HAKALAU FOREST

NATIONAL WILDLIFE REFUGE

Hilo, Hawaii

ANNUAL NARRATIVE REPORT

Calendar Year 1993

U.S. Department of the Interior
Fish and Wildlife Service
NATIONAL WILDLIFE REFUGE SYSTEM

HAKALAU FOREST NATIONAL WILDLIFE REFUGE
ANNUAL NARRATIVE REPORT
Calendar Year 1993

REVIEW AND APPROVALS

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Reviewed by: Regional Office (Region 1) — Date

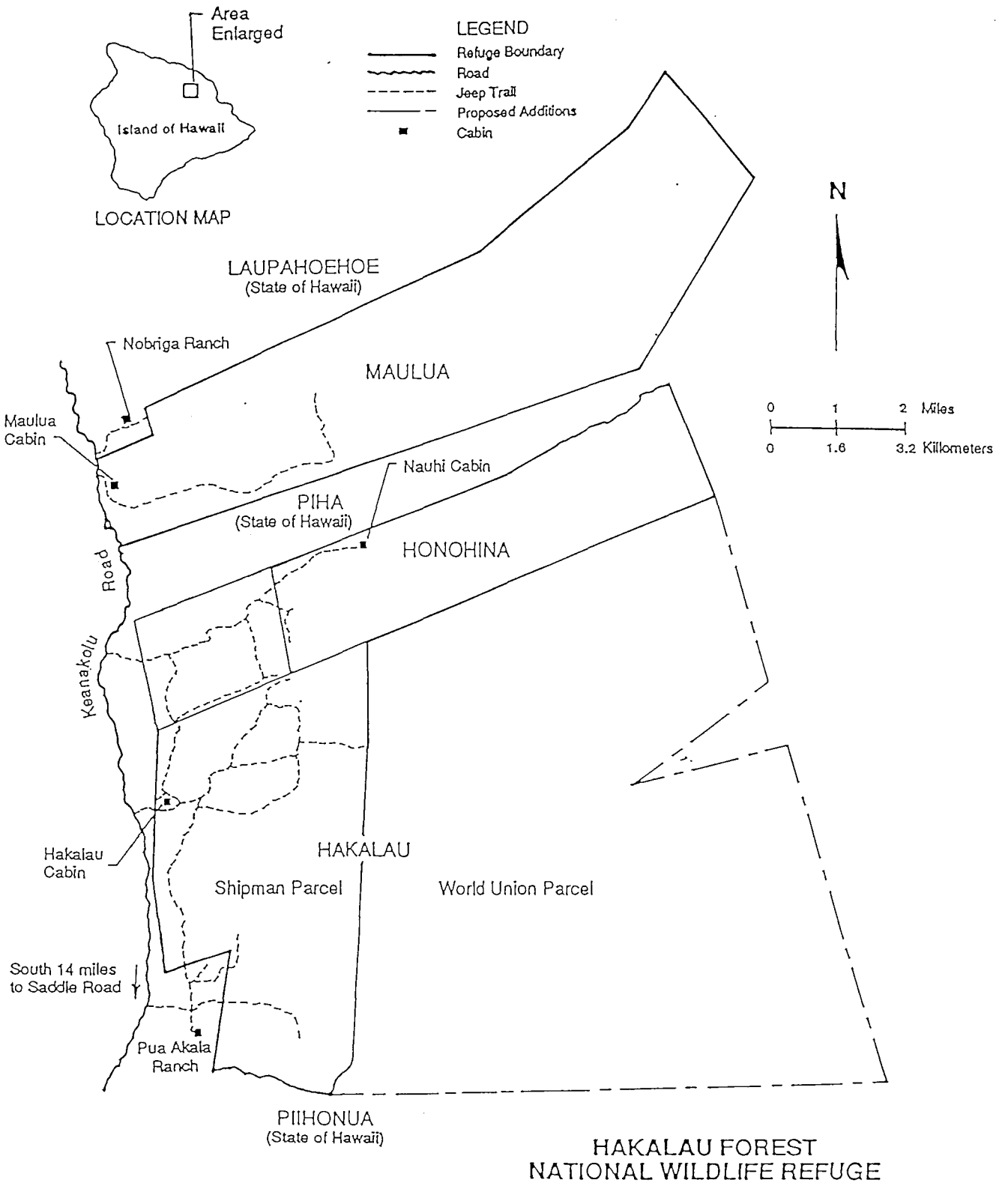
INTRODUCTION

Hakalau Forest National Wildlife Refuge was established October 29, 1985 with the purchase of two properties totaling 8,313 acres. Five additional parcels have subsequently been acquired bringing the current total area to 16,518 acres. Negotiations toward the purchase of two additional parcels totaling approximately 16,000 acres are ongoing. The refuge is located about 14 mi. northwest of Hilo, Hawaii on the windward slope of Mauna Kea. It lies between the elevations of 2,500 and 6,600 ft. and contains some of the finest stands of koa and ohia forest in Hawaii. The lower slopes receive very high rainfall and are vegetated with dense forests dominated by ohia and treeferns and bisected with numerous streams and gulches. Upslope, at elevations above 4,500 ft., koa becomes co-dominant with ohia. The typical structure of this forest is characterized by tall koa and ohia trees forming a closed canopy. Younger ohia trees dominate the mid-story and tree ferns and native shrubs form the understory. Higher elevations (above about 5,400 ft.) experience less rainfall and have been subject to considerable grazing pressure for over 100 years which has eliminated or severely reduced the native understory. A fairly dense canopy of mature koa and ohia trees over a ground cover of exotic grasses characterizes this area. Intensive grazing on the uppermost portion of the refuge (above about 6,000 ft.) has eliminated even the trees except for remnant individuals scattered through the gulches. This area is carpeted with introduced grasses including the noxious weed, gorse.

Hakalau Forest NWR was established to assure the protection, perpetuation and maintenance of five endangered forest bird species and their rain forest habitat. It supports a superb avifauna, rich in species and high in density. Thirty-nine bird species are found on the refuge including 14 endemics (of which 8 are endangered), 5 indigenous and 20 aliens. Substantial populations of four endangered forest birds occur on the refuge. They are the 'Akiapola'au, the Hawaii Creeper, the Hawaii 'Akepa and the 'Io (Hawaiian Hawk). The other four endangered birds found at Hakalau include the very rare 'O'u which is reported from the lower elevation ohia forests, the Nene (Hawaiian Goose) which nests in adjoining areas, the Koloa (Hawaiian Duck) which inhabits streams and stockponds on the refuge, and the 'Alae ke 'Oke'o (Hawaiian Coot). The endangered Hawaiian Hoary Bat and a number of candidate endangered plants are also found at Hakalau.

Figure 1 is a map of the Refuge. The administrative office is located within the Federal Building in downtown Hilo, the largest city on the Island of Hawaii. The address is 32 Kinoole St. Suite 101, Hilo, HI 96720. The phone number is (808) 933-6915. The FAX number is (808) 933-6917.

Figure 1.


Area Enlarged
Island of Hawaii
LOCATION MAP
LEGEND
Refuge Boundary
Road
Jeep Trail
Proposed Additions
Cabin
N
0 1 2 Miles
0 1.6 3.2 Kilometers
LAUPAHOEHOE
(State of Hawaii)
Nobriga Ranch
MAULUA
Maulua Cabin
Nauhi Cabin
PIHA
(State of Hawaii)
HONOHINA
Keanakolu Road
Hakalau Cabin
HAKALAU
Shipman Parcel
World Union Parcel
South 14 miles to Saddle Road
Pua Akala Ranch
PIIHONUA
(State of Hawaii)
HAKALAU FOREST
NATIONAL WILDLIFE REFUGE

HAKALAU FOREST NATIONAL WILDLIFE REFUGE

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A. HIGHLIGHTS

1. The *El Niño* condition, which began in the fall of 1991, persisted throughout 1992 and 1993 resulting in unusually dry springs and high mortality amongst planted koa seedlings. 1993 was the second driest of the seven years for which the refuge has recorded rainfall data. (Sections B. and F.3.b.)

2. On January 26, 1993, the Service took title to a 1,033.94 acre parcel owned by the Liliuokalani Trust. The purchase price was $1,339,000 ($1,295 per acre). This purchase brings the total acreage of the refuge to 16,518 acres. (Section C.1.)

3. Dr. Leonard A. Freed, University of Hawaii, and his graduate students, continued their ornithological research on the refuge. Their studies focused on behavior, demographics, genetics, disease, the evolution of sexual dichromatism and cavity-nesting in the Hawaii 'Akepa, and temporal arthropod abundance in the koa/ohia forest. During their seven years of banding at Hakalau, Dr. Leonard Freed and colleagues (chiefly, graduate student Jaan Lepson) have banded a total of 2,749 birds and have taken blood samples from 1,204. The banded total includes 229 endangered birds. The presence of avian malaria and avian pox continues to be documented. Dennis LaPointe, Dr. John Wingfield and Dr. Haruyoshi Ikawa also conducted studies on the refuge. (Section D.5.)

4. The Hakalau staff increased to nine individuals with the addition of another temporary full-time Maintenance Worker WG-4749-5. (Section E.1.)

5. Seventeen volunteer groups assisted the refuge for periods of 1-4 days. The 141 volunteers donated 1,342 person-hours of much-appreciated effort to pick koa seed pods, plant and fertilize koa seedlings, and control banana poka, gorse and holly. (Section E.4.)

6. Studies were initiated to determine if slope and aspect influence the winter survival of koa seedlings and whether simple structures will offer protection from freezing temperatures. (Section F.3.a.)

7. 39,000 koa seedlings were planted during 1992 with the assistance of a grant from the American Forestry Association. 76,000 seedlings have been planted since 1989. The seedlings are doing well though frost, drought and pigs have caused significant mortality. (Section F.3.b.)

8. Four *Cyanea shipmanii* plants were discovered at Hakalau. This rare lobelia was last seen in the late 1970's. The most accessible individual was fenced to protect it from feral ungulates. (Section F.3.c.)

9. Orchard Services was contracted to provide 140 hours of effort for foliar spray and basal bark applications of Garlon 3A and Garlon 4 herbicide on gorse. A total of 1,141 hours of chemical control has been expended by contractors since 1989. The Habitat Management team also expended 75 hours of chemical gorse control during 1993. The original gorse infestation is now totally controlled but continued effort is required to spray or grub young seedlings. (Section F.10.b.)

10. Plots were established to test the efficacy of a foliar spray application of Garlon 3A to control Florida blackberry. (Section F.10.c.)

11. Yellowjacket populations declined to relatively low levels during the fall of 1993 as moisture levels increased to normal. (Section F.10.g.)

12. The annual spring bird census was conducted. An apparent increase was seen for 8 of 12 forest bird species, but it is not known whether this is the result of management strategies or normal population variability. No consistent population trends are evident for any species during the seven-year-period over which the refuge has collected data. (Section G.2.)

13. A total of 118 pigs and 5 feral cows were taken by the Habitat Management team during the year. Feral cattle have been eliminated from the Middle Honohina and Shipman Management Units and only one or two remain in the Lower Honohina Unit. Pigs have been eliminated from the Middle Honohina Management Unit and about half the population has been removed from the Shipman Unit. (Section G.15.b.)

14. The hunting public took 18 pigs from the Upper Maulua Tract during 82 hunter-visits for an average of 0.22 pigs per hunter-visit. These figures are down from 105 hunter-visits and 0.36 pigs per hunter visit in 1992. This level of hunting pressure is insufficient to significantly reduce pig activity in the Upper Maulua Tract. (Section H.8.)

15. The Fred Smith Construction Company completed construction of the perimeter fence around the 1,800 acre Lower Honohina Feral Ungulate Management Unit (FUMU) in June. Three sides of the unit (35,843 feet) were fenced at a cost of $235,500. Three FUMUs have been fenced since the refuge was established. 126,584 feet (24.0 miles) of pig/cattle fence were constructed at a total cost of $656,614 ($5.19/foot or $27,388/mile). In November, the Fred Smith Construction Company began constructing the 35,200 foot pig/cattle fence around the perimeter of the 2,000 acre Upper Maulua Feral Ungulate Management Unit. (Section I.1.a.)

16. Steve's Ag Services completed a $35,000 contract to rehabilitate the road to Nauhi Cabin. The worst stretches were graveled and graded and a layer of road stabilization fabric was laid under the gravel in

swampy areas. All-weather-access to Nauhi Cabin is now possible. (Section I.2.)

17. On April 30 (Arbor Day), a ceremony was held during which the 1,000,000th tree funded nationwide by the American Forestry Association was planted at Hakalau. The event received national publicity and was attended by a number of officials. (Section J.3.)

B. CLIMATIC CONDITIONS

The climate at Hakalau Forest NWR is characterized by moderate temperatures and generally wet conditions. There is considerable variation within the refuge, however, depending primarily on elevation. Mean annual temperatures vary between about 65°F at the lower elevations and 53°F at the higher elevations. Daily temperatures in the vicinity of Hakalau cabin range between highs of 50°F to 75°F and lows of 32°F to 50°F.

Rainfall also shows significant variation with elevation. Approximately 300 inches of rain falls annually at the lowermost elevations of the refuge. Rainfall decreases to about 90 inches at the upper elevations bordering Keanakolu Road. For a 25-year period between 1906 and 1931, rainfall data were recorded at Pua Akala Ranch (elevation = 6,300 feet) which borders the refuge. Annual rainfall ranged between 38.3 and 144.4 inches with a median of 88.2 inches. During the past seven years, rainfall at Hakalau Cabin has varied between 46.47 and 159.56+ inches and averaged 84.71+ inches. At the higher elevations of the refuge, considerable moisture (perhaps as much as an additional 30%) is also received in the form of fog drip from cloud formations that usually gather in the early afternoon on the middle elevation slopes of Mauna Kea. These afternoon low clouds are responsible for the cool and damp climate that generally prevails at Hakalau.

Prevailing winds are from the SSE at about 5 knots. Mean daily humidities range from around 70% in the winter to about 85% in the spring and summer. Typically, humidity is lowest during the mid-morning hours and highest during the late afternoon and early evening.

A standard thermometer and rain gauge were installed on the refuge at Hakalau cabin (elevation = 6,440 ft) early in 1987. Data have been recorded by refuge staff since that date. Temperature and rainfall data for 1993 and average rainfall for the past seven years are summarized in Table I. 1993 was the second driest of the seven years for which the refuge has recorded rainfall data. Only 60.97 inches of rain were recorded compared to the seven year average of 86.78+ inches. (The "+" indicates the gauge overflowed a few times during the seven year period so the actual average is somewhat greater.) The dry weather resulted from the *El Niño* condition which began in the fall of 1991 and persisted throughout 1992 and 1993. The weather, and consequently the soil, was particularly dry during the spring and summer of both years. Dry weather is normally appreciated but not during the tree-planting season

which extends from April through July. Dry soil conditions resulted in unusually high planting mortality amongst the 18,000 koa seedlings planted in 1992 and the 39,000 seedlings planted in 1993. (See Section F.3.b.)

Table I. Meteorological observations at Hakalau Cabin (elevation = 6,440 ft) during 1993. Data were manually recorded from a maximum/minimum thermometer and a rain gauge.

Month	Absolute Minimum (°F)	Absolute Maximum (°F)	Rainfall (inches)	Average Rainfall (1987-1993)
January	30	65	1.70	9.11
February	32	68	0.67	5.52
March	34	70	3.39	8.99
April	34	77	3.73	4.83
May	38	70	4.44	5.07
June	38	73	1.95	3.33
July	40	72	18.33	9.53
August	40	74	4.03	5.41
September	40	78	3.09	7.25
October	38	72	4.81	5.23
November	34	70	5.17	12.47
December	33	68	9.66	10.04
		TOTALS	60.97	86.78+

Total rainfall for the year was only about 70 percent of the average for the last seven years. Rainfall at Hakalau is highly variable so any month can be unusually wet or unusually dry. In general, however, the wettest months seem to be November through March. The monthly extremes recorded at Hakalau Cabin since 1987 are 0.56 inches for April 1992 and 39.09+ inches for November 1990.

In February 1989, a sophisticated solar-powered meteorological station was installed on the flat immediately below Hakalau cabin (elevation = 6,400 ft). Every 15 minutes, the CR 10 data logger records air temperature, humidity, wind speed, wind direction, solar radiation at all wavelengths, solar radiation at photosynthetic wavelengths, and soil moisture and temperature at 10 cm and 50 cm depths. Rainfall is continuously recorded as it occurs in 0.01 inch increments. Seventy-five days of data can be stored in the memory unit which is unplugged every two months and taken to the Hilo office where the data are downloaded into the computer for compilation and analysis. No data are available for January and December of 1993 due to equipment failure. Mean monthly temperature data from the CR 10 are summarized in Table II. February is the coldest month and August is the warmest.

Table II. Monthly mean minimum, maximum and daily air temperatures (°C) recorded at the continuously recording weather station located on the flat below Hakalau Cabin (elevation = 6,400 ft) during 1989-93.

Month	Mean Minimum	Mean Maximum	Mean Daily
January	5.7	16.3	10.7
February	5.0	15.0	9.7
March	5.1	14.9	9.9
April	5.9	15.9	10.9
May	6.7	16.1	11.3
June	7.4	16.9	12.2
July	8.3	17.3	12.9
August	8.5	18.4	13.5
September	8.5	17.7	13.1
October	8.5	17.5	12.8
November	7.7	17.1	12.1
December	5.7	15.4	10.4

In March 1989, a rain gauge was installed on refuge property in the clearing immediately below the Pua Akala Ranch (elevation = 6,200 ft). It is monitored by students and faculty from the University of Hawaii. On January 6, 1993, a rain gauge was installed at Nauhi Cabin. It has subsequently been monitored by refuge staff and National Biological Service staff. 1993 rainfall data from four sites on the refuge are compared in Table III.

Table III. Monthly rainfall (inches) at four sites on the refuge during 1993. Data for the flat below the cabin (elevation = 6,400 ft) are very accurate and were derived from the solar powered station described above. Data from Hakalau Cabin (elevation = 6,440 ft) were manually recorded at weekly intervals. Data from the Pua Akala Clearing (elevation = 6,100 ft) and Nauhi Cabin (elevation = 5,160 ft) were manually recorded at intervals of 1-45 days so considerable interpolation was required to calculate monthly totals.

Month	Flat Below Hakalau Cabin	Hakalau Cabin	Pua Akala Clearing	Nauhi Cabin
January		1.70	0.57	1.39
February	0.46	0.67	1.17	3.90
March	3.21	3.39	3.25	4.96
April	3.49	3.73	6.40	4.01
May	3.81	4.44	5.33	5.11
June	1.52	1.95	3.42	5.40
July	18.46	18.33	24.44	12.98
August	3.45	4.03	5.57	10.26
September	3.02	3.09	4.25	3.97
October	5.39	4.81	5.81	8.21
November	4.25	5.17	7.00	7.10
December		9.66	7.60	6.39
	TOTALS	60.97	74.81	73.68

Table III shows that both Pua Akala clearing and Nauhi cabin receive more rainfall than Hakalau cabin. The lower elevation of these two sites, and the fact that both areas are surrounded by forest instead of open grassland, probably account for the difference.

Dry *El Niño* conditions persisted throughout the spring planting period causing some mortality amongst the newly planted seedlings though they were well mulched with grass and dirt clods at planting. The rains that finally came in July were very welcome.

The endangered 'akiapola'au uses its stout lower bill as a chisel and its decurved upper bill as a probe to capture insects. (JJ)

C. LAND ACQUISITION

1. Fee Title

On January 26, 1993, the Service took title (through The Nature Conservancy of Hawaii) to a 1,033.94 acre parcel (Tract 11b) owned by the Liliuokalani Trust. The purchase price was $1,339,000 ($1,295 per acre). Henceforth, the refuge will refer to this property as the Upper Honohina Unit. Title was acquired subject to an existing lease with the Parker Ranch which terminates April 30, 1996. The lease will be administered by the Realty Division of the Regional Office. Parker Ranch intends to continue grazing cattle on the property for the remainder of their lease.

