 1700's, with their subsequent introduction of animals, especially cattle, sheep, and goats "...and the sharp hooved animals feeding on the leaves and injuring the root systems soon destroyed the native forest in large areas." Carlquist also notes that "The destruction of Hawaiian flora and fauna has been indirect, as well as direct. Animals and plants introduced by man have gone wild. Pigs, goats, sheep, and other herbivores have been unleashed on a flora which has evolved under herbivore-free conditions...the disturbance the herbivores create paves the way for weeds that might not otherwise enter."[14]

Kay states that by 1885 the forests of the plateau of Waimea, Hawaii were entirely depleted by the damage caused by the bulk force and foraging of cattle.[15] Marie C. Neal notes that native mamane is found between 1,000-9,000 feet (305-2895 m) (to the tree line on Mauna Kea and Mauna Loa) and states "Herds grazing among mamane trees eat the leaves and young growth and threaten the existence of the tree."[16]

Feral animals have had considerable impact upon the Hawaiian landscape. Being an island ecosystem, the introduction of cattle (*Bos taurus*), sheep (*Ovis aries*), and goats (*Capra hircus*) in the late eighteenth century presented a problem for plant species not adapted to extensive trampling, grazing, and browsing. Pigs (*Sus scrofa*) were originally brought by the

Polynesians, with subsequent introductions in the early nineteenth century following European contact. Rooting and browsing by pigs has caused damage to the watersheds including forest floor, forests, and grasslands in many areas. Their affect on ferns, pukiawe, and seedling mamane has contributed to reducing the forest areas to savannas, but considerably more damage has been caused by cattle, goats, and sheep.[17]

Kramer indicates that the Hawaiian forests are susceptible to injury by cattle and notes that "trampling of the undergrowth causes the soil to dry out and the shallow-rooted trees cannot obtain the necessary moisture for survival." It was estimated that there were 10,000 wild cattle on Mauna Kea alone in 1904.[18] Destruction is intensified by eating and trampling young trees so there is no replacement for the older dying ones. In 1907 steps were taken toward protection of mamane forests by fencing.[19] This kept the livestock from going to the higher elevations of the Mauna Kea reserve, and hence, one can observe forest patches upslope, whereas downslope it is, at best, savanna. At present feral cattle are not as numerous as before. Goats and sheep also have done widespread damage to native plant species. It was noted that there were 75,000 goats on Hawaii in 1931.[20] Their habit of eating on slopes has resulted in considerable erosion. Special elimination programs have reduced their numbers; goats nevertheless are currently quite destructive.[21] In 1937 it was estimated that there were 40,000 feral sheep in Mauna Kea Forest Reserve (80,000 acres, 32,375 ha.,

which extends down to the 7,000 foot level, 2134 m), and Kramer indicates that sheep have caused damage to mamane trees and ohter vegetation and that exclosures show grass, herbs, and sprouting of mamane.[22] The present sheep population is still presumed to be beyond the estimated carrying capacity of 1,300-1,500 head, and efforts to control them have been instituted. A side effect is that by eating the seeds they destroy a food source of the palila (Psittirostra bailleui) which is an endangered bird. In addition, this degrades the bird's habitat, by not allowing the mamane to regenerate.[23] Other feral animals such as the horse (Equus caballus) and the donkey (Equus asinus) have not been present in such large numbers and have not been as damaging. However, the large numbers of feral cattle, sheep, and goats during the early part of the twentieth century certainly had extensive impact. Kramer notes that certain zones from sea level to 10,000 feet (3048 m) (C_1, C_2, D_3, E_1, and E_2 of Ripperton and Hosaka) were formerly forested by now are largely open grassland with a few trees and that this is due to overgrazing.[24]

Conclusions

The results of this study indicate that certain savannas on the Island of Hawaii have a low percentage of native plant species and a high frequency of introduced ones. The higher elevation site (#1) had basically a temperate zone floristic composition while the lower one (#2) contained more subtropical or tropical species. The research did not support the contention that since the area is an island, one might expect

low species diversity. The sites studied were found to support many types of plant species. The diversification may be accounted for by environmental differences and human influences, including introductions which resulted in most species being native to other areas, both temperate and tropical. Human impact through direct effect upon the landscape by clearing and planting, as well as the introduction of animals has been the major factor in the development of savannas in various areas of the Island of Hawaii.

NOTES

[1]Paper presented at the Association of Pacific Coast Geographers annual meeting, Portland, Oregon, June 13-16, 1978. Data were collected while the author was a Visiting Assistant Professor at the University of Hawaii, Hilo College (1975-1976). Current position is Assistant Professor of Geography and Coordinator of Environmental Studies at California State College, San Bernardino 92407.

[2]This of course varies with factors such as the type of island (e.g. high volcanic landform, coral atoll, etc.), its geologic age, size, and distance from other land areas. Also, this depends upon whether one is considering only naturally dispersed species or also including very recent introductions. Lowland Hawaii tends to have low diversity or richness of "native" biota (especially fauna) when compared to similar altitudinal zones in areas such as Central and South America. The idea of relative species diversity on islands such as Hawaii is to some individuals a matter of debate, especially when ecological opportunity and adaptive radiation are considered for selected taxa. Refer to: S. Carlquist, *Island Biology*, (New York: Columbia University Press, 1974), 660 pp.; and R. H. MacArthur and E. O. Wilson, *The Theory of Island Biogeography*, (Princeton, N.J.: Monographs

in Population Biology, 1, Princeton University Press, 1967), 203 pp. For comments pertinent to Hawaii also refer to: S. Carlquist *Hawaii, A Natural History* (Garden City, NY: The Natural History Press, 1970), 463 pp.; F. R. Fosberg, "Derivation of the Flora of the Hawaiian Islands," and H. St. John, "Endemics in the Hawaiian Flora, and a Revision of the Hawaiian Species of Gunnera (Haloragidaceae), Hawaiian Plants Studies 11," in E. A. Kay (Ed.), *A Natural History of the Hawaiian Islands, Selected Readings,* (Honolulu: The University of Hawaii Press, 1972), pp. 396-408 and 517-527; and D. Mueller-Dombois, "Some Aspects of Island Ecosystem Analysis," in F. B. Golley and E. Medina (Eds.), *Tropical Ecological Systems,* (New York: Spring-Verlag, 1975), pp. 353-366.

[3]K. A. Kershaw, Quantitative and Dynamic Ecology (New York: American Elsevier Publishing Company, Inc., 1964), 178pp. ; D. Mueller-Dombois and H. Ellenberg, *Aims and Methods of Vegetation Ecology,* (New York: John Wiley and Sons, 1974), 547 pp.; and D. W. Shimwell, *The Description and Classification of Vegetation,* (Seattle: University of Washington Press, 1971), 322 pp. Frequencies are noted at appropriate points, and in the species list. Significant cover class values are also noted at appropriate points in this paper. None of the species were highly sociable except in isolated cases, several were moderately so, but not enough for significant analysis purposes. Frequencies and cover class values proved to be more useful and this is is agreement with Mueller-Dombois and Ellenberg, 1974.

[4]Reconnaissance field work was conducted during October and November 1975, vegetation sampling in February 1976, and revisited as late as June 1976. Identifications and interpretations were primarily made by the author in consultation with various individuals (including R. Baldwin) at Hilo College. Numerous sites were observed througout the island. Two sites were selected and were initially covered in general with overall sampling and notes taken. This was followed by a total of 61 quadrats being sampled for this reconnaissance study from the two sites; four transects with a total of 46 quadrats in site #1 (25 at 5 m apart and 21 at 10 m apart); one transect of 15 quadrats (5 m apart) in site #2 with extensive reconnais-

sance sampling of the surrounding area to supplement the lower number of quadrats. Botanical references included: E. Haselwood and G. Motter (Eds.), *Handbook of Hawaiian Weeds,* (Honolulu: Experiment Station Hawaiian Sugar Planter's Association, 1966), 479 pp.; M. C. Neal, *In Gardens of Hawaii,* (Honolulu: University of Hawaii Press, 1968), 355 pp. A number of the Latin binomials are also known by synonyms. The names given in this paper are based upon the reference sources noted.