This purchase brings the total acreage of the refuge to 16,518 acres (seven parcels all owned in Fee Title by the Fish and Wildlife Service). Acquisition efforts were directed toward two additional parcels during 1993.

Condemnation proceedings were initiated by the Regional Director in 1989 for a 15,716 acre parcel owned by the World Union Industrial Corporation. An out-of-court settlement between the Service and World Union was reached on April 30, 1992 when the parties agreed on a total value of $10 million. On December 17, 1993, the State Board of Land and Natural Resources issued a Conservation District Use Permit to consolidate and re-subdivide the parcel. On the same day, it was learned that Congress approved the request to reprogram additional funds for the purchase. The Service will receive title to the property sometime in 1994.

In 1990, the Service learned that the W.H. Shipman Corporation was for sale and expressed interest in acquiring the 500 acre Pua Akala Ranch retained by the W.H. Shipman Estate (borders the southwest corner of the refuge) when the 4,994 acre Shipman Parcel was sold to the FWS in 1985. Initially, the owners were reluctant to break the property away from the corporation and sell it as an individual parcel but they reversed their position in 1992. In 1993 the Conservation Fund indicated their interest in purchasing the property (with funds from the Mellon Foundation) and donating it to the Service. A Level I contaminant Survey was conducted soon after. The removal of dilapidated structures and abandoned equipment will require considerable expenditure but no significant contaminants were found. The property is currently leased for grazing and encompasses about 200 acres of forest and 300 acres of grassland heavily infested with gorse. Before the refuge was established, this parcel was included within the proposed boundary.

D. PLANNING

2. Management Plan

With the assistance of Pete Weher and Mike Poe of the Regional Office, a site planning effort was initiated for Hakalau in 1992. Locations for existing and planned structures and roads were included in the first draft which also included elevational contours for the administrative site. The second and third drafts were completed in 1993 which included a new staff residence, an equipment maintenance building, a fuel dispensing/flammables storage area, helicopter pad, tree nursery, dog kennel, access roads, a field station for the University of Hawaii and a cabin for the National Biological Survey research crew. By the end of the year, construction was underway on the first phase of the NBS Cabin which is sited about 400 feet west of the refuge's cabin.

Tanya Rubenstein, a graduate student at the Yale University School of Forestry, submitted a preliminary proposal for a contract to complete a Forest Management Plan for Hakalau. Funding for a contract to prepare the plan will be sought in 1994.

4. Compliance with Environmental and Cultural Resource Mandates

A Section 7 Evaluation and Environmental Assessment were completed for the fence corridor clearing and construction of about six miles of pig/cattle fence around the Lower Honohina Feral Ungulate Management Unit. These documents along with the Conservation District Use Permit from the State of Hawaii allowed the fence construction described below under Section I.1.a.to proceed.

The Regional Archaeologist also surveyed the fence corridor to ensure that no cultural resources would be impacted by the project. During his visit, he also mapped and described the four cultural resource sites known from the refuge and examined potential sites for gravel pits and road re-alignments.

Intra-service Section 7 Evaluations and Compatibility Assessments were completed for numerous other projects in 1993 including fence construction in the Upper Maulua Unit, the open house, additional access to the public hunting area, feral ungulate control assistance from the U.S. Navy SEAL Team, limiting factors research by the National Biological Service, biological research by the University of Hawaii, and seven Special Use Permits.

5. Research and Investigations

a. Forest Bird Research

1) University of Hawaii Studies

Forest bird research was initiated in 1987 at Hakalau by Dr. Leonard A. Freed, Professor of Zoology, University of Hawaii. In 1993 his Special Use Permit (HAK-1-93) was renewed. The focus of his research is to "conduct ornithological research within Hakalau Forest NWR to include observational, demographic, behavioral and genetic studies." The permit is for a five-year period and is renewable subject to compliance with the Special Conditions. Freed and his students are using basic research techniques including mist netting, banding, collecting blood samples for disease and DNA analysis, and making nesting and behavioral observations. Four study sites have been established by Freed and his students. The bulk of the research occurs within a 20 hectare forested area centered around an open meadow at the top of the Pua Akala Tract and is called the Upper Pua Akala Site. A second study area was established several hundred meters northwest of the Spring Water Camp area within Maulua Tract in 1992. Two additional sites were established in 1993. One is located 1,000 meters below the upper Pua Akala site and is termed the Lower Pua Akala Site. The other straddles Hakalau Stream in the lower Shipman management unit and is called the Pedro Site.

Aerial net structures have been set up at each of these sites except for the Pedro Site.

Several distinguished scientists joined Freed for short periods at Hakalau. They included Dr. Glen Woolfenden, University of Florida and Dr. Steve Hubble, Director of the Center for Tropical Forestry and Chairman of the Committee for the National Institute for the Environment.

Ten students from the Avian Biology course at the University of Hawaii at Manoa visited the Pua Akala study site for one day in November.

Nine University of Hawaii personnel were officially associated with the field studies at Hakalau during 1993. Drs. Leonard Freed and Rebecca Cann (Chief Investigators) were assisted by graduate students, Matt Burt, Scott Fretz, Patrick Hart, Jaan Lepson, Joby Rohrer, Katie Swift and Eric VanderWerf.

Mr. Lepson camped in the Pua Akala meadow almost continuously since 1987, operating mist-nets, banding and bleeding birds, and observing bird behavior to obtain information for his PhD dissertation on temporal plumage maturation of the endangered 'akepa. Scott Fretz stayed intermittently at the camp while collecting insects for his research comparing arthropod abundance at two sites of differing endangered bird abundance. Other students assisted Freed in netting and banding activities. Capture, banding and blood sampling activities are summarized in Tables IV and V.

Table IV. Summary of birds captured and banded during 1993 by Dr. Leonard Freed and colleagues.

	Newly Banded Individuals		Recaptures	
	Pua Akala	Maulua	Pua Akala	Maulua
ENDANGERED SPECIES				
Hawaii 'Akepa	25	0	23	0
Hawaii Creeper	9	0	1	0
'Akiapola'au	0	0	0	0
TOTAL	34	0	24	0
OTHER NATIVE SPECIES				
'Oma'o	4	1	6	1
'Elepaio	6	0	6	0
Common 'Amakihi	35	21	24	5
'Apapane	60	18	9	3
I'iwi	89	17	41	3
TOTAL	194	57	86	12
INTRODUCED SPECIES				
Red-Billed Leiothrix	7	1	1	0
Japanese White-Eye	14	9	7	3
House Finch	4	0	0	0
Nutmeg Mannikin	1	0	0	0
TOTAL	26	10	8	3
GRAND TOTAL	254	67	118	15

Table V. Summary of birds banded and bled by Dr. Leonard Freed and colleagues during the life of their study.

Year	Banded All Species	Banded Endangered	Bled All Species
1987	381	57	0
1988	461	34	91
1989	475	49	119
1990	325	23	232
1991	366	23	258
1992	320	9	206
1993	421	34	298
1993	421	34	298
TOTAL	2,749	229	1,204

During 1993, Dr. Freed and his colleagues found 17 endangered 'akepa nests of which at least 10 fledged young successfully. Others nests may have fledged young but their status was not determined. All 'akepa nests were in ohia and koa tree cavities but not all previously used cavities were used in 1993. Three trees have had the same cavity used for three years. In some instances, new tree cavities were used that had not apparently been used in the past. The height of natural cavities averaged 7 meters. 'Akepa used trees with an average DBH of 1 meter which is significantly larger than the 0.5 meter DBH of random tree diameter at Pua Akala. The smallest tree used by 'akepa was .68 meter DBH.

In 1992, the researchers designed and mounted 61 artificial cavities on large ohia and koa trees that had been previously used by 'akepa for nesting. These artificial cavities were constructed of six-inch black ABS pipe with a rubber cap, wooden bottom and tree bark glued to the outside as camouflage and to the inside walls to provide a rough surface to assist the birds in exiting the cavity. Though natural nest cavities averaged 7 meters in height, the artificial cavities were placed at an average height of only 3-4 meters due to the difficulty associated with higher placement. No active 'akepa nests were observed in the artificial cavities by the end of the 1993 nesting season but rat nests were found in two. Both rat nest sites were located near gulches and were adjacent to pilo and akala plants, which may have attracted the rats to the sites.

Extensive flocks of 'akepa and Hawaii creeper, including many juveniles, were observed during the summer indicating high reproductive success for these species during 1993.

Based on long term studies, male 'akepa acquire their bright orange plumage just prior to their third potential breeding season. Counting the hatch year as the first year, they apparently breed in adult plumage only during their fourth year and thereafter.

Avian malaria and pox continue to be found on the refuge. Using a molecular probe developed by Dr. Rebecca Cann and used to detect subclinical malarial infections, Dr. Freed and associates found evidence that a malaria epizootic took place at Pua Akala during late 1988 and early 1989. Subsequently, only a single apapane has tested positive for malaria at Hakalau. An amakihi that tested positive for malaria in 1989, was recaptured in 1993 indicating some survival in this species. The molecular probe may have the ability to identify birds that are tolerant or resistant to the disease and to identify strains of malaria with different degrees of virulence. The discovery of malaria at this elevation opens the question of whether the disease was contracted on the refuge or at lower elevations with subsequent dispersal to the refuge. The UH staff will attempt to use the molecular probe to identify malarial DNA in the hemolymph of insects found at Hakalau.

Pox-like lesions were found on all species of native birds on the refuge, although rarely on the endangered birds. The survival and reproductive success of birds with lesions are being monitored to determine demographic effects. Dr. Rebecca Cann is attempting to design a molecular probe for pox virus similar to the one she designed for malaria.

Pox-like lesions were found on birds in both the Pua Akala and Maulua study sites during 1993 in the following proportions:

Species	Upper Pua Akala	Lower Pua Akala	Maulua
'Akepa	6%	25%	N\A
'Amakihi	15%	38%	19%
'Apapane	6%	0%	24%
'Elepaio	0%	0%	N\A
Hawaii Creeper	0%	0%	N\A
House Finch	0%	N\A	N\A
I'iwi	8%	11%	5%
Japanese White-eye	20%	0%	8%
Nutmeg Manikin	0%	N\A	N\A
Omao	10%	N\A	0%
Red-Billed Leiothrix	0%	0%	0%

Analysis of a slowly evolving region of mitochrondrial DNA is revealing some patterns among Amakihi. Most of the ancient lineages present at Pua Akala are also present at Maulua, but Maulua birds also have a lineage present among Amakihi at Hanawi Natural Area Reserve on Maui.

There were two casualties associated with the University of Hawaii mistnetting activities in 1993. An Omao was found dead, tangled in the edge of a furled net. New furling techniques will be used to prevent this type of accident in the future. Later in the year, an Amakihi was found dead shortly after being placed in a net bag. The cause of death was not identified.

Dennis LaPointe, a graduate student at the University of Hawaii, Department of Entomology, completed a study at the refuge for his ongoing work on determining the range of mosquitoes on the Island of Hawaii. Two monitoring and trapline transects were set up, one at Maulua Tract and one at Pua Akala Tract. Low numbers, of mosquitoes (*Culex quinquefasciatus*) were collected between 4,300 and 5,900 feet elevation at Maulua and none were collected at Pua Akala. None of the Hakalau mosquitoes were found to be infected with avian malaria, contrasting with the Kulani area of the Big Island, where 29% of the mosquitoes were infected. Mosquito larvae were found in several types of artificial containers at the Maulua Tract including an old bath tub used as a cattle trough and within numerous tires used to hold down a pond liner. The bath tub was turned over to prevent it from holding water and the tires were removed from the refuge to prevent further breeding. No larvae were found during a thorough search of numerous hapu'u cavities located at the lower elevations of the study site.

Interestingly, mosquito distribution at Hakalau followed the reverse elevational pattern from that of the LaPointe's Stainback Highway/Kulani study site where more mosquitoes were found at lower elevations. This pattern may be a function of the peridomestic habit and dispersal behavior of *Culex*. Breeding sites and hosts are found in association with cattle ranching which may provide favorable conditions for high elevation *Culex* populations. At Hakalau, the thick forest may limit dispersal of wind blown mosquitoes, but in the higher elevation open pastures, dispersal is facilitated by the open conditions.

2) <u>University of Washington Studies</u>

Dr. John Wingfield and research assistants Kathleen Hunt, Creagh Bruenner and Randall Mullen from the University of Washington conducted a three month study entitled " Hormonal Basis of Reproductive Cycles in Endemic Forest Birds of Hawaii" under SUP 4-93. Their major objective was to determine whether or not it is possible to collect blood samples and perform laparotomies on wild native Hawaiian forest birds (but not endangered species) without disturbing their breeding cycle or compromising the fitness of the birds being sampled. Dr. Wingfield and his assistants performed laparotomies on 37 Amakihi, 53 I'iwi, 36 Apapane, 3 Omao and 18 Japanese White-eyes. Although two birds died, an Amakihi and a Japanese white-eye, recapture rates and resightings of laparotomized birds were equal to or greater than recapture rates and resightings of non-laparotomized birds. Behavioral observations of laparotomized birds indicated that normal behavior (foraging, feeding, singing, calling, flying etc) occurred within 45 minutes of release. These data indicate that the techniques for blood taking and laparotomy are safe and reliable if used with care by trained people.

Wingfield found very few birds in reproductive condition during the study period but all species showed a wide range of gonadal development from undeveloped (non-breeding) to near full functional development. This variation in gonadal state is unlike the more synchronous seasonal development seen in north temperate species. Plasma levels of

testosterone varied independently of testis mass, (except I'iwi) suggesting that other factors also regulate secretion of sex steroid hormones. Hawaiian forest birds also showed a marked increase in corticosterone in response to stress. These hormones are known to have deleterious effects on reproductive function and behavior patterns. This stress response varied among individuals, possibly in relation to body size.

A blood sample is taken from a young 'i'iwi for disease and genetic studies. (JJ)

3) National Biological Survey Studies

Late in 1993, the National Biological Service began setting up study sites at Hakalau for research entitled "Research on Factors Limiting Native Forest Birds in Wet Forests of Hawaii" conducted under SUP-1-94. Three similar elevation intensive study plots, each approximately one square kilometer in area, were set up in the Pua Akala, Honohina and Maulua Tracts. These plots were further divided by transects spaced at 50 meter intervals throughout the plots. Research will begin in early 1994 on the following: forest bird demography, habitat, food resources, predators and disease.

Several meetings were held to discuss the coordination of future bird research at Hakalau Forest NWR. Staff from HFNWR, NBS and UH discussed ways to prevent duplication of effort, to facilitate cooperation between all parties and to share such data as band numbers, color band combinations and blood samples.

b. Soils Research

In 1992, Dr. Haruyoshi Ikawa, Department of Agronomy and Soil Science, University of Hawaii was awarded a $10,000 contract to conduct a study of the physical, chemical, mineralogical and mycorrhizal properties of the soils at Hakalau relative to problems with koa seedling establishment and growth. The study will continue at least through 1994. During 1992 and 1993, soil samples were collected from three sites at Hakalau where there were problems establishing koa seedlings and three sites where there were no problems. Analysis of these samples is underway. Also, approximately 1/2 ton of soil was collected from the same sites for use in the study to determine the response of koa seedlings to mycorrhizal inoculation.

E. ADMINISTRATION

1. Personnel

Hakalau Forest NWR is part of the Hawaiian/Pacific Islands NWR Complex. The 1993 Complex staff was comprised of 47.0 FTE's broken down as follows:

Refuge Complex Administration	8.5 FTE
Remote Island Refuges	15.0 FTE
Guam NWR	1.0 FTE
Oahu Refuges	4.5 FTE
Kauai Refuges	10.0 FTE
Hakalau Forest NWR	8.0 FTE
TOTAL	47.0 FTE

Two new employees were added to the Hakalau staff during 1993 and one departed. Patrick Bryan began working on June 6 as a Maintenance Worker WG-4749-5, temporary intermittent and was subsequently converted to

temporary full-time. Jerry Laronel began working on November 1 as a Maintenance Worker WG-4749-5, temporary full-time. Both of these men are part of the habitat management team responsible for fence construction and maintenance, feral ungulate and predator control, and weed control. After 2-1/2 years on the Hakalau staff, Anthony Texeira (WG-4749-6), who was also part of the Habitat Management team, departed on September 17 to take a Motor Vehicle Operator position with the Kaloko-Honokahau National Park near his Kona residence.

Three employees were promoted during the year. On February 21, Lynne Hanzawa was promoted from Office Automation Clerk, GS-326-4 to Administrative Support Assistant, GS-303-5. On March 21, Richard Wass was promoted from Refuge Manager, GS-485-11 to GS-485-12. On September 5, John Jeffrey was promoted from Wildlife Biologist, GS-486-9 to GS-486-11.

Three employees were converted. On March 7, Terence Takiue was converted from Maintenance Worker WG-4749-5, temporary full-time to temporary intermittent. On March 21, Anthony Texeira was converted from Maintenance Worker WG-4749-6, temporary full-time to permanent full-time. On November 17, Patrick Bryan was converted from Maintenance Worker WG-4749-5, temporary intermittent to temporary full-time.

At the end of 1993, the Hakalau staff was comprised of the following individuals:

a. Richard C. (Dick) Wass, Refuge Manager, GS-485-12, Permanent Full Time, entered on duty January 1, 1987 as a GS-485-11.

b. John J. (Jack) Jeffrey, Wildlife Biologist, GS-486-11, Permanent Full Time, entered on duty September 9, 1990 as a GS-486-9.

c. Jon R. Emig, Maintenance Worker, WG-4749-7, Permanent Full Time, entered on duty April 20, 1988 as Temporary Full Time.

d. Lynne H. Hanzawa, Administrative Support Assistant, GS-326-5, Permanent Full Time, entered on duty January 12, 1993 as a GS-326-4.

e. Andrew (Andy) H. Kikuta, Maintenance Worker Foreman WS-4749-4, Permanent Full Time, entered on duty June 14, 1992.

f. Victor B. Souza, Jr., Maintenance Worker, WG-4749-5, Temporary Full Time, entered on duty August 3, 1992.

g. Terence M. (Terry) Takiue, Maintenance Worker, WG-4749-5, Temporary Intermittent, entered on duty August 3, 1992 as Temporary Full-Time.

h. Patrick G. (Pat) Bryan, Maintenance Worker, WG-4749-5, Temporary Full Time, entered on duty June 6, 1993 as Temporary Intermittent.

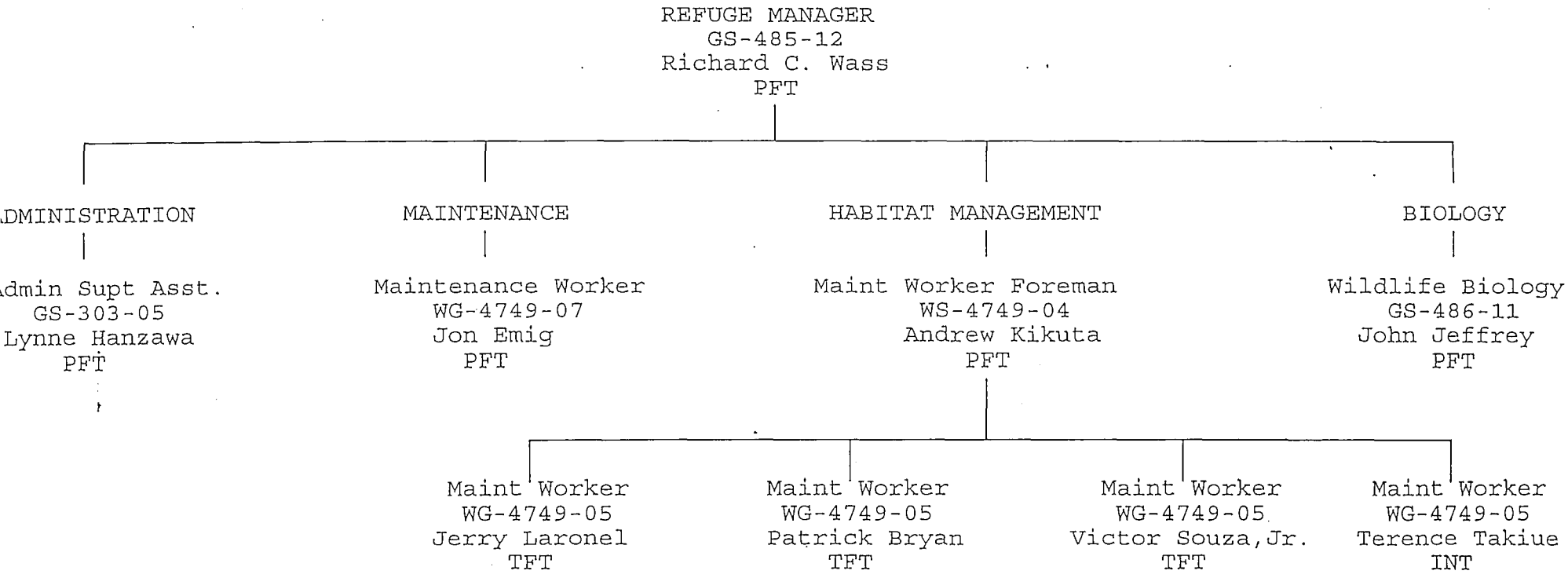
i. Jerry S. Laronel, Maintenance Worker, WG-4749-5, Temporary Full-Time, entered on duty November 1, 1993.

An organizational chart for the Hakalau staff is depicted in Figure 2.

The 1993 Hakalau Forest NWR staff. Front row, left to right: Victor Souza (Maintenance Worker), Jon Emig (Maintenance Worker) and Jack Jeffrey (Wildlife Biologist); middle row: Jerry Laronel (Maintenance Worker), Patrick Bryan (Maintenance Worker) and Andy Kikuta (Maintenance Worker Foreman); back row: Lynne Hanzawa (Administrative Support Assistant), Terry Takiue (Maintenance Worker) and Dick Wass (Refuge Manager).

FIGURE 2.

HAKALAU FOREST NATIONAL WILDLIFE REFUGE - 1993
(12516)



The history of employee strength for Hakalau Forest NWR since the refuge was established is summarized as follows:

Calendar Year	Permanent	Term	Temporary Full-Time	Temporary Intermittent	Total FTE
1985	-	-	-	-	0
1986	-	-	-	-	0
1987	1.0	-	-	-	1.0
1988	1.0	-	0.7	-	1.7
1989	1.0	-	1.0	-	2.0
1990	1.3	-	1.7	-	3.0
1991	2.7	-	1.3	-	4.0
1992	4.0	-	2.3	-	6.3
1993	5.5	-	1.8	0.7	8.0

4. Volunteer Program

Volunteer assistance is generally provided by groups from Oahu, Maui and the Big Island which travel to the refuge for a 2- or 3-day weekend. The groups of 6-12 individuals provide their own transportation to the Big Island and their own food. The refuge usually provides transportation from Hilo, the facilities at Hakalau Cabin, and tools to accomplish the job. A member of the refuge staff generally accompanies the group to direct their efforts. For three-day trips, the group is usually given the last day to hike and observe birds with the refuge biologist as a guide. The bird hike is a major incentive because most of the refuge is closed to the general public. Each volunteer who provides two or more days of effort is also given a "Hakalau T-shirt" or a FWS volunteer cap as an expression of thanks.

Seventeen volunteer groups assisted the refuge during 1993 for periods of 1-4 days. The 141 volunteers donated 1,342 person-hours of much-appreciated effort to pick koa seed pods, plant and fertilize koa seedlings, and control banana poka, gorse and holly. A brief description of each volunteer group visit follows:

a. January 26-28. Ken and Darleen Fiske of Woodstock, Illinois spent 35 person-hours identifying tree species on a digitized map of the pasture area. Their effort was coordinated by Jack Jeffrey.

b. April 9-11. Nine volunteers from the Honolulu Sierra Club (led by Kost Pankiwskyj) fertilized 5,000 koa seedlings during 110 person-hours of effort. The effort was coordinated by Barry Orlando.

c. May 1. Eight volunteers from the Hilo Rotary Club (led by Mike Robinson) planted 1,000 koa seedlings during 40 person-hours of effort. Pat Bryan and Jon Emig assisted the effort.

d. May 15-16. Eight volunteers from the Hilo High School Hikers Club (led by Julie Williams) planted 3,000 koa seedlings during 90 person-hours of effort. Barry Orlando, Jon Emig and Dick Wass assisted the effort.

e. May 22-23. Seven Volunteers from the University of Hawaii at Hilo and the West Hawaii Sierra Club planted 3,000 koa seedlings during 80 hours of volunteer effort. Barry Orlando and Jon Emig assisted the effort.

f. May 29-31. Eleven volunteers from the Honolulu Sierra Club (led by Annette Kaohelaulii) planted 4,000 koa seedlings during 99 person-hours of effort. Pat Bryan and Jon Emig assisted the effort.

g. June 5-6. Six volunteers from the Puna Outdoor Circle planted 3,500 koa seedlings during 70 person-hours of effort. Barry Orlando and Jon Emig assisted the effort.

h. June 11-13. Nine volunteers from the Maui Sierra Club (led by Anna Mae Shishido) planted 4,000 koa seedlings during 90 person-hours of effort. Pat Bryan and Jon Emig assisted the effort.

i. June 19-20. Twelve volunteers from the Moku Loa Group, Sierra Club (led by Lorrie Ellison) planted 3,250 koa seedlings during 96 person-hours of effort. Barry Orlando and Jon Emig assisted the effort.

j. June 26-27. Nine volunteers from the Honolulu Office, Fish & Wildlife Service planted 3,250 koa seedlings during 81 person-hours of effort. Pat Bryan, Jack Jeffrey and Dick Wass assisted the effort.

k. July 3-5. Nine volunteers from the Honolulu Sierra Club (led by Jim Waddington) planted 3,750 koa seedlings during 90 person-hours of effort. Barry Orlando and Jon Emig assisted the effort.

l. July 10-11. Four volunteers from Na Ala Hele planted 1,000 koa seedlings during 40 person-hours of effort. Pat Bryan and Jon Emig assisted the effort.

m. July 26-28. Five student interns from The Nature Conservancy plus Pauline Sato cut holly and banana poka, grubbed gorse and pulled thistle during 91 person-hours of effort. Jack Jeffrey coordinated the effort.

n. September 4-6. Ten volunteers from the Honolulu Sierra Club (led by Gerald Toyomura and Helen Sing) cut holly and banana poka during 125 person-hours of effort. Jon Emig assisted the effort.

o. November 12. Ten volunteers from the Hawaii Forest Industry Association (led by Mike Robinson) picked two bags of koa seed pods during 30 person-hours of effort.

p. November 20-21. Fifteen volunteers from the National Biological Survey picked 15 bags of koa seed pods during 105 person-hours of effort. Jack Jeffrey assisted the effort.

q. December 11-12. Seven volunteers from the Junior Greenpeace Club, Konawaena High School picked five bags of koa seed pods during 70 person-hours of effort. Barry Orlando assisted the effort.

5. Funding

Hakalau Forest NWR receives its funding through the Hawaiian/Pacific Islands NWR Complex. The FY 1993 funding for the Complex follows:

Refuge Complex Administration	$336,700
Remote Island Refuges	995,700
Oahu Refuges	481,600
Kauai Refuges	442,000
Hakalau Forest NWR	729,000
TOTAL	$2,985,000

Hakalau received $729,000 in funding for FY 1993 which included operations and maintenance funding totaling $468,100, a special congressional appropriation in the amount of $250,000 for the construction of pig/cattle fence and $10,900 from the American Forestry Association (AFA) to assist with the propagation and outplanting of koa seedlings. The AFA grant was administered by the Big Island Resource Conservation and Development Council and was used primarily to pay a coordinator to organize and lead volunteer tree-planting crews.

The history of funding for Hakalau Forest NWR since the refuge was established is summarized as follows:

Year	Establishment (FWE)	Operations & Maintenance (RW)	Special Appropriation	Other Contributions	Total
FY86	$130,000	-	-	-	$130,000
FY87	$75,000	$23,000	-	-	$98,000
FY88	-	$180,000	-	-	$180,000
FY89	-	$161,500	-	-	$161,500
FY90	-	$226,100	$237,500	$3,000	$466,600
FY91	-	$271,300	$251,000	$3,500	$525,800
FY92	-	$483,700	$289,300	$4,600	$777,600
FY93	-	$468,100	$250,000	$10,900	$729,000

6. Safety

Maintenance Worker Terry Takiue was sidelined for about eight weeks with a fractured finger. He sustained the injury on December 10, while using a mechanical device to shuck koa seed pods at the State Tree Nursery in Kamuela.

Excepting the Administrative Support Assistant, the entire Hakalau staff attended a half-day training session on helicopter sling load safety. The proper use of sling load equipment, swivel hooks, cable attachment, personal protection gear and safety procedures were covered during the Office of Aircraft Services course at Hilo Airport.

7. Technical Assistance

The Refuge Manager continued his active participation on the multi-agency Gorse Steering Committee and the Forestry Subcommittee of the Resource Conservation and Development Council. The committees were regularly appraised of the refuge's efforts to control gorse and plant koa seedlings.

The Refuge Manager also continued to participate on the Animal Species Advisory Commission which advises the Governor regarding the introduction of new animal species to Hawaii and related matters.

The Maintenance Worker Foreman traveled to Kalaupapa, Molokai to participate in a scoping session to update the Kalaupapa National Historic Park's resource management plan.

In January, the biologist assisted Hawaii State Division of Forestry and Wildlife personnel with the post-hurricane Iniki forest bird survey of the Alakai Swamp area on the Island of Kauai.

The biologist coordinated the training of Haleakala NP and Hawaii Volcanoes NP personnel for the State's Kipuhulu Valley forest bird survey. He also assisted in the survey by conducting forest bird censuses on transects within the valley.

The biologist assisted by Paul Conry, State Division of Forestry and Wildlife and George Martin established transect 14 for the annual State Forest Bird Survey. The 53-station (5.4 mile) transect transverses a thickly forested and heavily gulched area ranging from 4,600 to 2,200 feet elevation in the Hakalau Forest NWR and the Laupahoehoe Natural Area Reserve.

The biologist and J. Jacobi, National Biological Service, conducted a two day pre-survey calibration and training session at Kulani forest for the Big Island Forest Bird Survey at the Kau Forest Reserve. Personnel attending were from the State Division of Forestry and Wildlife, U. S. Fish and Wildlife Service, National Park Service, The Nature Conservancy of Hawaii, University of Hawaii and Bishop Estate.

In May, biologist Jeffrey assisted with the logistical support and conducted bird censuses in the Kau and Laupahoehoe areas for the Big Island Forest Bird Survey. Early in the month Jeffrey and Eric Nishibayashi (NPS) censused transect 5, above the town of Pahala, on the southeastern side of Hawaii. This was the first time since the Hawaii Forest Bird Survey in the mid to late 1970's that the Kau, Kapapala, Laupahoehoe and the Honomalino Forest Reserves on the Big Island have been surveyed. During the last week in May, Jeffrey censused transect 13 and portions of transect 14 with Vikki Grievey (NPS) within the Laupahoehoe Natural Area Reserve adjacent to the Refuge. Jeffrey also coordinated radio checks with other census teams and picked up teams at the end of their transect. At the request of Scott Johnston USFWS, Ecological Services, the staff biologist along with NBS, HVNP, DOFAW and

ES personnel, assisted in the planning and implementation of a Hawaiian Hawk survey on the Big Island. He assisted the coordinators, Mike Morrison and Linnea Hall from the Western Foundation of Vertebrate Zoology with orientation, logistical support and surveys. These surveys were conducted to ascertain the population size of the Hawaiian Hawk to determine if down-listing of this endangered species to threatened is warranted.

8. Other (Includes Conference and Workshop Attendance)

The Refuge Manager attended a two-day alien plant workshop in Honolulu sponsored by The Nature Conservancy. The major product of the workshop was a prioritized listing of research and management needs for alien plants.

The Refuge Manager attended the Hawaii Conservation Conference at the Hilo Hawaiian Hotel. As a substitute for Complex Manager Rauch, he gave a talk on his "three worst nightmares" (wildlife and habitat management concerns).

The Refuge Manager attended the Hawaii Forestry Industry Association Conference at the Hilo Naniloa Hotel titled "Forestry--A Bridge to the Future". The conference focused on the replacement of sugar cane with forestry products as an economic base for the Hamakua District of the Big Island.

The Maintenance Worker Foreman attended a Predator Control Workshop in Honolulu sponsored by the Wildlife Society. Experts from New Zealand were invited to share their experiences and success stories with land managers and biologists from many natural resource management agencies.

F. HABITAT MANAGEMENT

3. Forests

Formerly, koa and ohia forests extended above the upper reaches of the Refuge. One hundred and fifty years of logging, burning and cattle grazing, however, have reduced the upper elevation forests to exotic grassland pastures with scattered native trees. Current management plans call for reforestation of these treeless areas. Below the pastures are forests with a complete canopy but with incomplete understory caused by the devastating effects of feral cattle and pigs. Management, in the form of feral ungulate removal, will promote natural understory regeneration in these areas.

a. Interagency Agreements and Studies

Interagency Agreements between the FWS and the U.S. Forest Service's Pacific Southwest Forest and Range Experiment Station were signed in 1986 and 1988 "for the purpose of developing guides for re-establishing the native forest on pasture areas of the Hakalau Forest NWR...." The

objectives were to conduct field trials to determine what native forest regeneration methods are most efficient and cost effective and to provide management prescriptions for future large-scale reforestation effort. Much has been accomplished under these agreements over the years and the Forest Service continues to monitor and experiment in three study sites on the refuge: Magnetic Hill, the Woodland Exclosure and Triangle Paddock.

1) Magnetic Hill Exclosure Study

In May 1987, an experimental reforestation plot of about 6 acres was established and fenced in open grassland below Magnetic Hill at the 6,500 ft elevation. The objectives of this study were to evaluate survival and growth of koa plantings at two spacing distances, as well as growth and survival of mamane, sandlewood and ohia plantings. Because of site planting flaws, effects of microsite rather than spacing, have been observed. Three year survival rates of koa within this site were high averaging 84% for the 2 meter spacing and 74% for the 2.5 meter spacing. Koa seedling survival elsewhere on the refuge at similar elevation is significantly lower. The factors responsible for the high survival rate at Magnetic Hill are unknown. Climatic data are unavailable but perhaps the winter of 1987 was unusually mild. In 1993, Forest Service staff planted an additional 1,000 koa seedlings in this exclosure.

2) Woodland Exclosure Understory Species Out-planting Trials

With assistance from refuge personnel, the Forest Service established a second experimental reforestation plot (a 40-acre area termed the Woodland Exclosure) in July 1987. It is located at an elevation of about 5,500 ft in the Honohina Tract within the Middle Honohina Feral Ungulate Management Unit. The objectives of the current Woodland Exclosure study are: 1) To determine the patterns of and requirements for natural regeneration of native plant species after cattle removal; and 2) To test out-planting methods for eight native understory plants (ohia, olomea, olapa, kolea, kawau, pilo, and two *Clermontia* species). All species planted survived reasonably well despite the lack of rainfall due to an *El Niño* induced drought.

During a short reconnaissance to the Woodland Exclosure, Refuge Biologist Jeffrey and Paul Scowcroft, U.S. Forest Service found that the wind storm on January 6, 1993 had caused minor damage to a number of plant species in the area. Several large koa and ohia trees had fallen and many of the young koa trees (>4m tall) were wind blown and partially defoliated. Several had broken trunks or branches. The ground was littered with small branches and leaves. Several planted *Clermontia lindseyana* plants had lost branches. The 5 planted *Clermontia pyrularia* plants checked were intact and one had flower buds. This plant, planted in 1990, is the first *C. pyrularia* outplanting to flower.

3) Triangle Paddock Seed Source Study

The third Forest Service study site is located in Triangle Paddock and overlaps the Refuge's 1989 koa planting at an elevational range of 5,700 to 6,400 ft. The objectives of this study are to test survivorship and growth rates for planted koa seedlings grown from seeds of known parentage. Data analysis indicates that parentage had little effect on seedling survival or growth along any of the tested elevational gradients. All trees had poor survivorship and growth at high elevations, but most did well at lower elevations. Variations in growth and survival were detected at all elevations and were most likely due to microsite differences. Variation in growth and survival of koa seedlings from any given parent tree is as large as that between seedlings from different parent trees.

4) Fertilizer Studies

Refuge staff established plots to monitor the 1992 koa fertilization test in the Hakalau and Pedro areas of the Hakalau Tract. The objective was to determine whether four ounces of 10-30-10 grannular fertilizer placed in two dibble holes about six inches on either side of a koa seedling would increase growth and survival. Five plots were set up ranging from high to low elevations. Seedlings were randomly chosen from each of the two fertilized and the one non-fertilized rows and marked with a one meter stake and colored flagging. The study was abandoned in 1993 because of poor survivorship due to drought and pig damage which masked the effect of fertilizer. Subjective comparisons of unfertilized and fertilized seedlings elsewhere on the refuge indicate that fertilizer boosts growth significantly for the first few months.

5) Slope and Aspect Study

Winter frosts have caused high mortality to koa seedlings at Hakalau, particularly within the high elevation areas. An inverse relationship has also been found between elevation and growth. There are also indications that slope and aspect may influence growth and survival of koa seedlings at Hakalau. A study to test the influence of slope and aspect on growth and survival was initiated in October of 1993. Plots were established on three topographic positions (ridge top, slopes and bottoms or flats) and four aspects (north, south, east and west) at two elevational gradients within the frost-prone open pastures of the Hakalau Tract. Six hundred and twenty seedlings were each marked with a small flag, individually numbered with aluminum tags, measured for height and foliage width and assigned to a vigor scale. The condition of each plant will be assessed throughout the winter of 1993. Air temperature and soil moisture will be monitored continuously with a CR10 Data Logger and strategically placed thermocouples. Soil depths and soil moisture levels will also be recorded.

6) Frost Protection Study

In November 1993, a study was initiated to determine whether or not certain structures or materials would protect koa seedlings from damage by frost. A block of koa seedlings (averaging 32 cm tall) planted six months earlier was selected as the study site. These trees are located at the highest elevation of the refuge (about 6,640 feet elevation) and are, therefore, exposed to the coldest temperatures. Ten structures of each type were deployed over/around healthy koa seedlings on November 4, 1993, before the first frost of the season. Height and breadth were measured for each seedling within the structures as well as for 20 unprotected seedlings designated as controls. Because feral pigs were also a problem in the area, the protective material/structure was either attached to a three-foot-tall hog-wire cylinder placed around the seedling or placed within the cylinder so neither the seedling nor the protective structure would be damaged. The following structures and materials were tested:

1. A "Wall O' Water" teepee (approximately 18 inches tall) containing 3 gallons of water which absorbs solar heat during the day and releases it at night.

2. A 2-foot-diameter cylinder of 36-inch hogwire covered with 6 mil clear polyethylene sheeting which will transmit light, but not air and moisture. The top perimeter was vented.

3. A 2-foot-diameter cylinder of 36-inch hogwire covered entirely covered with "Reemay" polyester fabric through which light, moisture and air pass.

4. A 2-foot-diameter cylinder of 36-inch hogwire with the east-facing (downhill) half of the cylinder walled with black shade-cloth. This design prevents rapid warming from the early morning sun.

5. A 2-foot-diameter cylinder of 36-inch hogwire with the west-facing (uphill) half of the cylinder walled with black shade-cloth. This design offers protection from the cold air descending from higher elevations at night.