[5]J. C. Ripperton and E. Y. Hosaka, "Vegetation Zones of Hawaii," *Hawaii Agricultural Experiment Station, Bulletin No. 89,* (Honolulu: University of Hawaii, 1942), 60 pp. For a study of Mauna Kea during the same general time period refer to: C. E. Hartt and M. C. Neal, "The Plant Ecology of Mauna Kea, Hawaii," *Ecology,* Vol. 21, No. 2 (1940), pp. 237-266.

[6]Soils were sampled and studied by the author. Site descriptions were based upon observations and data collected in consultation with soil survey reports. M. G. Cline (Ed.), *Soil Survey; Territory of Hawaii,* (United States Department of Agriculture, Soil Conservation Service, In Cooperation with the Hawaii Agricultural Experiment Station, Series 1939, No. 25, September 1955), 644 pp. plus maps; W. W. McCall, "Soil Classification in Hawaii," (Cooperative Extension Service/University of Hawaii/Circular 476, 1975), 32 pp.; and H. H. Sato, W. Ideda, R. Paeth, R. Smythe, and M. Takehiro, *Soil Survey of the Island of Hawaii, State of Hawaii,* (United States Department of Agriculture, Soil Conservation Service, 1973), 115 pp. plus photomaps.

[7]See footnote 5.

[8]Numerous studies have been made in various areas--the following list is only a sampling. J. S. Beard, "The Savanna Vegetation of Northern Tropical America," *Ecological Monographs* Vol. 23, No. 2 (1953), pp. 149-215; J. Blydenstein, "Tropical Savanna Vegetation of the Llanos of Colombia," *Ecology* Vol. 48, No. 1 (1967), pp. 1-15; G. Budowskii, "Tropical Savannas, A Sequence of Forest Felling and Repeated Burnings," *Turrialba* Vol. 6, Nos. 1-2 (1956), pp. 23-33; T. L. Hills, "The Savanna Biome: A Case Study of Human Impact on Biotic Communities," in I. R. Manners and M. W. Mikesell (Eds.),

Perspectives on Environment, AAG Commission on College Geography, Publication No. 13 (1974), pp. 342-373; C. L. Johannessen, "Savannas of Interior Honduras," *Ibero-Americana* No. 46 (1963) 160 pp. (Berkeley: University of California Press); M. Lamotte, "The Structure and Function of a Tropical Savannah Ecosystem," and G. Sarmiento and M. Monasterior, "A Critical Consideration of the Environmental Conditions Associated with the Occurrence of Savanna Ecosystems in Tropical America," in F. B. Golley and E. Medina (Eds.), *Tropical Ecological Systems: Trends in Terrestrial and Aquatic Research,* (New York: Springer-Verlag, 1975), pp. 179-222 and 223-250; C. Sauer, "Man in the Ecology of Tropical America," in C. Salter (Ed.), *The Cultural Landscape,* (Duxbury, 1969), pp. 136-142; and H. Walter, *Ecology of Tropical and Subtropical Vegetation,* (Translated from German by D. Mueller-Dombois and edited by H. H. Burnett), (New York: Van Nostrand Reinhold Co., 1971), 539 pp.

[9]See footnote 2.

[10]Cline, *op. cit.,* footnote 6, p. 29.

[11]For example: N. H. Monteith and C. D. Sherman, "The Comparative Effects of Calcium Carbonate and of Calcium Silicate on the Yield of Sudan Grass Grown in a Ferruginous Latosol and a Hydrol Humic Latosol," *Hawaii Agricultural Experiment Station, University of Hawaii, Technical Bulletin No. 53,* (1963), 40 pp.; R. H. Suehisa, O. R. Younge, and G. D. Sherman, "Effects of Silicates on Phosphorus Availability to Sudan Grass Grown on Hawaiian Soils," *Hawaii Agricultural Experiment Station, University of Hawaii, Technical Bulletin No. 151* (1963), 40 pp.; Y. N. Tamimi, L. B. Sherrod, S. M. Ishizaki, and T. Izuno, "The Effects of Levels of Nitrogen, Phosphorus, and Potassium Fertilization Upon Beef Production on Kikuyugrass," *Hawaii Agricultural Experiment Station, University of Hawaii, Technical Bulletin No. 76* (1968), 12 pp.; O. R. Younge and K. K. Otagaki, "The Variation in Protein and Mineral Composition of Hawaii Range Grasses and its Potential Effect on Cattle Nutrition," *Hawaii Agricultural Experiment Station, University of Hawaii, Bulletin No. 119* (1958), 27 pp.

[12]T. S. Newman, "Man in the Prehistoric Hawaiian Ecosystem," *op. cit.* footnote 2, pp. 598-600.

[13]Cline, *op. cit.*, footnote 6.

[14]Cline, *op. cit.*, p. 28, footnote 6; Carlquist, 1970, *op. cit.*, footnote 2, p. 179.

[15]E. A. Kay, "Hawaiian Natural History: 1778-1900," in Kay, *op. cit.*, footnote 2, p. 631.

[16]M. C. Neal, *In Gardens of Hawaii*, Bernice P. Bishop Museum Special Publication 50, (Honolulu: Bishop Museum Press, 1965, 924 pp.), pp. 413 and 442.

[17]R. J. Kramer, *Hawaiian Land Mammals*, (Rutland, Vermont: Charles E. Tuttle Company, Inc., 1971), 347 pp.; P. Q. Tomich, *Mammals in Hawaii: A Synopsis and Notational Bibliography*, Bernice P. Bishop Museum Special Publication 57, (Honolulu: Bishop Museum Press, 1969), 238 pp.

[18]Kramer, *op. cit.*, footnote 17, p. 278.

[19]Tomich, *op. cit.*, footnote 17, p. 101. The use of goat exclosures shows that native plant recorvery is at least partially possible as noted by Mueller-Combois, 1975, *op. cit.*, footnote 2, pp. 362-363.

[20]Tomich, *op. cit.*, footnote 17, p. 107.

[21]Many people in Hawaii hunt pigs, sheep, and goats for food and recreation. As a result, there is strong opposition to efforts aimed at significantly reducing the populations of these feral animals. As previously noted, exclusion of grazing animals can result in a recovery of native plants.

[22]Kramer, *op. cit.*, footnote 17, pp. 318, 319, 321.

[23]Hawaii Audubon Society, *Hawaii's Birds*, (Honolulu: Hawaii Audubon Society, 1975), p. 77.

[24]Kramer, *op. cit.*, footnote 17, pp. 184-185/Table 4.

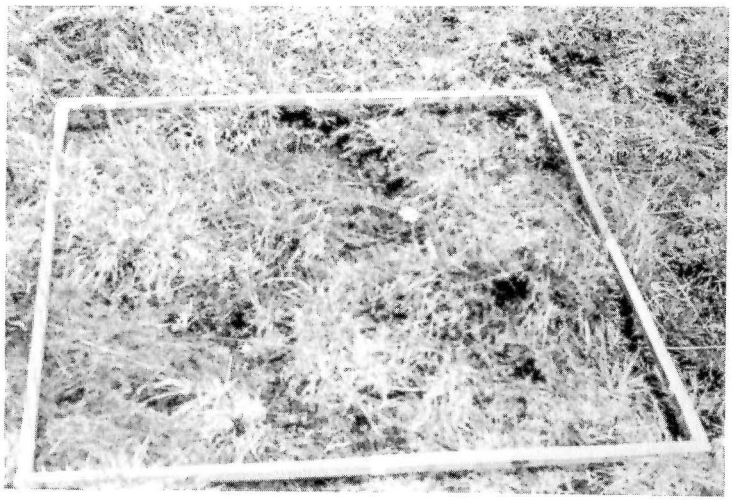


Figure 4
Meter-Square Sampling Quadrat

Table 1

FLOWERING PLANTS FROM SITES ONE AND TWO

Origin and Date First Recorded in Hawaii

INTRODUCED

Achillea millefolium L. (Common Yarrow)--Native of Eurasia and North America; (N); #1 (4)