6. A 2-foot-diameter cylinder of 36-inch hogwire roofed with black shade-cloth. This design slows the loss of heat radiating up from the ground at night.

7. A 4-1/2-inch-diameter by 2-foot-tall "Tubex Tree Shelter".

8. A 3-foot-square piece of 6 mil black polyethylene sheeting laid on the ground around the seedling. The black plastic may help to increase ground temperature during the day.

9. A 2-foot-diameter circle of redwood bark chips 2-3 inches deep laid on the ground around the seedling. The bark chips may help to conserve ground heat.

10. A 2-foot-diameter cylinder of 36-inch hogwire with no protective fabric attached to the top or side. This is a control to determine if the wire cylinder alone offers frost protection.

On December 4, after several heavy frosts, the koa frost deterrent structure experiment was checked. Preliminary results indicated that several of the structures could be ruled out as protecting the young koa trees against frost damage. All of the controls (no protection) had severe damage, as did both of the mulches. The most protection was afforded by the "Reemay" and polyethylene full coverings, the "Wall-O-Waters" and the shade cloth on the east side. Slightly more damage was seen on the plants protected with shade cloth on top, "tubex" and shade cloth on the west side. Heavy frost damage was noted on many other unprotected koa seedlings in adjacent high elevation areas. Monitoring will continue until the end of the frost season in April 1994.

7) Koa Growth and Survival Studies

During 1989, 11,000 koa tree seedlings were planted in the 400 acre Triangle Paddock area of the refuge. Planting sites were prepared with a disc-harrow to reduce competition from exotic pasture grasses. Koa seedlings (10" to 18" tall) were then planted in the exposed soil. Fifteen subsamples from this planting at different elevations are measured annually for growth and survival.

Approximately 2,500 seedlings in fifteen plots, at elevations between 5,600 and 6,400 feet were re-measured in September 1993. Overall survival from the time of planting to the present (1989 to 1993) is about 72% (Figure 3). Survival varied from 42% at the higher elevations to 100% at the lower elevations. Much of the mortality at higher elevations resulted from frost during the winter months. During 1992, an *El Niño* event generated drought conditions over the Hawaiian Islands which caused a dramatic decrease in rainfall at Hakalau. Although the drought did not seriously impact survival of these three-year-old-trees, growth rates were reduced (Figure 4). Rainfall increased in 1993 resulting in a higher growth rate. The mean sapling height for 1993 was 88 inches (tallest tree 200 inches). Tree heights averaged 74 inches at the highest elevation and 96 inches at the lowest elevation. Higher temperatures, fewer heavy frosts, and greater moisture enhanced the survival and growth at lower elevations. Survival and growth data for 1989 through 1993 are summarized in Figures 3 and 4.

8) Frost Tolerance Study

Studies at the Magnetic Hill Exclosure have shown that frost tolerance in native trees is variable. Koa seedlings survived the same winters that killed ohia and mamane seedlings. To aid in understanding freezing mechanisms and to determine the factors contributing to differing survival rates for mamane and ohia seedlings, Dr. Guillermo Goldstein, University of Hawaii and his graduate students conducted field studies at Hakalau and laboratory studies at the U.H. Manoa campus February - August, 1993.

Figure 3.

Average survival of koa seedlings, planted in 1989, by year and elevation

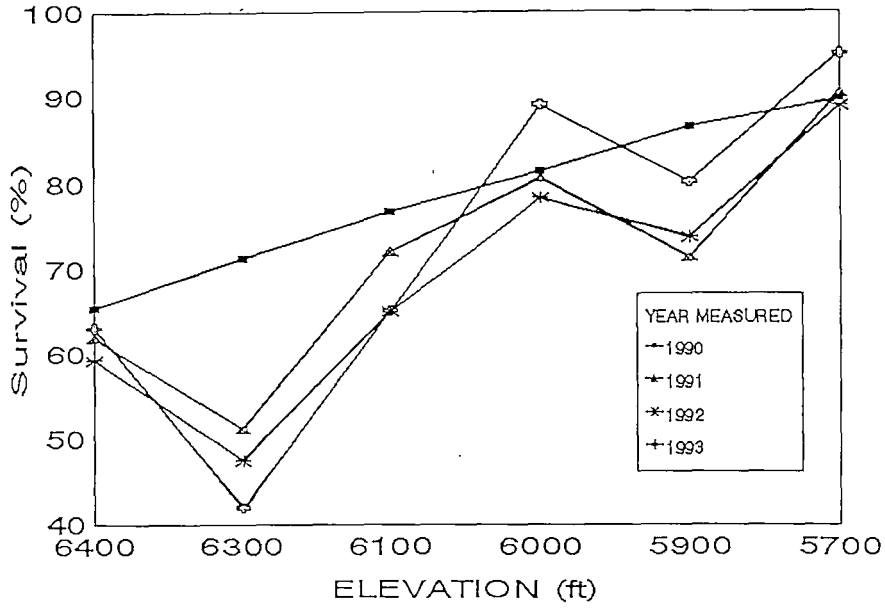
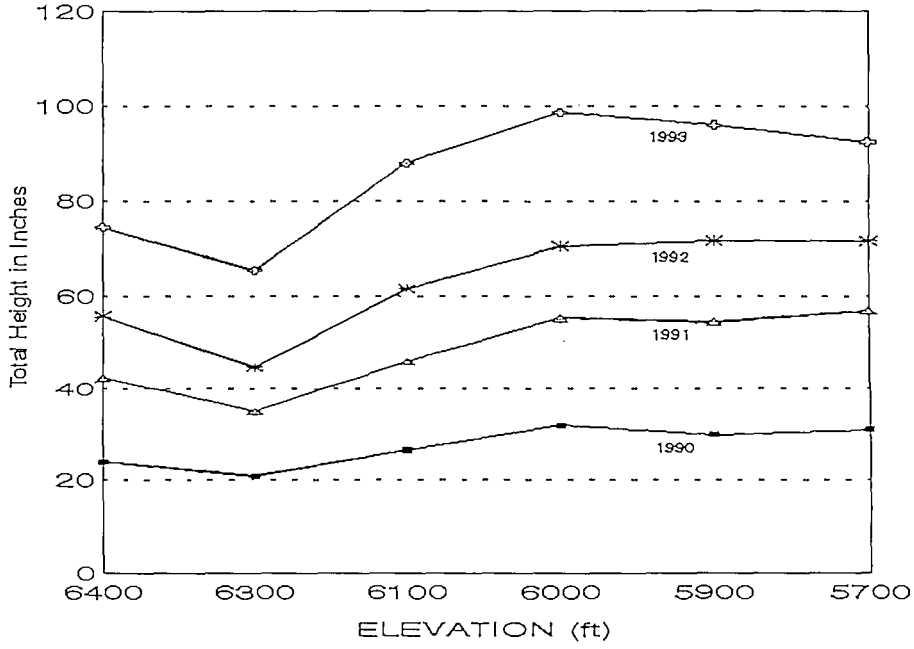


Figure 4.

Average height of koa seedlings, planted in 1989, by year and elevation



They found that mamane tolerates extracellular ice formation, particularly when seedlings are from high-elevation plants and are properly acclimated to cold temperatures. It appears that mucilage may act as an ice nucleating substance that increases supercooling and lowers the temperature at which the leaf cells freeze and irreversible tissue damage occurs.

In ohia, ice nucleation occurs close to the temperature at which irreversible tissue damage occurs. Although no elevational differences in tolerance were seen, the data suggest that pubescent ohia have a higher tolerance to frost damage than do glabrous varieties and that temperature acclimation for the pubescent types is not as important. Also, it appears that pubescent plants tend to decrease liquid water content in the leaves at lower temperatures than do glabrous plants, thereby, increasing freeze tolerance and reducing tissue damage.

9) Koa Seedling Survival Study

During 1993, Michael Robinson, Resource Management was contracted to 1) produce a map of the planting sites for the koa seedlings planted at Hakalau during 1992 and 1993; 2) determine first winter and first summer survival for these seedlings; and 3) relate survival to elevation, slope, aspect and other factors. Robinson's December 1993 report is titled "Koa Seedling Survival Study, 1992 and 1993 Plantings" and includes a nice set of maps that will be useful for subsequent record-keeping and for mapping additional planting sites. Robinson made the following conclusions:

1) Survival over the summer months for the 1992 planting was excellent with 92.6% of the seedlings still alive. By the following year, however, winter frosts reduced survival to 67%. Survival was inversely related to elevation. Only 42% of the seedlings planted above 6,200 feet survived the winter while 90.5% of the seedlings planted below 6,200 feet survived the winter.

2) For the 1993 plantings, Robinson attributed the increased mortality of seedlings planted with the hoedad (compared to seedlings planted with a dibble stick) to be due to dry conditions during the time of planting. (Subsequent data, however, indicated that planting technique does affect mortality and that trees planted with a hoedad did suffer higher mortality.)

3) For the 1993 plantings, average height of fertilized seedlings exceeded that of non-fertilized seedlings by almost 12 inches.

4) Two-thirds of the mortality that occurred during the first summer for the 1993 plantings was due to pigs. Drought and competition from pasture grasses also caused some mortality during the first summer.

b. Reforestation Program

By 1989, enough was known to go beyond the experimental stage and initiate a full-scale reforestation program on the refuge. Koa was chosen because the propagation methods are best known for this species. Additional species will be planted in the future as techniques for their propagation are better defined. The current establishment of koa stands in open pasture areas will improve the chances for later success with other species. These newly planted koa trees will add organic matter and nitrogen, acidify the soil, moderate temperature extremes and provide shade for future plantings of ohia and understory species.

1) Koa Planting - 1989

During 1989, 11,000 koa tree seedlings were planted in the 400 acre Triangle Paddock area of the refuge. Planting sites were prepared with a disc-harrow to reduce competition from exotic pasture grasses. Koa seedlings (10" to 18" tall) were then planted in the exposed soil. Growth and survival of these seedlings has been monitored on an annual basis. (See F.3.a.) The trees are now large enough to reproduce naturally via root sprouts and to provide habitat to native birds. 'Amakihi are occasionally seen amongst the lower 1989 planting.

2) Koa Planting - 1991

In 1991, 5,000 seedlings were planted below Hakalau Cabin and along the north side of Kolekole Stream above Middle Road. Six parallel continuous strips were laid out 12 feet apart from 6,400 ft to 5,500 ft elevation to test six planting site preparations for grass removal: discing, burning, scalping, weed-wacking, herbicide and no preparation. Discing was found to be the most effective planting site preparation method. After seven months, seedling survival rate at the highest elevation disced plot averaged 79% compared only 30-39% for the other five methods. After one year, survival rates for discing averaged 61% for all elevations versus 31% for all other treatments. The greatest growth occurred in the herbicide treatment which averaged 22.0 inches. The disced treatment was second in growth rate averaging 19.1 inches.

3) Koa Planting - 1992

Early in 1992, a partnership was created to help meet Hakalau's goal of reforesting the higher elevation, open grassland portions of the refuge. Although sufficient volunteer labor was available to help with the seed picking and planting, supervision of volunteer crews was needed to relieve the refuge staff on weekends. The Big Island Resource Development Council (RC&D) helped to form the partnership of sponsoring entities to conduct a five year reforestation project. Under this partnership, the refuge manages the project, prepares the planting sites, and provides volunteer transportation and lodging, plantation maintenance and protection, technical support and overall supervision and direction. The RC&D manages a $31,300 grant from the American Forestry Association to plant 126,000 koa seedlings at Hakalau. As a

condition of the grant, the plantings will be designated a Global ReLeaf Heritage Forest. The funds are used primarily to the pay a Crew Leader to organize and supervise volunteer crews of seed pickers and tree planters. The RC&D has contracted a forestry consulting firm, Resource Management, to administer the grant, provide technical assistance and to coordinate the recruitment and supervision of paid Crew Leaders. The State Division of Forestry and Wildlife (DOFAW) germinates and grows the seedings from seed provided by the refuge.

Under this partnership, 18,000 koa seedlings were planted during 1992 in Hakalau 2, Hakalau 4 and Pedro paddocks which are largely unforested. Again the trees were planted in three-row-wide corridors oriented in the mauka-makai (uphill-downhill) direction between the upper boundary and the top of the forest. The rows were spaced about 12 feet apart and the seedlings within each row were spaced about 12 feet apart. Planting sites were created by a contractor using a five-tined ripper mounted behind a Case 450 caterpillar tractor. A strip of turf approximately four feet by four feet was peeled back to expose mineral soil. The method worked well. It was faster than a disc which requires two passes and the grass does not grow back as fast. Planting sites created by the ripper also appear to be less attractive to pigs, probably because less freshly turned soil is exposed. Ten three-row-wide planting corridors were created in Hakalau 2, Hakalau 4 and Pedro Paddocks in April by the contractor (Steve's Ag Services). Between May 1 and July 5, five groups of volunteers planted the 18,000 seedlings. Barry Orlando was contracted by Resources Management to help organize and to lead the planting crews and he did an excellent job.

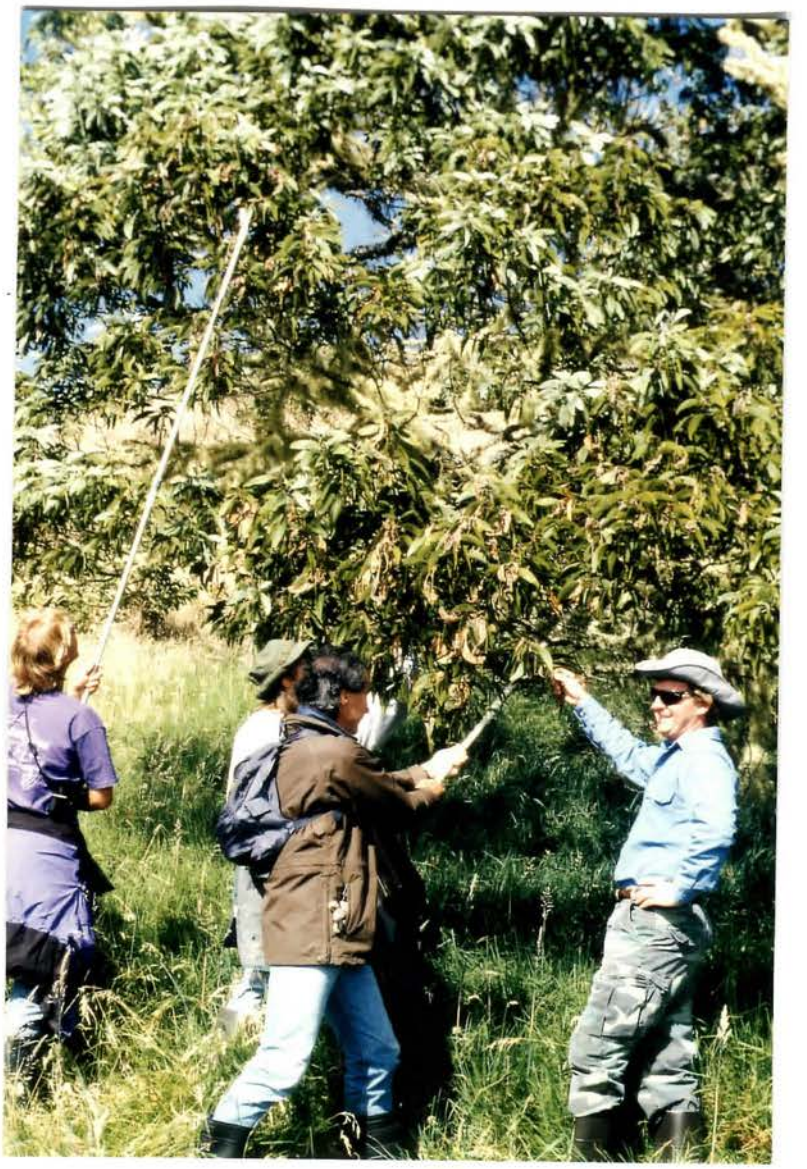
4) Koa Planting - 1993

1993 was a banner year for koa planting at Hakalau. 39,000 seedlings were planted in Barn 1, Barn 2, Hakalau 1 and Hakalau 3 paddocks (south of Hakalau Gulch) and in the Hakalau Cabin paddock by 11 groups of volunteers. The groups were organized and led by Barry Orlando, Patrick Bryan and the refuge staff. As in 1992, the trees were planted under the partnership between the American Forestry Association, the Big Island Resource Conservation and Development Council, the State Division of Forestry and Wildlife and Hakalau Forest NWR. Again, the seedlings were planted in three-and four-row wide, mauka-makai corridors through upper elevation grassland areas between the upper edge of the forest and the upper boundary of the refuge. Plantings occurred between April 5 and July 10.

The Refuge's own Caterpillar D4H crawler dozer was used for the first time this year to create the planting sites. A ripper cannot be attached to this tractor because a winch is permanently mounted on the back. Instead, a blade rake, fabricated and designed by Steve Baczkiewicz, was attached to the corner of the bulldozer blade. The blade rake has four tines of 1" x 5" steel bar spaced 12 inches apart (so it is three feet wide). The rake is attached to the corner of the main blade and extends about 12 inches below the bottom of the blade. While the tractor is moving forward, the main blade is lowered so the

tines of the blade rake penetrate 8-10 inches into the soil and peel back a three foot by four foot strip of turf to expose mineral soil. This method is faster and more comfortable than using the ripper because the tractor operator faces forward. With a single blade rake, 500 - 600 planting sites can be scalped per hour. The method is slightly faster when blade rakes are mounted on both corners of the main blade but it is nearly impossible to get two well-formed planting sites due to the uneven terrain. Also, the planting sites are only about seven feet apart instead of the 10-12 feet that is preferred.

Nine thousand of the above seedlings were planted during a five-day period by professional tree planters Randy Bond and Jay Hanson who volunteered their time in exchange for airline tickets purchased by the AFA grant. Randy and Jay used the planting technique practiced in the Pacific Northwest, namely the use of "hoedads". This tool works well in the hands of an experienced planter with a very strong wrist and back but the dibble stick technique is more efficient when planting is done by a group of volunteers. Randy and Jay each averaged about 1,000 trees per day while volunteers average only about 200 trees per day.



Koa seed pods are collected each year by volunteers. (DW)

Tree planting efforts at Hakalau since the refuge was established are summarized in Table VI.

Table VI. Summary of koa seedlings planted at Hakalau Forest NWR.

Year	Number of Seedlings	Lead Agencies	Paddocks Planted
1987	2,000	U.S. Forest Service staff	Magnetic Hill
1989	11,000	Volunteers, refuge staff	Triangle
1991	5,000	Volunteers, refuge staff	Cabin, Hakalau 4
1992	18,000	Volunteers, refuge staff, AFA partners	Cabin, Hakalau 4 Pedro
1993	39,000	Volunteers, refuge staff, AFA partners	Barn 1, Barn 2, Cabin, Hakalau 1, Hakalau 3
1993	1,000	U.S. Forest Service staff	Magnetic Hill
TOTAL	76,000		

5) Seed Collection

All koa seedlings planted at Hakalau are germinated from seeds picked from trees growing on or adjacent to the refuge to ensure that the seedlings are adapted to local conditions. Koa seed production in the Hakalau area was relatively high during both 1992 and 1993, possibly the result of dry conditions during both springs. In 1992, nine volunteer groups picked 47 bags of pods which yielded 120 lbs of seed. In 1993, four volunteer groups picked 35 bags of pods yielding 52 lbs of very clean seed plus 20 lbs of seed mixed with dirt and residue. Seed pods were mechanically shucked at the State Tree Nursery.

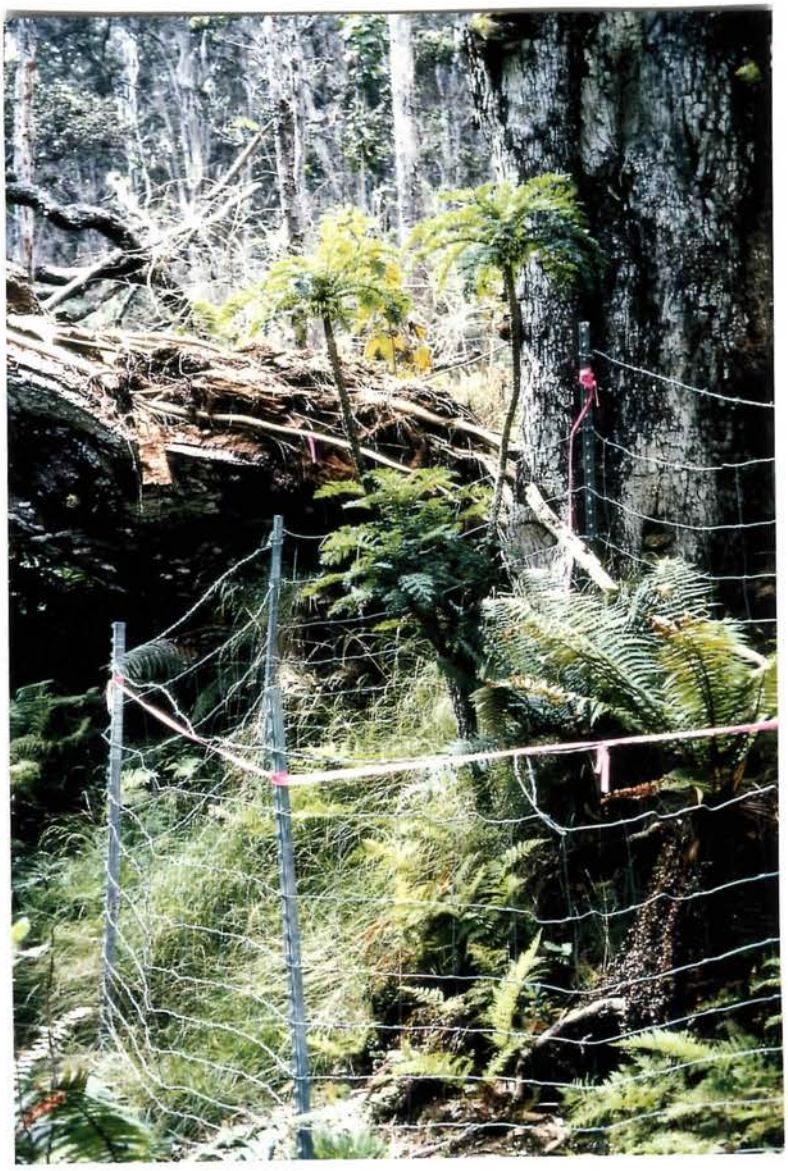
c. Rare Plants

In 1990 and 1991, fruits of *Clermontia pyrularia* were collected by refuge staff from the last and only known plant, found in the Piha area. These were sent to Fern Duvall (DLNR) for seed extraction and germination. On December 5, 1990, twelve of the prodgeny were outplanted in the Woodland Exclosure and in June of 1992 twenty-five more of these endangered plants were outplanted in the Pua Akala and Honohina Tracts of the Refuge. The six- to eight-inch plants were planted along established transects on rotted log and soil substrates. In January 1993, the tallest *C. pyrularia* planted within the Woodland exclosure was found with flower buds. All of these outplantings are monitored to record survival, vigor, growth rates and first flowering dates.

In June 1993, Maintenance Worker Foreman, Andy Kikuta discovered a *Cyanea shipmanii* between transects 3 and 4 at 6,000 ft elevation. This rare lobelia species, proposed for listing as endangered, was last seen in the late 1970's. Several weeks after the discovery, three more *C. shipmanii*, as well as six *Clermontia lindseyana*, were found in an adjacent gulch. Fruits from these plants were collected by refuge staff and sent to Greg Koob, Lyon Arboretum; Fern Duvall, at the Olinda Facility on Maui; and The National Tropical Botanical Gardens on Kauai.

Seedlings of *C. shipmanii* will be returned to the refuge for out-planting.

The most accessible individual of *Cyanea shipmanii* was fenced by the refuge Habitat Management crew in order to protect it from destruction by feral ungulates. The other plants are growing on the face of a steep walled gulch and are naturally protected.



Four endangered *Cyanea shipmanii* plants (haha) were discovered on the refuge. The largest was fenced to protect it from pigs and cattle. (JJ)

7. Grazing

Native Hawaiian plants are ill-adapted to withstand grazing pressure. Consequently, the 100-year period of grazing at Hakalau has had a devastating impact on the upper-elevation forests. The elimination of grazing, therefore, is a primary management objective for the refuge.

Five of the seven parcels currently comprising the refuge were leased for grazing at the time of their acquisition by the FWS. As conditions of sale, the Service consented to continued grazing by the lessees on four of the parcels for three years or more or until the end of the lease.

Under Cooperative Agreement and Special Use Permit, the Pua Akala Ranch was allowed to graze portions of the Shipman Parcel from October 1985 to October 1989. Pua Akala Ranch, presently managed by Willie Andrade, currently grazes cattle on a 500 acre parcel adjoining the southwest corner of the refuge which is still owned by the W.H. Shipman Estate. Pua Akala Ranch cattle, however, no longer graze any portion of the refuge.

Grazing by the Alfred Nobriga Ranch on the 1,942 acre upper Maulua Parcel occurred from 1987 through 1991, initially under a Cooperative Agreement, and for the last two years under Special Use Permits. During January and February of 1992, the bulk of Mr. Nobriga's herd was removed. About a dozen head of strays and wild cattle continued to graze this parcel during 1993. Construction of a new perimeter fence to facilitate cattle and pig control within the Upper Maulua Unit began in October 1993 (see I.1.).

As mentioned above (C.1.), the 1,034 acre Upper Honohina Unit was added to the refuge in January 1993 subject to an existing lease with the Parker Ranch which terminates April 30, 1996. Parker Ranch intends to continue grazing cattle (about 260 head) on this property for the remainder of their lease. This is the only unit of the refuge currently grazed by domestic cattle.

9. Fire Management

A Fire Management Plan was completed for Hakalau in 1988. It includes a section on prescribed burning which discusses the use of fire to burn patches of gorse killed by earlier applications of herbicide. Five prescribed burns were conducted in 1989, 1990 and 1991 which eliminated 99% of the larger gorse patches. No prescribed burns were conducted during 1992 or 1993 and it appears there will be no further need for gorse control burns on the refuge as long as the young plants are regularly controlled with herbicide and no new gorse-infested property is acquired.

10. Pest Control

A major management concern for Hakalau Forest NWR is the establishment and spread of alien plants which crowd out and compete with native species and provide little or no habitat for the endangered birds the refuge is mandated to protect. Banana poka (*Passiflora mollissima*), gorse (*Ulex europaeus*), prickly Florida blackberry (*Rubus argutus*) and bull thistle (*cirsim valgare*) are invading species that require control measures.

a. Banana poka

On the Refuge, only the Maulua tract (bounded by Laupahoehoe and Piha) and the northern edge of the Honohina tract (bounded by Piha) are presently infested with banana poka. Cattle grazing has helped to control this weed in the past but active effort is now required because the cattle have been removed from all but the Upper Honohina Unit. Poka is controlled manually by uprooting small plants and severing large stems with a machete or pruning shears. Roots and cut ends are suspended in the air because they will re-root if touching the ground or in contact with wet vegetation. Both methods are labor intensive.

In 1990 and 1991, Honua Landscaping was contracted to conduct 317 hours and 240 hours of manual poka control effort within the upper Maulua tract. Volunteer groups led by refuge staff expended a great deal of additional control effort in upper Maulua and middle Honohina to the point where it is now estimated that over 90% of the mature (fruiting) vines have been removed. No poka control was contracted during 1992 or 1993 due to funding limitations but staff and volunteer efforts continued. During 1993, two groups of volunteers spent about 150 person-hours and refuge staff also spent about 150 person-hours severing stems and pulling vines in upper Maulua and Honohina so the areas remain relatively free of poka.

b. Gorse

Gorse is a noxious weed that formerly occurred in large patches on the upper-elevation grasslands in the southwestern corner of the refuge. It provides no habitat for native wildlife, grows in impenetrable thickets in which no native plants can establish, and poses a fire hazard.

Gorse control through use of herbicide, fire and manual removal was initiated at Hakalau in 1988 and has resulted in the eradication of almost all plants except for young seedlings. Since 1989, contractors have provided manpower to chemically control gorse. Each successive year has seen a reduction in man-hours needed to do the job. Although the infestation has been greatly reduced, the 30 year seed viability results in a continual problem with new sprouts. Also, heavy rains and feral pigs carry the seeds into the forest and downstream requiring geographical expansion of efforts.

Gorse prefers the open sunlit pasture areas but also occurs within the forest, particularly in sunny clearings and at wide openings in streambeds. A considerable amount of staff and volunteer effort was expended to manually removing gorse from streambeds within the forest. Herbicide is not used to control gorse in or near the forest because of the potential adverse impacts on native plants.

The chemical control of gorse has evolved since the Service prohibited the use of Tordon 22K which bears the label "restricted use". Escort was applied as a foliar spray in 1990 but was found to be less effective than Tordon. In 1991 and 1992, Garlon 4 mixed with water was applied as a foliar spray. In 1993, Garlon 3A mixed with water was used as a foliar spray because it was slightly cheaper than Garlon 4. Garlon seems to work as well as Tordon so will continue to be used to control gorse for the foreseeable future.

In many instances, the roots of mature plants are not killed by the foliar application of herbicide and/or fire. Beginning in 1990, Garlon 4 was mixed with diesel and applied as a basal bark treatment to root crowns and stumps. This treatment proved effective and is still used to kill the roots of the few remaining mature gorse plants on the refuge.

Honua Landscaping was contracted by the refuge in 1989 and 1990 to provide 360 man-hours and 283 man-hours, respectively, of herbicide application effort toward gorse control. Orchard Services was contracted in 1991 and 1992 to provide 258 man-hours and 100 man-hours of herbicide application effort on gorse.

In 1993, Orchard Services was again contracted to provide 140 hours of chemical gorse control at a cost of $4,900. Effort was focused on re-sprouting root crowns and new seedlings in the southwest corner of the refuge which previously harbored the worst infestation. As before, the Refuge provided the herbicide, surfactant and water, while the contractor provided the equipment and manpower. Garlon 3A was used in a 1.7% formulation in water as a foliar spray and Garlon 4 was used in a 4% formulation in diesel as a basal bark treatment on root crowns.

During 1993, the Refuge staff provided an additional 75 man-hours of chemical gorse control in the peripheral areas of the infestation. The concentration of the Garlon 3A solution varied depending on the time of year and the phenology of gorse. A concentration of 1.7% was used during the slow growing months and the concentration was reduced to 1% during the peak growing periods. This strategy produced excellent results and reduced environmental exposure. The Garlon 3A label suggests that a 2% solution be used for gorse. Refuge staff also expended 207 man-hours grubbing gorse in streambeds and inside the forest where herbicide use is inappropriate.

The considerable effort described above has resulted in good control of the original infestation. Few mature (seed producing) plants remain on the refuge. Continued effort, however, is required for several more

years to kill the young plants which sprout from the remaining seedbank and seeds washed onto the refuge from above by heavy rains.

c. Blackberry

Florida Blackberry (*Rubus argutus)* has been categorized as one of the most habitat disruptive alien plants in Hawaii. Years of grazing by cattle and rooting by pigs have created unnatural forest openings and soil disturbances allowing blackberry to gain a foothold, competing with native plants for space and nutrients. An alien plant survey, completed in 1992 within the 550 acre Middle Honohina Unit, showed that an explosion of blackberry has occurred since the removal of feral cattle and pigs.

Manual control of blackberry is nearly impossible because the broken roots readily resprout. The only feasible control method appears to be the use of herbicide. In 1991, a study was initiated to determine if a couple of drops of Roundup applied to the cut stem would provide effective control. Though labor intensive, this "clip and drip" method was found to provide effective control in situations where a foliar spray application has the potential for damaging nearby native vegetation.

To test the efficacy of a foliar spray application of Garlon 3A on blackberry, twenty 10 X 10 meter plots, each with a 5 X 5 meter subplot, were established in 1993 within the high density blackberry area in the Middle Honohina Unit. A detailed vegetation analysis was completed for each 5 X 5 meter subplot. Ten random plots were sprayed with a 0.5% Garlon 3A and water solution. All blackberry plants in the plots were sprayed although other exotic and native plants were also sprayed due to their proximity to the blackberry plants. All plants within the plots will be monitored to determine the effects of the herbicide on the target and non-target plant species as well as determining native plant recruitment in the absence of blackberry.

d. Bull Thistle

In 1993, a bull thistle (*Cirsium vulgare*) control effort was initiated by refuge staff. The bull thistle prefers disturbed areas near roads, gates, corals, stockponds and other areas frequented by cattle. This biennial weed produces hundreds of airborne seeds and can rapidly colonize an area where grass cover is thin. Control is achieved through manual grubbing or severing the roots with a machete, hoe or shovel. Refuge staff expended 101 man-hours grubbing thistle in upper Maulua, upper Honohina and along Keanakolu Road.

e. Other Plant Pests

An exotic plant, previously unidentified and thought to be potentially habitat disruptive, was identified by Derral Herbst of the Bishop Museum. *Photenia davidiana* is common in the Nauhi area of the refuge. It has small bright red fruits that are eaten and dispersed by native and alien bird species. Numerous young plants and seedlings of this species are found around the base of native trees throughout the area. A control program for this species is under consideration.

Many years ago, holly was planted as an ornamental around Pua Akala Cabin and elsewhere within the 500 acre parcel still owned by the W.H. Shipman Estate. Holly is now well established on nearby portions of the refuge because the berries are readily eaten by the 'Oma'o. About 53 person-hours of volunteer effort were expended during 1993 removing holly trees from the Pua Akala tract.

f. Rat Control

One of the conditions associated with the issue of the Special Use Permit (HAK-1-88, Amendment 5) that allowed construction of the rain shelter in Pua Akala Meadow was that a rat control program would be initiated in the shelter area by the Permittee (Dr. Leonard Freed, University of Hawaii). Food storage and preparation at the shelter could cause an increase in the local rat population by providing a previously unavailable food source. Rats are known nest predators and an increase in their numbers might result in increased predation on eggs and nestlings of native birds. Resident graduate students trapped rats intermittently in the shelter area from January through December 1993. The catch during 35 trap nights was one Black rat (*Rattus rattus*), and 8 house mice (*Mus domesticus*).

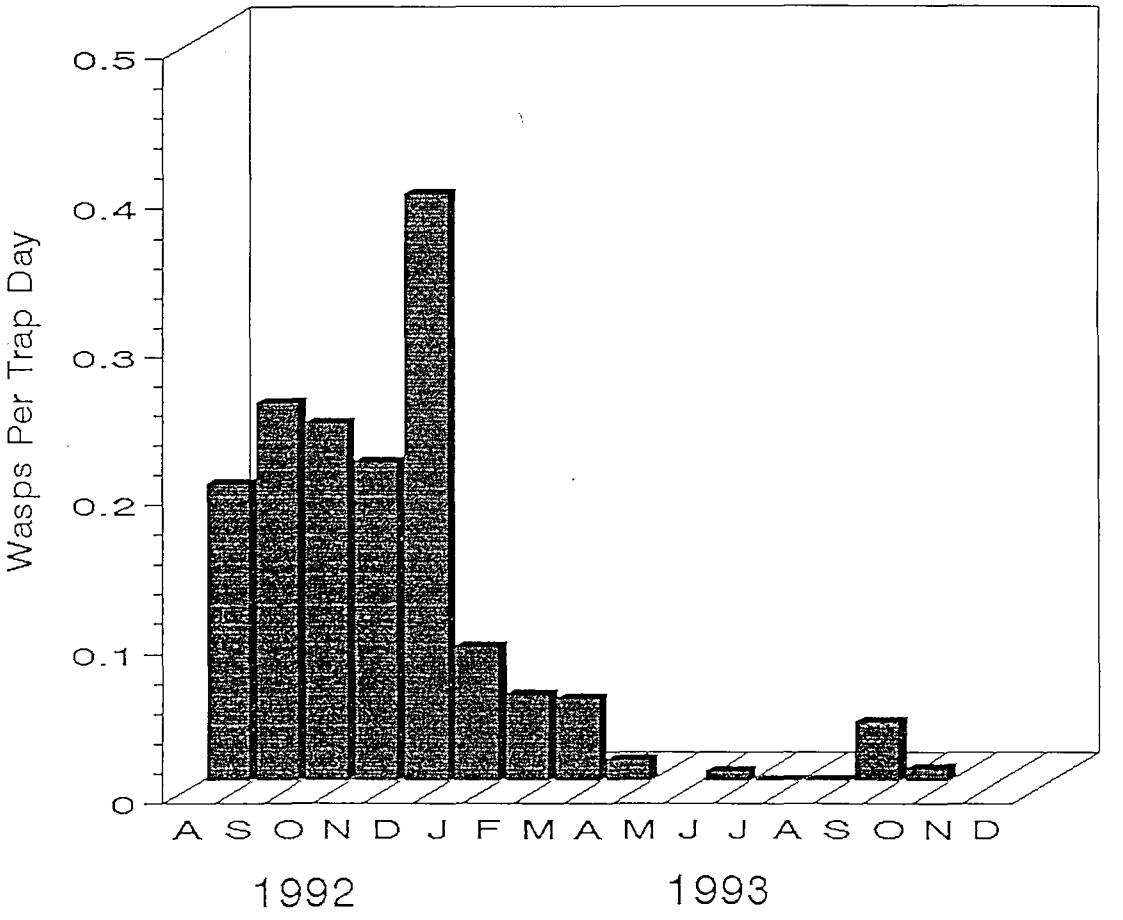
g. Yellowjacket Wasps

Over the past few years, introduced yellowjacket wasps (*Paravespula pensylvanica*) have been seen in low numbers on the refuge. A Yellowjacket monitoring program was initiated in August 1992 and continues year round on a bi-monthly basis. Small plastic wasp traps, baited with the aromatic attractant heptyl-butyrate, have been placed at 100 foot elevational intervals along the Maulua, Honohina, Pedro, and Pua Akala roads.

The dry conditions resulting from a double *El Niño* event during 1991-93, were conducive to over-wintering and expansion of wasp range and numbers during the fall of 1992 as shown in Figure 5. As the *El Niño* dissipated in the second half of 1993, moisture levels returned to normal and yellowjacket numbers decreased. High moisture levels prevent queens from establishing new nests and fungal infections in old nests kill larval wasps preventing expansion of the colony. A slight increase in trapped wasps was noted during the fall of 1993 but the increase was much smaller than during the previous fall. The Pua Akala Road area continues to show the highest densities. A few wasps were also trapped along Nauhi Road indicating overwintering nests in that area.

Figure 5.

Average trap rates for 20 yellow-jacket wasp traps at 200 foot elevational increments along Pua Akala, Pedro, Nauhi and Maulua Roads. (5 traps along each road)



G. WILDLIFE

2. Endangered and Threatened Species

Hakalau Forest NWR was established for the purpose of protecting and restoring endangered forest bird populations and their habitat. The Hawaii 'Akepa, the Hawaii Creeper, the 'Io (Hawaiian Hawk) and Koloa (Hawaiian Duck) are relatively common endangered birds at Hakalau. Four other endangered birds, the 'Akiapola'au, the 'O'u, the Nene (Hawaiian goose) and the 'Alae ke 'Oke'o (Hawaiian Coot) are rare. The endangered Hawaiian Hoary Bat, Hawaii's only land mammal, also occurs on the refuge.

Systematic population surveys are required to ascertain the status of the all bird species, to track their population trends and to measure their response to management efforts. Surveys were conducted bi-annually twice (spring and fall) from 1987 to 1992 but will be conducted only annually (spring) beginning in 1993. Inter-agency teams from the Fish and Wildlife Service, National Park Service, Hawaii State Department of Land and Natural Resources, the University of Hawaii and volunteers from the private sector continue to assist in the survey.