Conyza canadensis (L.) Crongq. (Small-leaf Horse Weed; Canada Fleabane)--Native to Temperate North America; (H & M); #2 (7)

Emilia sonchifolia (L.) DC. (Floras Paintbrush; Red Pualele)--Native to Old World Tropics; (H & M); #2 (93)

Erodium cicutarium (L.) L'Her. (Redstem Filaree; Herons Bill)--Native to Mediterranean Region; (H & M); #1 (7)

Geranium carolinianum var. australe (Benth.) Fosb. (Wild Geranium; Cranesbill) --Australia (probably); early introduction; (N); #1 (4)

Hypochoeris radicata L. (Hairy Cats-ear)--Native to Mediterranean Area; (H & M); #1 (93)

Indigofera suffruticosa Mill. (Indigo)--Native to West Indies; about 1850; (H & M); #2 (*)

Opuntia megacantha Salm-Dyck (Prickly Pear; Panini)--Native to Mexico; about 1809; (H & M); #2 (7)

Pennisetum setaceum (Forsk.) Chiov. (Fountaingrass; Feather Fingergrass)--North Africa; 1926; (R); #2 (100)

Pennisetum setosum (Swartz) L. C. Rich. (Feathery Pennisetum)--Tropical America; 1921; (R); #2 (40)

Plantago lanceolata L. (Narrow-leaved Plantain)--Native to Eurasia; (H & M); #2 (73)

Poa annua (Annual Bluegrass)--Europe; 1864; (R); #1 (46)

Prosopis pallida (Humb. and Bonpl. ex. Willd.) HBK. misdetermined in Hawaii as P. chilensis, P. juliflora) (Mesquite, Algaroba, Kiawe); P. pallida from South America; after 1828; (N); #2 (*)

Rhynchelytrum repens (Wld.) C. E. Hubb. (Natal Redtop)--Africa; 1895; (R); #2 (53)

Solanum nodiforum Jacq. (?) (Black Nightshade; Popolo)--Throughout Temperate and Tropical Regions; (Probably of Accidental Introduction to Hawaii); (H & M); #2 (27)

Sochus oleraceus L. (Sow Thistle; Pualele)--Native to Europe; Early Introduction; (H & M); #2 (13)

Taraxacum officinale (L.) Weber in Wiggens (Dandelion; Lau-Lele)--Native to Europe; (H & M); #1 (49)

Waltheria americana L. (Hialoa)--Native to Tropical America; Very Early Introduction; (H & M); #2 (60)

NATIVE TO HAWAII

Sophora chryophlla (Salisb.) Seem. (mamane)--(N); #1 (*)

Styphelia tameiameiae (Cham.) F. Muell. (pukiawe)--(N); #1 (2)

UNDETERMINED SPECIES OR ORIGINS

Agrostis sp.--(R); #1 (Of 12 species listed by Rotar, only 2 are native to Hawaii (98)

Compositae--(?); #1 (2)

Euphorbia--Introduced Weed (?); #1 (22)

Medicago--Introduced from Europe (?); #1 (9)

Rumex acetosella L. (Sheep Sorrel; Sour Dock)--Introduced Weed (?); #1 (26)

Sida sp. (S. falix Walp.?, S. cordifolia L. ?) (Sida; Lei ilima; 'Ilima) --Pantropical Weed; (H & M); #2 (73)

Trifolium sp. (Clover)--Introduced from Europe (?); #1 (2), #2 (7)

Verbesina sp. (?)--#2 (20)

EXPLANATION OF SYMBOLS

Source for origin (see footnote 4):