Fourteen downslope transects, 500 or 1,000 meters apart and two to five kilometers long, were established to cover the entire refuge as well as the Piha tract managed by the State Division of Forestry and Wildlife (Figure 6). Count stations (239 total) were established on each transect at 200 meter intervals. During a standard survey, all birds seen and heard at each station during an eight-minute count period are identified and distances to each are estimated.

The 1993 Hakalau forest bird survey was conducted during the last two weeks of March. Refuge staff, J. Jeffrey and A. Kikuta, were assisted in the count by Jim Jacobi USFWS and volunteer Reggie David. Included as trainees during this survey were Tonnie Casey (Bishop Estate), Ann Carter (The Nature Conservancy, Maui) and Lance Tanino (Windward Community College student). Weather during the six day survey was clear and optimal for the census.

Table VII lists population estimates (1988-1993) for forest bird species found on the refuge and Figure 7 graphically depicts the population trends.

Data for twelve forest bird species counted shows an increase in mean population size for eight of the species between 1992 and 1993. While this upturn can be interpreted as the result of refuge management actions, it is doubtful that this is the case. Normal population swings due to climatic effects on breeding success and food availability, as well as observer variability, can cause variations of similar magnitude. Population trends documented through long term monitoring will more accurately portray the response to management actions.

Figure 6.

Location of transects used to monitor forest bird populations and feral ungulate activity

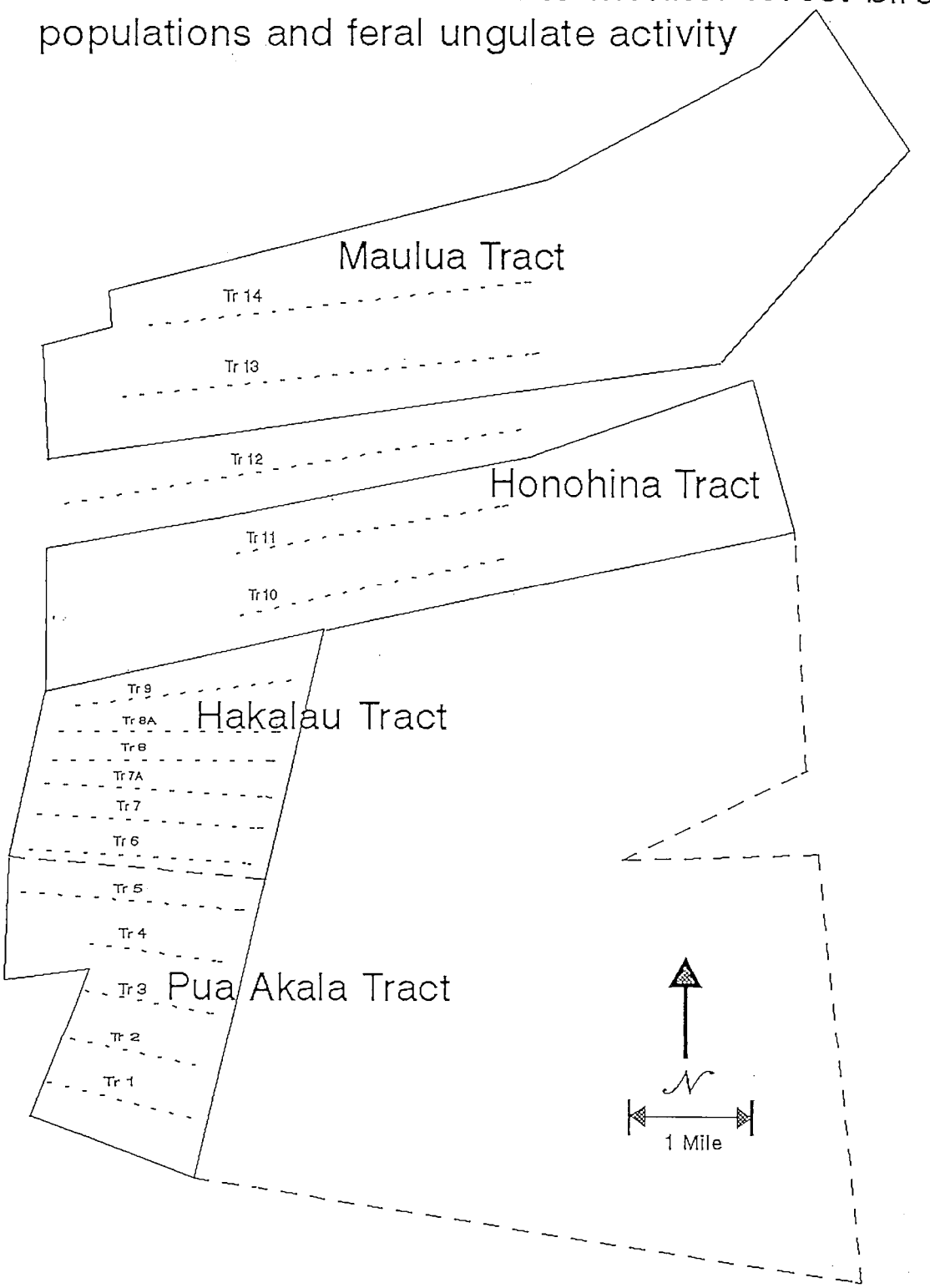
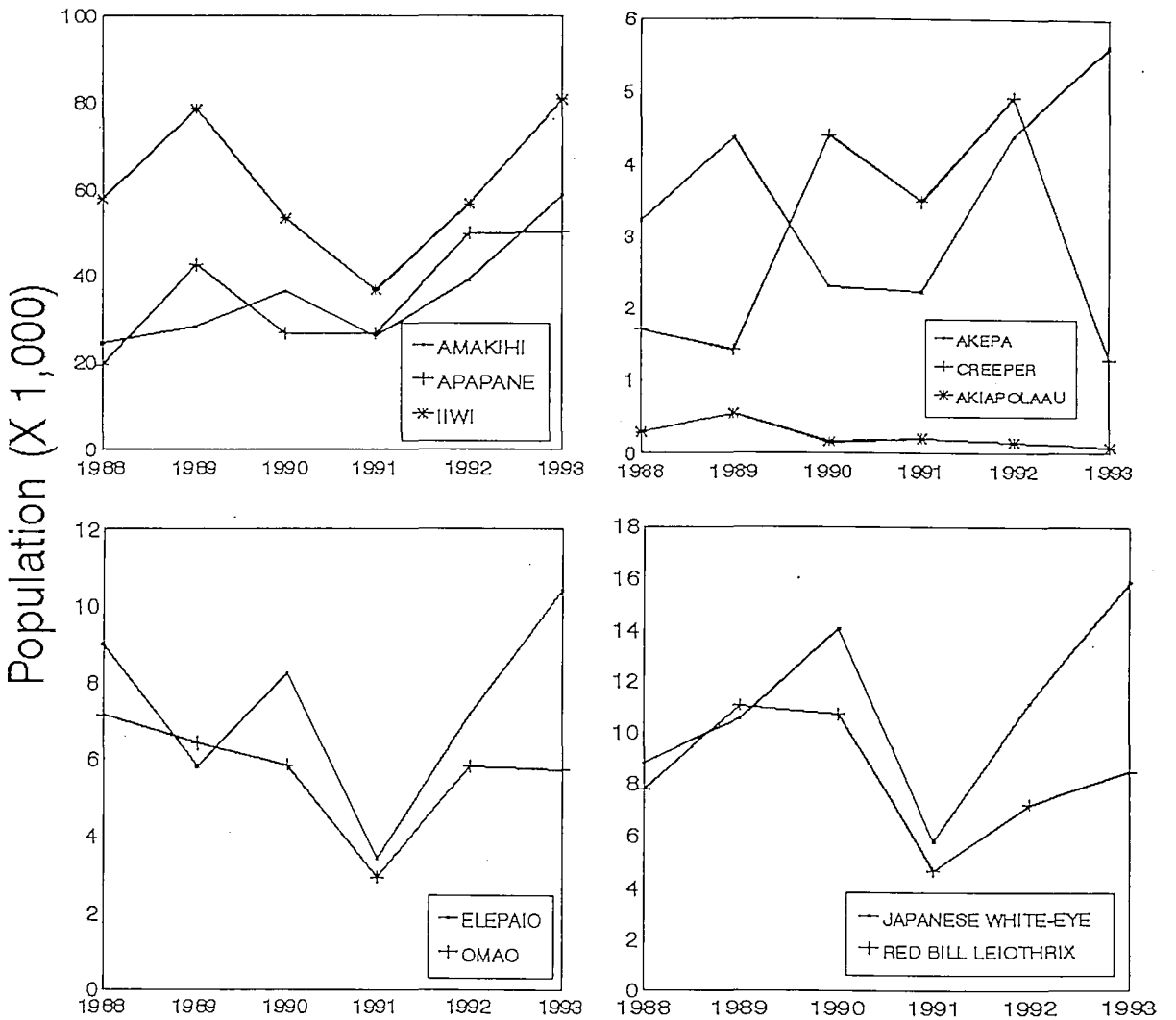


Table VII. Annual forest bird population estimates for Hakalau Forest National Wildlife Refuge

Year	1988	1989	1990	1991	1992	1993
Akepa	3,218	4,366	2,297	2,227	4,385	5,619
Akiapolaau	279	537	157	206	147	77
Amakihi	24,279	28,212	36,383	26,000	39,027	58,712
Apapane	19,237	42,483	26,632	26,471	49,776	50,099
Elepaio	9,007	5,806	8,246	3,404	7,139	10,411
Hawaii creeper	1,704	1,419	4,400	3,477	4,930	1,282
Iiwi	57,765	78,545	53,308	36,673	56,609	80,753
Omao	7,154	6,412	5,839	2,939	5,815	5,716
House finch	4,552	1,975	1,717	1,515	1,904	1,053
Japanese white-eye	8,815	10,546	14,044	5,777	11,132	15,854
Northern cardinal	401	366	605	571	420	532
Red-billed leiothrix	7,799	11,052	10,703	4,681	7,211	8,473

Figure 7.

Population trends for forest birds at Hakalau Forest National Wildlife Refuge from 1988-1993.



3. Waterfowl

Recent research by graduate student Dennis LaPointe has indicated that some ponds on and around the refuge are potential breeding sites for *Culex* mosquitos, vectors for avian diseases that infect native forest birds. Most ponds in the pasture areas were constructed by ranchers as watering holes for cattle. The use of these stockponds as breeding grounds for mosquitos may have far reaching impacts on native forest bird populations. Karen Evans from USFWS, Environmental Services, was questioned as to the possibility of draining some or all of these man-made ponds on the refuge. Evans appraised refuge personal concerning potential conflicts with wetland/endangered species statutes (Koloa) if the refuge were to modify or destroy old stockponds to prevent mosquito breeding. Evans accompanied the refuge biologist on an inspection of some of the stockponds. One pond in the Middle Honohina Unit was found to contain mosquito larvae during this survey.

At the request of Evans, the refuge biologist conducted three refuge-wide waterfowl surveys during the fall of 1993 to determine the frequency of pond use by the endangered Koloa (Hawaiian Duck) and other water-bird species. Thirty-six stockponds on and around the refuge were surveyed. Thirteen stockponds on the refuge had sufficient water to be utilized by waterfowl, the remaining 17 were dry. Off the refuge, 6 with water were checked. Waterfowl species and numbers observed during the three surveys are summarized in the following table:

Species	10/8/93	10/29/93	12/3/93
Common golden-eye		1	
Gadwall		2	
Green-winged teal			5
Mallard	2		2
Pintail		4	

Koloa, mallard/koloa hybrids, lesser scaup, northern shoveler and an unidentified dowitcher were also seen during the fall but not on the survey days.

6. Raptors

Between 1991 and 1993, 4 known 'Io (Hawaiian Hawk) nests and 6 possible nest sites fledged at least 18 young at Hakalau Forest NWR. Most nests were found near the upper edge of the forest where the staff spends most of their time. No systematic nest searches have been conducted and all of the sightings were from incidental observations. Known nests were visited at least once during the fledgling period when the young are actively calling and not all nests were active during any one year.

14. Scientific Collections

In 1993, the refuge was again selected as a collection site by the Hawaii State Department of Land and Natural Resources for their survey of disease and parasites in exotic game birds. Under SUP-7-93, Paul Conry and assistants from the Division of Forestry and Wildlife collected and necropsied 2 Ring Neck Pheasants and 7 Wild Turkeys in February. No malaria was detected in any of these birds but four turkeys were diagnosed with parasitic infections, two with *Capillaria*, one with *Coccidiosis*, and one with both of these infections.

15. Animal Control

Feral pig and cattle control continues to be a high priority management objective at Hakalau. Hawaiian plants are not adapted to the grazing pressure of these introduced ungulates and are easily suppressed by them. Pigs find several species of native plants particularly delectable and have the destructive habit of rooting up vegetation and the top layer of soil in search of earthworms and edible roots. Cattle graze on native plants, especially tender young shoots and trample small trees, ferns, and roots. Both animals also heighten soil erosion, contribute to weed dispersal and disrupt soil nutrient cycles.

The need for fences to exclude feral ungulates has been well documented by other agencies such as Hawaii Volcanoes National Park. The fences are constructed of triple-galvanized posts and wire. T-posts are spaced at 10-foot intervals to support 47-inch hogwire. The hogwire is further anchored to the substrate by anchor posts inserted between each pair of T-posts. Barbwire is attached to the bottom of the hogwire to prevent pigs from squeezing under and 8" above the hogwire to prevent cattle from going over.

Three fenced feral ungulate management units have been created at Hakalau: the 550 acre Middle Honohina Unit, the 5,000 acre Shipman Unit, and the 1,800 acre Lower Honohina Unit (Figure 8). A fourth unit, the 1,942 acre Upper Maulua Unit, was under construction at the end of 1993. The fences (totaling 24 miles in length) are monitored at monthly intervals and after heavy rains and high winds to ensure their integrity and make necessary repairs.

Ungulate control effort and take in each of the management units are summarized in Tables VIII - X and in the paragraphs that follow.

A considerable number of cattle and pigs shot by the staff are field dressed and packed out. The meat is taken for personal use by the staff or donated to the Salvation Army which is the only charity that will accept "uninspected" meat. This practice is supported by residents of the Big Island who adamantly oppose leaving meat to rot in the forest.

Figure 8.

Feral ungulate management units at Hakalau Forest National Wildlife Refuge

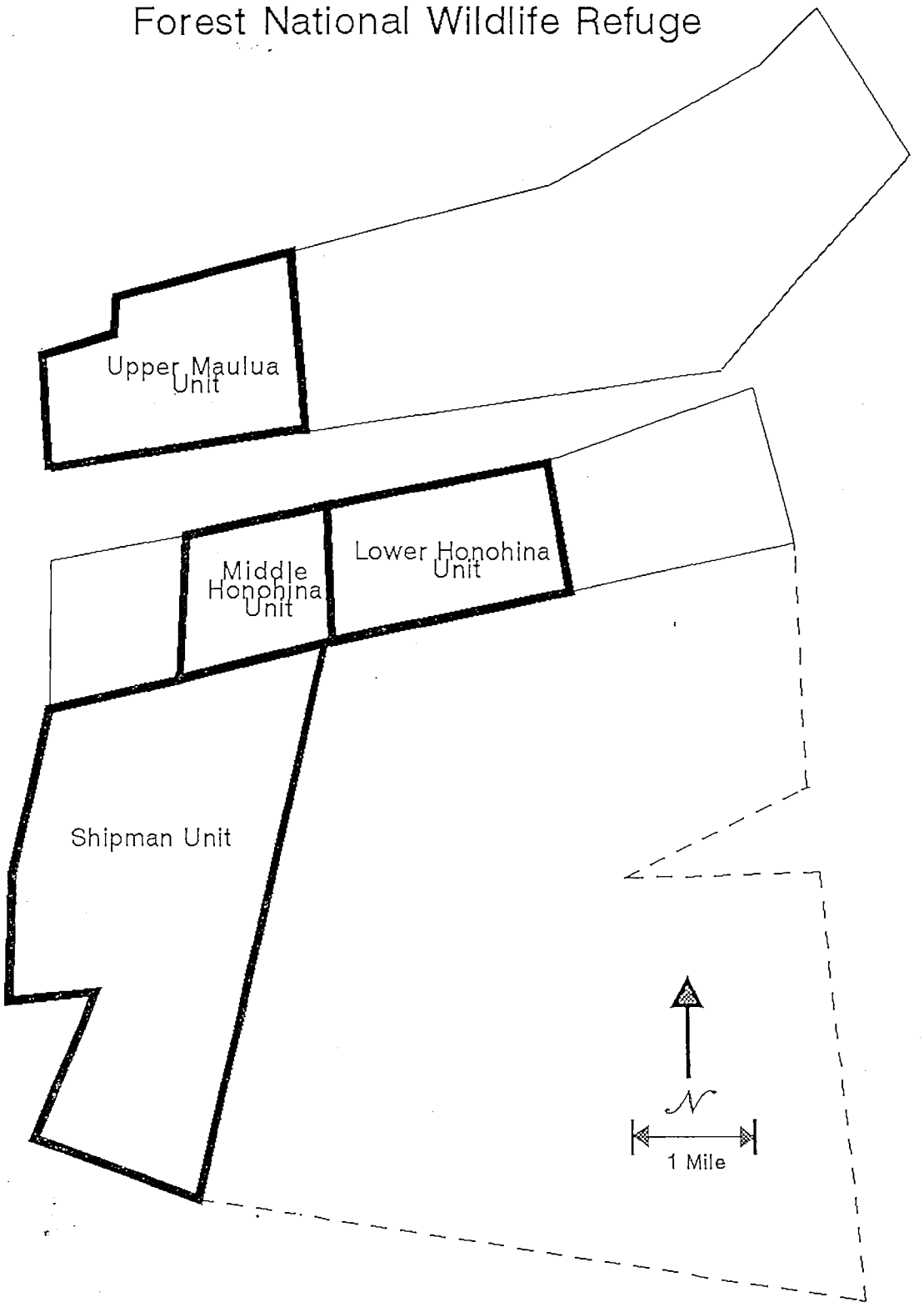


Table VIII. Feral ungulate control effort (person days) and take at Hakalau Forest National Wildlife Refuge by Management Unit or area for 1991.

Feral Ungulate Management Unit	Staff Hunting Effort	Public Hunting Effort	Pigs Taken			Cattle Taken		
			Staff Hunting	Snaring	Public Hunting	Staff Hunting	Contract Hunting	Aerial Hunting
Middle Honohina Unit (550 acres)	0	0	-	-	-	-	-	-
Shipman Unit (5,000 acres)	37	0	41	4	-	14	11	40
Lower Honohina Unit (1,800 acres)	No hunting occurred. Unit was not yet fenced.							
Maulua Public Hunting Area	No hunting occurred. Area was not yet open for public hunting.							

Table IX. Feral ungulate control effort (person days) and take at Hakalau Forest National Wildlife Refuge by Management Unit or area for 1992.

Feral Ungulate Management Unit	Staff Hunting Effort	Public Hunting Effort	Pigs Taken			Cattle Taken		
			Staff Hunting	Snaring	Public Hunting	Staff Hunting	Contract Hunting	Aerial Hunting
Middle Honohina Unit (550 acres)	0	0	-	-	-	-	-	-
Shipman Unit (5,000 acres)	28	0	31	36	-	-	14	-
Lower Honohina Unit (1,800 acres)	No hunting occurred. Unit was not yet fenced.							
Maulua Public Hunting Area	0	105	-	-	38	-	-	-

Table X. Feral ungulate control effort (person days) and take at Hakalau Forest National Wildlife Refuge by Management Unit or area for 1993.

Feral Ungulate Management Unit	Staff Hunting Effort	Public Hunting Effort	Pigs Taken			Cattle Taken		
			Staff Hunting	Snaring	Public Hunting	Staff Hunting	Contract Hunting	Aerial Hunting
Middle Honohina Unit (550 acres)	1	0	1	-	-	-	-	-
Shipman Unit (5,000 acres)	114	0	87	30	-	-	-	-
Lower Honohina Unit (1,800 acres)	11	0	0	-	-	5	-	-
Maulua Public Hunting Area	0	82	-	-	18	-	-	-

a. Middle Honohina Unit

The 550 acre Middle Honohina unit was fenced in 1988. All feral cattle and all but a few pigs were removed in 1989 with assistance from the Resources Management Division, Hawaii Volcanoes National Park. Fence inspections have been conducted periodically thereafter. A bull that jumped over the fence was removed in 1992. No significant fence damage and no evidence of pig ingress was found until 1993 when a breach in the east boundary was discovered. Two staff hunts produced a large boar. Late in the year, more fresh pig spoor was found in this unit and a pig was observed during a banana poka control effort. Subsequent staff hunts were unsuccessful.

b. Shipman Unit

The perimeter fence around the Shipman Unit was completed in 1991. Feral cattle eradication began in 1990. Cattle were targeted before pigs because: 1) cattle suppress natural reforestation to a greater degree than pigs; 2) cattle are easier to remove because they offer more obvious targets and occur in lower numbers; and 3) cattle have the potential for breaking through the new fence when frightened. During 1990-92, 171 feral cattle were removed from the Shipman unit under an aerial and ground hunting contract with the Resources Management Division, Hawaii Volcanoes National Park, by staff hunting, and under a contract with Ernest Pung. No cattle spoor has subsequently been seen in this unit.

Systematic pig removal in the Shipman Unit began in 1992 when 31 pigs were removed through staff hunting and 36 were taken in snares. Most of the effort began in the last quarter of the year after the Habitat Management Supervisor and two additional workers were hired. About 100 snares were set in the Pedro Road area. Snares are checked at least once a week to dispatch animals that are not killed outright by the choking action of the noose.

Staff effort in the Shipman Unit increased in 1993. The resultant take was 87 pigs by hunting and 30 by snares. Staff hunting efficiency increased significantly in June with the signing of an agreement to use hunting dogs belonging to one of the staff (Victor Souza). The refuge agreed to provide food and veterinary care for the dogs in return for their use. The refuge will obtain its own dogs in 1994 upon completion of the dog kennel (Section I.1.b.)

In August, two fenced pig traps with one-way gates were constructed in the Shipman unit. They are designed for multiple capture with a swinging gate and a 200 square feet pen. The gate was designed at Hawaii Volcanoes National Park and has been used successfully there. The traps were baited with papayas on several occasions but caught no pigs. In September, a one-way gate was installed on the east boundary of the Shipman unit to allow pigs to move into the World Union property. No evidence (tracks) to document use of the gate was observed in 1993.

Feral pigs grow to 200 lbs at Hakalau and cause considerable damage to native plants and animals.

c. Lower Honohina Unit

The 35,843 ft lower Honohina fence was completed in 1993 (see Section I.1.a.). The final inspection occurred in May. A staff hunt in August produced five cattle. This effort was aided by the use of a cattle dog which held the animals at bay while the shooters sneaked into range. Sign from only a single cow was observed in lower Honohina after this hunt.

A systematic pig control effort in lower Honohina was not initiated in 1993 due to lack of staff and resources. The use of snares is probably the best method for controlling pigs in this unit due to its remote location and inaccessibility. However, the method is controversial and will not be used in lower Honohina until a feral ungulate management plan is approved for the refuge.

d. Maulua Unit

Construction of the perimeter fence around the 1,942 acre upper Maulua feral ungulate management unit began in November 1993 and will be completed early in 1994 (Section I.1.b.). The fence will prevent the ingress of wild cattle and pigs from the neighboring tracts of Piha and Laupahoehoe and the consequent spreading of banana poka seeds and damage to native vegetation.

No staff hunting occurred in Maulua during 1993 because the entire 7,240 acre Maulua Tract was opened to public hunting in February 1992 (Section H.8.). The hunting public removed 38 pigs in 1992 and 18 pigs in 1993. The Nobriga Ranch also removed about a dozen domestic and feral cattle from this unit in 1993.

e. Pig Control by U.S. Navy SEAL Team

SUP-10-93 was issued to Lt. Command Michael P. Wood and the U.S. Navy SEAL Delivery Vehicle Team ONE to allow a six-man team to visit the refuge November 15-19. The purpose of the exercise was to control pigs feeding in the open pastures and damaging recently planted koa seedlings, as well as to provide training for the SEAL team. The SEALs set up surveillance points on prominent ridges in the upper Shipman Unit and used night vision equipment (starlight scopes) to search for pigs moving out of the forest at night to feed in open areas. The team was armed with M-14, M-16 and 50 cal sniper rifles. The SEALS spent four nights in their surveillance/ambush positions. Unfortunately, they had to contend with rain and fog every night and saw no pigs.

f. Feral Ungulate Surveys

The 1993 feral ungulate survey was conducted with the help of the habitat management staff during the month of September. All Refuge transects were monitored for pig and cattle activity which involved surveying over 4,300 5 X 10 meter plots for pig and cattle spoor less than 30 days old. The results are summarized in Table XI. (Transect locations are shown in Figure 5.)

Table XI. REFUGE-WIDE 1990-1993 PIG AND CATTLE ACTIVITY

	PIG			CATTLE		
TR#	1990	1992	1993	1990	1992	1993
1	37%	12%	31%	30%	0	0
2	39%	22%	26%	6%	0	0
3	76%	9%	44%	25%	0	0
4	76%	16%	35%	41%	0	0
5	47%	7%	29%	11%	0	0
6	40%	19%	29%	12%	0	0
7	83%	57%	32%	16%	0	0
7A	42%	51%	15%	8%	0	0
8	10%	6%	9%	0	0	0
8A	32%	3%	16%	2%	0	0
9	15%	31%	20%	35%	0	0
10*	-	54%	57%	-	0	0
11*	-	61%	80%	-	3%	2%
13T	-	3%	28%	-	0	0
13B	-	68%	99%	-	0.5%	0
14T	-	31%	63%	-	29%	9%
14B	-	64%	100%	-	0	0

* Only stations outside to 550 acre Middle Honohina Unit exclosure fence were included in the calculations. No pigs or cattle sign have been recorded inside this unit.

No recent cattle sign was found on Transects 1 - 9 during the July 1993 survey which indicates the Shipman Feral Ungulate Management Unit (as well as the Middle Honohina Unit) is cattle free. A few wild cattle still occur in the Lower Honohina Unit (Transect 11) and the Upper Maulua Unit (Transect 14 Top).

Pig activity averaged 42% for all stations across the refuge in 1993 compared to 30% in 1992, indicating an overall increase in pig numbers. It is gratifying, however, to see that the pig population declined in Triangle Paddock and in the areas bordering Hakalau Gulch (Transects 7 - 9) where staff hunting and snaring were focused this year. The population increase within the upper Maulua (Transects 13T and 14T) and middle Maulua areas (Transects 13B and 14B) is surprising because public hunting was initiated in these areas in 1992. The 1992 surveys, conducted before (Jan 92) and after (Jul 92) the public hunting program began, showed a decrease in pig activity six months after public hunting began. The 1993 survey, however, shows the pig population returning to pre-hunting levels.

Pig activity in pastures and forested areas is compared in Table XII which indicates that pigs are more abundant in pastures, perhaps because they prefer to feed on earthworms which are more abundant and accessible in grassland areas. During 1993, pigs were probably also attracted to the freshly turned soil in the pasture areas which resulted from the use of the blade rake to create sites for planting koa seedlings (F.3.b.4)).

Table XII. COMPARISON OF PIG ACTIVITY IN PASTURE AND FOREST SECTION OF FOUR TRANSECTS IN THE HAKALAU TRACT

	1992		1993	
TR#	Pasture	Forest	Pasture	Forest
5	4%	9%	28%	26%
6	36%	8%	41%	21%
7	64%	58%	44%	20%
7A	59%	44%	16%	14%

16. Marking and Banding

As noted above under Section D.5., Dr. Leonard Freed and colleagues banded 421 birds during the year including 34 endangered birds; 25 'Akepa and 9 Hawaii Creeper. The totals for his five-year study are 2,749 banded birds of which 229 are endangered. This banded population is an extremely valuable study resource.

17. Disease Prevention and Control

Disease has been implicated as one of the main factors in the continued decline and extinction of the Hawaiian avifauna. Avian malaria and

avian pox are two diseases known to infect native bird populations. Avian malaria is probably transmitted by mosquitos and is generally found at elevations below 4,000 feet. The recent discovery of this disease on the refuge in both forest birds and game birds captured above 6,000 feet is discouraging though the birds may have been infected during flights to lower elevations in search of food. Identification of the vectors is urgently needed.

Avian pox lesions have also been found on forest birds captured above 6,000 feet on the refuge. Pox virus is spread by mosquitos, through contact with contaminated surfaces, and from one bird to another through direct or secondary contact. Open lesions on the feet may contaminate branch and leaf surfaces giving rise to pox infections in birds landing on these substrates. Researchers handling birds in mistnetting operations must be especially careful. Diseases may be spread to subsequent captures if an infected bird is caught and persons handling the bird do not disinfect hands, banding tools, holding bags and mistnets. Dr. Freed and associates are following a disinfection protocol suggested by refuge staff to prevent the spread of diseases in native and exotic birds captured at their study site.

A fine resolution molecular probe is currently being developed for avian pox by Dr. Rebecca Cann. This probe should give greater detection rates than present methods. Blood from birds captured during ongoing mistnetting operations will be cryogenically preserved for later testing once the molecular probe is developed.

H. PUBLIC USE

1. General

Public access to the refuge was initiated on February 1, 1992 with the opening of the 7,240 acre Maulua Tract to pig hunters during state holidays and the first three weekends of each month and to non-hunters on the last weekend of each month. Reservations are required for all visitors. Access is through Maulua Gate and includes the use of Maulua Road which extends two miles to the bottom of the upper Maulua unit. Reservations are required for all visitors using the Maulua Gate access. Reservations from hunters numbered 212 in 1992 (Feb-Dec) and 195 in 1993. Reservations from non-hunters numbered 64 in 1992 and 15 in 1993. The number of actual visitors is unknown but is estimated to be about half the number of reservations. The long drive (two hours each way) and the rough road discourage all but the most avid and adventuresome hunters, hikers and birders.

Access to the Maulua Tract from the lower end was opened July 1, 1993 (H.8.). Visitors using this access must hike two or three hours across state property (Piha or Laupahoehoe) to reach Maulua. The number of visitors using the lower access is unknown because reservations are not required and the area is not monitored by refuge personnel. It is probably very low (1-2 dozen hunters per year?).

A four-panel leaflet titled "Hunting and Public Access" was printed in 1992 for distribution to visitors and those seeking information about the visitation program. The leaflet includes a map of the area open to visitation and describes the reservation procedure, rules and management objectives of the hunting and visitation program. Publication of the general refuge brochure, which was also to have occurred before the refuge was opened to the public, has been delayed.

Hakalau is a relatively new refuge and is the only refuge in the national system established primarily for the conservation of forest birds and their habitat. Consequently, considerable effort is expended to familiarize organizations and off-island decision-makers with the refuge and its unique problems and needs. Refuge tours, which often include helicopter overflights, are the usual means for accomplishing this objective. A few hours are often spent walking through the forest observing native birds and plants. If time permits, the visitors may also be shown the experimental reforestation plots, tree-planting efforts, feral ungulate control programs, weed control projects and the Hakalau cabin and associated facilities. Management objectives and strategies, funding and staffing needs and a wide variety of other subjects are discussed by the Refuge Manager and refuge staff who accompany the visitors.

Noteworthy visitors to Hakalau during 1993 included:

Febuary 8. Gerry Jackson, Deputy Asst. Regional Director of Ecological Services, Patty Hutton, Ecological Services and Brooks Harper, Ecological Services helicoptered to the refuge in the company of Jim Jacobi. Barbara Maxfield and the Refuge Manager met them at Hakalau for a ground tour and briefing.

March 3. Dave Olsen, Assistant Director for Refuges and Wildlife toured the refuge with Jerry Leinecke, Jim Jacobi and the Refuge Manager. Cloudy weather precluded the use of a helicopter.

April 29. Russ Bickler and Roger and Alice Bason, forestry consultants, and Patricia Tummons, Editor of "Environment Hawaii" toured the refuge in the company of the Refuge Manager. They were particularly interested in the tree-planting program and would like to assist future planting efforts.

May 5. Sixteen Fish & Wildlife Enhancement project leaders took time out from a 3-day business meeting to tour the refuge with Jim Jacobi and the Refuge Manager.

August ?. Sue Masica, Chief of Staff, Interior Appropriations Subcommittee, toured the refuge with the Refuge Manager and Biologist as part of a two-week visit to assess Hawaii DOI needs. Other members of the group included Scott Derrickson, National Zoo, Robert Smith, Ecological Services Honolulu, Jim Jacobi, Hawaii Research Group, Gene Conrad, U.S. Forest Service and Jeff Cilek, The Peregrine Fund.

December 9. Eight members of the EPA Regional Response Team visited the refuge in the company of the Refuge Manager.

December 16. Three members of Senator Daniel Inouye's staff (Mark Fox, Washington Office, George Steuer, Honolulu Office and Wayne Tanaka, West Hawaii Office) toured the refuge with the Refuge Manager and Biologist. They viewed reforestation efforts and native birds and plants at Pua Akala during the briefing and discussion of management issues.

December 20. Margo Stahl, Section 7 Coordinator and Loyal Mehrhoff, Listing Botanist, Ecological Services toured the refuge with the Manager and Biologist. Endangered birds and plants were viewed and Section 7 issues were discussed.

December 28. Bruce Babbitt, Secretary of the Interior and the Refuge Manager helicoptered over the refuge for a birds-eye view of current reforestation and fencing projects. On the ground at Pua Akala, they joined Jerry Leinecke, Thane Pratt and the Refuge Biologist for a briefing on refuge issues and a birding tour. The Secretary expressed keen interest in the biological resources and management issues and impressed us all with his support.

7. Other Interpretive Programs

In recognition of National Wildlife Week, the refuge held its first "open house" on Saturday April 24, 1993. The event was widely publicized in local newspapers and on the radio. The response was much greater than expected and required that the participants be divided into a morning and an afternoon session to accommodate them all. Two hundred sixty people phoned in their reservations and were subsequently sent a letter describing the field trip and what to bring. Participants met at the Pu'u Huluhulu hunter checking station at 8:00 and 12:00 a.m. and followed a Service vehicle in to the refuge. Public vehicles numbered 24 in the morning and 29 in the afternoon. About 85 people were counted in the morning and 100 in the afternoon. A 15 minute orientation was given by the Refuge Manager and the visitors were offered a choice of three hikes of varying length and difficulty or a motor tour of Maulua Tract. The large group then broke up into seven smaller groups, each led by a member of the refuge staff or a volunteer familiar with the birds and natural history of Hakalau. The tours and hikes lasted 2-3 hours and everyone had opportunities to view native birds and plants as well as discuss management issues with their guide. The event was a huge success with everyone expressing appreciation and satisfaction. The "Open House" will likely become an annual event.

Because Hakalau Forest NWR is closed to the general public, film-makers, photographers, and journalists are encouraged to visit the refuge and then "interpret" the resources and management efforts

through their media to the public. The following such activities occurred during 1993:

For the fifth year in a row, a Special Use Permit (SUP-1-93) was issued to Jack Jeffrey to allow photography of birds, plants and Hakalau scenery for possible publication and sale. Jack allows the refuge and other federal and state agencies to use his photos at no cost. Several of his photos have also been used in widely-circulated publications.

SUP-8-93 was issued to Richard Rasp, Chief of Interpretation, Hawaii Volcanoes National Park to allow his crew to film birds, plants and scenery at Hakalau for possible use in a visitor orientation film to be shown at the Park Visitor Center.

The biologist assisted a three-person film crew from Environmental Reports, San Francisco, with the filming of a short "eco-spot" to be aired on national TV news. Footage was taken of fence construction, rare and alien plants, and forest regeneration.

Each year refuge personnel spend some time "off-refuge" making presentations to conservation, student and special interest groups. The following is a summary of such presentations made during 1993:

The Refuge Manager presented two slide shows about the refuge to science classes at Waiakea Intermediate School. He gave a slide talk to the EPA Regional Response Team at Kilauea Military Camp to orient them for the visit the following day. He also gave a slide talk to the Sierra Club in Honolulu on the refuge and reforestation efforts.

8. Hunting

The 7,240 acre Maulua Tract was opened to public hunting and other uses beginning February 1, 1992. The hunting program has three objectives: 1) Employ public hunting as a low-cost management tool to reduce feral pig populations. 2) Gain public relations benefits by opening an area that has never been open to hunting before. 3) Provide the public with a quality and safe hunting experience in accordance with State and Federal laws.

Reservations are required for all visitors who access Maulua from the upper end (i.e. through Maulua Gate) and are limited to a maximum of 12 during hunting days for safety reasons. These hunters are allowed to hunt pigs on state holidays and during the first three weekends of each month. State hunting regulations apply except there is no limit to the number, size or sex of pigs taken because one of the program objectives is to maximize the control effort.

Beginning July 1, 1993, hunters were also permitted to access Maulua from the lower end. This access requires a 2-3 hour hike across property owned and managed by the State Division of Forestry and

Wildlife for public hunting (Piha or Laupahoehoe). (Direct access to lower Maulua across the privately owned Robertson property is not permitted by the landowner due to liability concerns.) The use of hunting dogs is permitted in lower Maulua and, in order to conform with State regulations for lower Piha and Laupahoehoe, the bag limit is two pigs of any size and sex. Reservations are not required for lower Maulua and hunting is permitted on any day of the week.

Take and effort data are not collected from hunters in lower Maulua due to multiple entry/exit points and because there is no telephone or other contact with hunters prior to entry. The long and arduous hike that is required to access lower Maulua probably limits the number of hunter visits to less than 20 per year. All hunters accessing Maulua from the upper end are asked to complete a form summarizing their take and effort as they exit Maulua Gate. These data plus the number of reservations are summarized in Table XIII for 1993.

TABLE XIII. Hunter reservations, visits and take for upper Maulua during 1993.

MONTH	NUMBER OF RESERVATIONS	NUMBER OF VISITS	NUMBER OF PIGS TAKEN	PIGS/HUNTER
January	21	4	0	0.00
February	9	8	2	0.25
March	17	3	2	0.67
April	11	4	2	0.50
May	10	4	0	0.00
June	28	9	5	0.56
July	28	0	0	-
August	16	10	2	0.20
September	8	7	0	0.00
October	21	10	1	0.10
November	16	16	3	0.19
December	10	7	1	0.14
1993 TOTALS	195	82	18	0.22
1992 TOTALS	212	105	38	0.36

The initial response in 1992 to the opening of Maulua for pig hunting was good with 105 people making reservations to hunt the first month. Hunters soon realized, however, that hunting on the refuge was no better than in the adjoining state-managed areas of Piha and Laupahoehoe so their numbers declined markedly after the first few weekends. There was further decline in 1993 as shown in Table XIII. Hunter success also declined from about one pig per three hunter-days in 1992 to about one pig per four hunter-days in 1993. This is less than that reported by the State for Piha and Laupahoehoe (0.41 pigs per hunter-day) where food (banana poka fruit) is more abundant. The sex ratio of pigs taken by hunters in upper Maulua was 3:2 (boars:sows). Feral ungulate activity surveys conducted in 1993

indicate that this level of hunting pressure is insufficient to significantly reduce pig activity.

11. Wildlife Observation

Bob Sundstrom, Victor Emanuel Tours, was again issued a Special Use Permit (SUP-3-93) to conduct guided bird tours in the Pua Akala area of the refuge. About 20 people visited the refuge on March 4 and 14 people visited on November 4.