H & M : Haselwood and Motter

N : Neal

R : Rotar

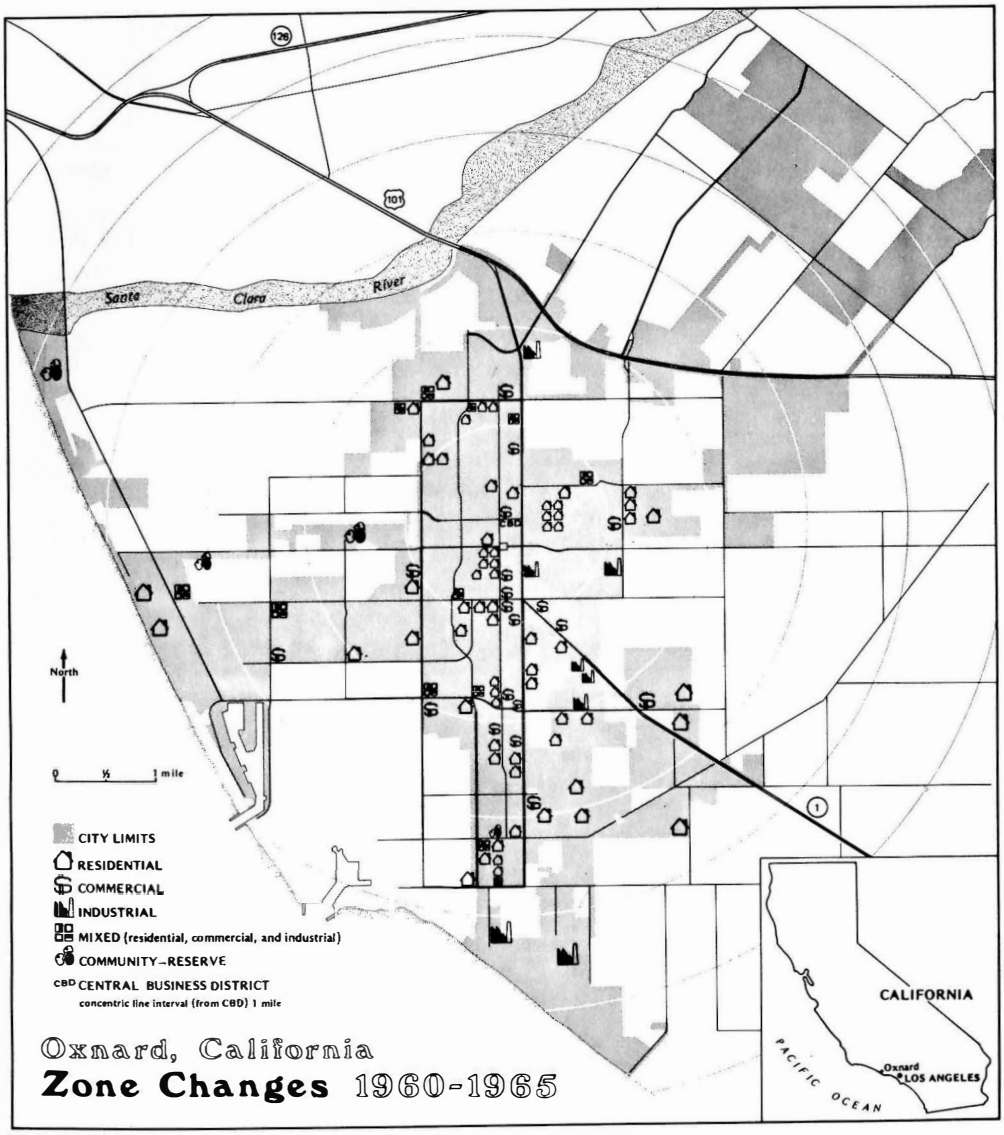
Site number and percent frequency (percent of sample quadrats in which species is present):

Example: #1 (93): Site number one and present in 93 percent of the sample quadrats

#2 (*) : In site area number two but not in sample plots

(Site one: 46 quadrats; Site two: 15 quadrats; Total quadrats: 61)

Table 1 (Continued)


126
101
Santa Clara River
North
0 ½ 1 mile
CITY LIMITS
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
MIXED (residential, commercial, and industrial)
COMMUNITY-RESERVE
CBD CENTRAL BUSINESS DISTRICT
concentric line interval (from CBD) 1 mile
Oxnard, California
Zone Changes 1960-1965
1
CALIFORNIA
PACIFIC OCEAN
Oxnard
LOS ANGELES

Map 1