Douglas Pratt visited the refuge again under SUP-5-93 on October 23 to view native birds with a group of seven people.

17. Law Enforcement

No law enforcement actions occurred in 1993. Relatively few patrols were made in the public hunting area due to decreasing hunter participation, good compliance with hunting regulations and more pressing duties for refuge staff. Refuge Officer Emig did attend the week-long Refuge Officer In Service refresher training at the Federal Law Enforcement Training Center in Marana, Arizona in April.

I. EQUIPMENT AND FACILITIES

1. New Construction

a. Fence

On September 28, 1992, a contract was awarded to Smith Construction Company for construction of an estimated 33,000 feet of pig/cattle fence to enclose the 1,800 acre Lower Honohina Feral Ungulate Management Unit (Figure 8). The contract was subsequently amended to include hand-clearing of portions of the fence corridor and construction of an additional smooth-wire fence on the Piha boundary. Construction of the lower Honohina fence was completed in June 1993. Final measurements are Section 1, Piha (north) side = 16,255 feet; Section 2, World Union (south) side = 14,238 feet; and Section 3, bottom (east) side = 5,350 feet for a total of 35,843 feet and a total cost of $235,500 ($6.57 per foot or $34,691 per mile). Helicopter delivery of materials and the inaccessibility of the worksite are partially responsible for the high cost. A significant portion of Section 1 was erected several feet to the refuge side of the Honohina/Piha boundary so the pig/cattle fence could be situated on ridges where it is easier to construct and maintain. Where this was the case, 9,818 feet of inexpensive smooth-wire fence (costing $22,681) was constructed to delineate the exact boundary. The Piha/Honohina boundary was surveyed by the R.M. Towill Corporation at a cost of $19,319.

The pig/cattle fence was constructed of woven wire mesh and barbed wire with steel T-posts at 10-foot intervals and stress panels utilizing galvanized posts at corners and elevation changes. The fence is designed to be cattle and/or pig proof for its full length. Two construction specifications were used. One is designed to exclude both cattle and pigs and was used in upper elevation areas where cattle are present (about 70% of the total length). This specification requires 7' T-posts and 47" woven wire with a barbed wire strand at ground level and another strand 8" above the woven wire. The other specification is designed to exclude pigs only and reduces costs at lower elevations where cattle do not occur. This design uses 6' T-posts and 39" woven wire with barbed wire only on the bottom. Both specifications called for anchoring the bottom of the fence between the regular fence posts by attaching the woven wire and the barbed wire to specially prepared 26" T-post sections, which are driven into the ground so that no gap greater than 2" exists under the completed fence.

In June, the fence contract with the Smith Construction Company was amended to include construction of approximately 35,200 feet of pig/cattle fence around the 2,000 acre Upper Maulua Feral Ungulate Management Unit and 14,500 feet of pig/cattle fence to complete the enclosure of the 1,034 acre Upper Honohina Feral Ungulate Management Unit. Specifications are similar to those for the lower Honohina fence except existing old cattle fences must also be removed. Costs to fence these units are estimated at $195,840 for upper Maulua and $81,200 for upper Honohina. These costs ($5.57 per foot) are less than for lower Honohina because access is better.

Fence materials packages are assembled in a staging area for helicopter delivery to the fence corridor. (DW)

The R.M. Towill Corporation used Global Positioning System technology to relocate the 1-1/2" metal pipes which mark the bottom two corners (Piha side and Laupahoehoe side) of the upper Maulua unit at a cost of $6,430. Construction of the upper Maulua fence began in November and should be completed by early next year. The upper Honohina fence will not be constructed until the summer of 1995 because the Parker Ranch has a grazing lease on the property through April 1996.

Since the refuge was established, 126,584 feet (24.0 miles) of pig/cattle fence have been constructed at a total cost of $656,614 ($5.19/foot or $27,388/mile). Three feral ungulate management units (the 550 acre Middle Honohina Unit, the 5,000 acre Shipman Unit and the 1,800 acre Lower Honohina Unit) have been enclosed (Figure 8).

b. Dog Kennel

In September, Kawika General Contracting was awarded a $36,110 contract to construct a three-pen dog kennel ($24,325) at the Hakalau Cabin complex and to rehabilitate the foundation, roof, windows and exterior of Nauhi Cabin ($11,785). The cabin rehab is a Maintenance Management System project. Both projects will be completed early in 1994.

c. National Biological Service Cabin

In December, Steve Fancy and the National Biological Service crew began construction on the first phase of their 24' x 20' cabin at the Hakalau Cabin complex. Phase 1 will be completed in January 1994 and will be used to house about eight people conducting research in lower Pua Akala on factors that limit forest bird populations. The NBS cabin and research is covered by SUP-1-94. NBS will own and maintain the cabin throughout the period they conduct research on the refuge (about six years). Ownership will revert to the refuge when the NBS research is finished.

2. Rehabilitation

On July 31, 1992, the refuge elected to exercise its option to continue the contract with Steve's Ag Services for road rehabilitation at Hakalau, allocating $35,000 for continued grading and graveling of Nauhi Road and additional work on other roads. Steve constructed a custom all-wheel-drive dump truck especially for this project. Difficulty in procurement of parts for the truck delayed mobilization of his other equipment until 1993. Meanwhile, the refuge staff spent many hours stockpiling gravel at the Nauhi pit for this project.

Steve began working on the Nauhi Road early in 1993 and completed the project by September. Most of the worst stretches of the road between the gravel pit and Nauhi cabin received gravel. A layer of road stabilization fabric (Mirafi) was laid under the gravel in the wet

spots. A parking and turn-around area at Nauhi cabin was also graveled to provide space for up to six vehicles. For the first time ever, all-weather access to Nauhi cabin is now possible. Steve also delivered gravel to the Hakalau cabin area, creating pads for the proposed dog kennel and associated water catchment tank.

3. Major Maintenance

In order to keep up with increased visitor and staff use, the photovoltaic charging capacity at Hakalau Cabin was increased in 1991 to 400 watts with the addition of four new Solec 40 watt panels. Six new Trojan T-105 storage batteries were added, to increase cabin capacity to 3,850 amp-hours. In 1992 the solar panel array was repositioned and rewired to provide more efficient solar energy collection and delivery to the cabin storage batteries. In January 1993, eight new Trojan T-105 batteries were added to the system, increasing capacity by 60% to 6050 amp hours.

The Norcold AC/DC/PROPANE GAS refrigerator at Hakalau Cabin required repeated maintenance in 1993. The propane gas system seems especially prone to clogging and fouling from dust and soot which falls from the heated refrigerator element. The unit was operated on AC power from the cabin storage batteries during repairs to the gas system, but the battery storage system is not large enough to allow permanent AC use.

The Hakalau Cabin water pressure system was upgraded in 1993 with the installation of a custom designed system consisting of the latest generation 4 GPM diaphragm pump, an adjustable pressure switch and a 4.4 gallon expansion tank.

Generator powered lighting was added to the garage in 1993, and porch lights operating on the existing solar/battery system were installed on the cabin.

4. Equipment Utilization and Replacement

In July 1993, the refuge received a new 1993 Dodge Ram 250 4WD pickup (license G63-19305) to replace the 1989 Chevrolet pickup that had so much structural trouble. The Dodge is leased from GSA and came with automatic transmission, limited slip differential and a red paint job. A tool box and front bumper winch were installed locally.

In July 1993, the refuge also received a new 1993 maroon Ford Bronco sport utility vehicle (G62-21034) to replace the Jeep Cherokee. This vehicle is leased from GSA and is fitted with numerous options including cloth upholstery, tilt steering wheel, inflatable seat back, cruise control, 5-speed manual transmission and anti-lock brakes.

In November 1993, the refuge took possession of a heavy-duty, diesel-powered 1987 Chevrolet pickup (I-165982) obtained as excess property from the military through the Defense Re-utilization and Marketing

Office (DRMO). The refuge, therefore, owns this vehicle which is equipped with automatic transmission and a 24 volt military electrical system. It seemed like a good deal so a 1985 Chevrolet Blazer was also tagged for delivery to the refuge in early 1994. Both vehicles came with camouflage paint and some surface rust so were repainted tan before delivery to the refuge.

Two Honda Four-Trax 4WD ATV's were also obtained from DRMO in 1993. They came with bald tires and no batteries or keys but, otherwise, are in excellent condition. They will join Hakalau's other two Honda ATV's.

The refuge's vehicle fleet consisted of three pickups, three sport utility vehicles and four ATV's by the end of the year plus a Caterpillar D4H crawler dozer.

6. Computer Systems

A modem was hooked up on the Administrative Support Assistant's computer to give the Refuge E-Mail and data-link capabilities.

In October, the Refuge took delivery of a new 486SX/25 Northgate computer with color screen. This "notebook" computer will be used at Hakalau cabin and in the office during periods when the three desktop computers are already in use.

8. Other

In October, the refuge took delivery of a new Canon NP2120 copier to replace the old copy machine.

Hakalau received excess property as a result of the closing of the U.S. Coast Guard LORAN station at Upolu Point in late 1992. Hand and power tools, hardware supplies, electrical and plumbing supplies, a flammable liquids storage locker and office and household furniture were included in the transfer which took several trips using Refuge and Coast Guard pickups in January, February and March.

J. OTHER ITEMS

1. Cooperative Programs

In February, Wildlife Biologist Jack Jeffrey assisted Hawaii State Division of Forestry and Wildlife personnel with the post-hurricane-Iniki forest bird survey of the Alakai Swamp area on the Island of Kauai. The survey found large areas of forest canopy completely defoliated, but in most areas the shrub layer was still intact. Overall bird densities for the common species were low and none of the four endangered birds that inhabit the area were detected.

In March, Jeffrey assisted Haleakala and Volcano National Park staff with training their personnel for the Kipuhulu Valley forest bird survey. He also assisted with the survey. Only two endangered bird species were detected--the crested honey-creeper and the Maui parrotbill.

In April, Jeffrey assisted the State Division of Forestry and Wildlife with clearing and setting up "Transect 14" for the Big Island Forest Bird Survey. The 53-station (5.4 mile) transect traverses a thickly forested and heavily gulched area at elevations between 4,600 and 2,200 feet through Hakalau Forest NWR at the upper end and Laupahoehoe Natural Area Reserve at the lower end.

In May, Jeffrey assisted with training and logistical support and conducted bird censuses in the Kau and Laupahoehoe areas for the Big Island Forest Bird Survey. The Kau, Kapapala, Laupahoehoe and Honomalino Forest Reserves have not been surveyed since the mid to late 1970's.

3. Items of Interest

On April 30 (Arbor Day), a ceremony was held during which the 1,000,000th tree funded nationwide by the American Forestry Association was planted at Hakalau. Officials present included Virginia Goldstein, County Planning Director; Bill Grey, President of the Hilo Rotary Club; Nelson Ho, President of the local chapter of the Sierra Club; Mike Robinson, representing the Resource Conservation and Development Council; Barry Orlando and Patrick Bryan, Volunteer Coordinators; Ray Rauch, Complex Office; members of the refuge staff; and a video news cameraman. The event was publicized nationally in the American Forestry Association magazine and locally in the Hilo Tribune Herald which included an editorial commendation.

On May 11, the Refuge Manager presented Hawaii County Mayor Steve Yamashiro a revenue sharing check for $35,102. The mayor was also briefed regarding refuge management objectives and strategies.

4. Credits

This narrative was written by Dick Wass, Refuge Manager, Jack Jeffrey, Wildlife Biologist, Andy Kikuta, Maintenance Worker Foreman and Jon Emig, Maintenance Worker. Lynne Hanzawa, Administrative Support Assistant and Ernette Saragosa, Office Automation Clerk produced the narrative. The photographs were taken by Jack Jeffrey (JJ) and Dick Wass (DW).

L. INFORMATION PACKET

Hunting and Public Access leaflet is attached to the back cover.

No Access to Piha or Laupahoehoe

The adjacent tracts of Piha and Laupahoehoe are managed for public hunting and conservation of native species by the State of Hawaii. A telephone reservation obtained through the State Division of Forestry and Wildlife is required to enter Upper Piha and Upper Laupahoehoe. No person may access Upper Piha or Upper Laupahoehoe from Upper Maulua even if he or she is holding a valid reservation for Piha or Laupahoehoe. Access between Lower Maulua and the lower portions of Piha and Laupahoehoe is not restricted.

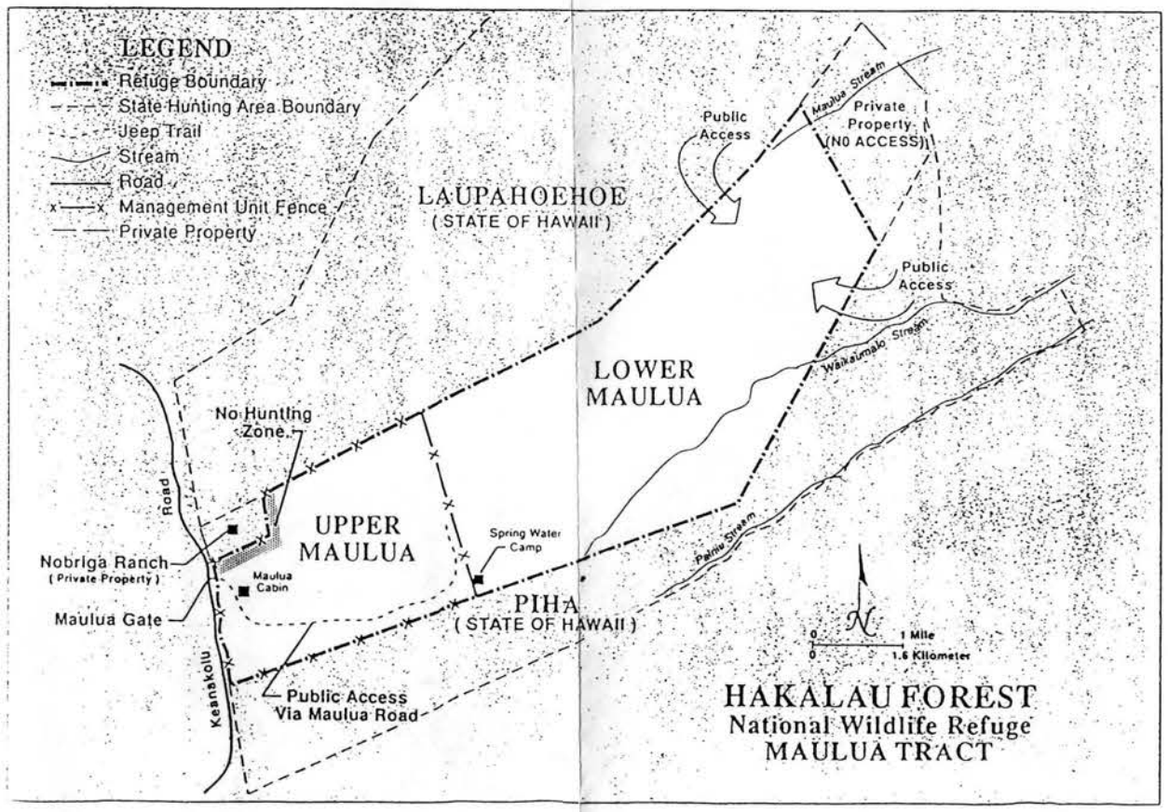
Signs and Boundaries

These signs designate zones, boundaries, and regulations. The wording applies to the area behind the signs. They will help locate your position on the map. The boundaries between Lower Maulua and the lower portions of Piha and Laupahoehoe are not fenced, signed or marked.

This sign is posted along the refuge boundary. Only the Maulua Tract is open for public hunting and visitation.

Used alone or beneath a refuge boundary sign. The area behind this sign may be hunted and visited as permitted by refuge regulations.

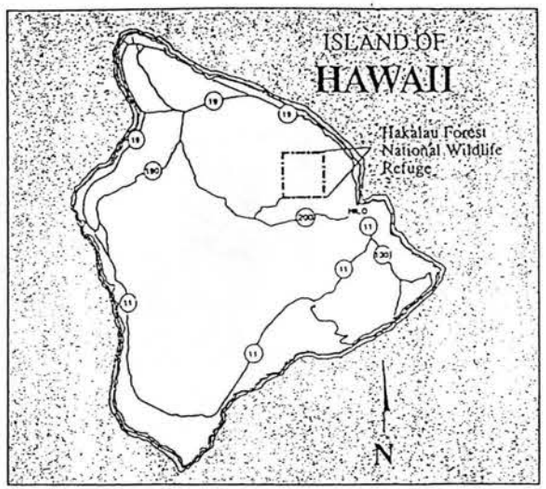
The area beyond this sign is owned and managed by the State of Hawaii. No person may enter the area from the refuge.



This sign designates the no hunting zone in the northwest corner of Maulua Tract. No shooting is permitted between this sign and the boundary fence.

This sign is posted along Maulua Road which is the only access for four-wheel-drive vehicles.

Motor vehicles are not allowed beyond this sign. Do not block access.



For More Information Contact:

Refuge Manager
Hakalau Forest National Wildlife Refuge
32 Kinoole Street, Suite 101
Hilo, Hawaii 96720
Telephone: (808) 933-6915

U.S. Department of the Interior
Fish and Wildlife Service
RF 12516 August 1995

No person shall, on the basis of race, color, sex, age, national origin, religion, physical or mental restrictions, be excluded from participation in, denied the benefits of, or be otherwise subjected to discrimination in any program or activity of the U.S. Department of the Interior.

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HAKALAU FOREST

NATIONAL WILDLIFE REFUGE

HAWAII

HUNTING and PUBLIC ACCESS

Public Access

Only the Maulua Tract of Hakalau Forest National Wildlife Refuge(NWR) is currently open to the public. All other portions of the refuge are closed. The Maulua tract can be accessed from either the Upper (west) end through Maulua Gate or the Lower (east) end across state property (Piha Game Management Area or Laupahoehoe Natural Area Reserve).

Access to Upper Maulua is permitted on Saturdays, Sundays, and state holidays between sunrise and sunset. Hunting is permitted on state holidays and the first three (or four) weekends of each month. The last weekend of each month is reserved for non-hunting activities such as hiking, birdwatching, and photography.

Access to Lower Maulua is permitted any day between sunrise and sunset and is obtained by crossing through either the Piha State Game Management Area or Laupahoehoe Natural Area Reserve. The public may not enter or cross through private property immediately below Lower Maulua. Lower Maulua is accessed by crude unmarked trails and an arduous hike of at least two hours.

Reservations

Every visitor to Upper Maulua including hunters, birders, hikers, and photographers requires a reservation. A hunting or visitation day for Upper Maulua may be reserved by calling the Hakalau Forest NWR office at (808)933-6915, between 8:00 a.m. and 4:00 p.m., three Wednesdays before the activity day desired. Hunters calling for reservations will be asked to provide (1) caller's telephone number; (2) current Hawaii hunting license number for each person in the group; (3) license plate number(s) of vehicle(s) to be used; and (4) description of vehicle(s) to be used. Group hunting reservations are limited to four persons per group. Other visitors will be asked to provide (1) caller's telephone number; (2) the number of people in their group; (3) license plate number(s) of vehicle(s) to be used; and (4) description of vehicle(s) to be used.

Limited Number of Reservations

For safety reasons, the maximum number of reservations accepted for any hunting day in Upper Maulua is twelve. All visitors on hunting days must possess a state hunting license. The number of reservations accepted for a non-hunting day is unlimited.

Feral wild Pigs

Huntable Species and Bag Limits

Only pigs may be hunted on the refuge. There is no limit on the number or size of pigs that may be taken in Upper Maulua. For hunters accessing Lower Maulua, the bag limit is two pigs of either sex in conformance with state regulations. All other wildlife and domestic animals are protected.

Use of Dogs

Hunting dogs may be used by hunters accessing Lower Maulua across state property. Dogs are also permitted only within the fenced 2,000 acre Upper Maulua Management Unit. Dogs are not permitted in other Upper Maulua areas below the bottom fence of the management unit because there is no fence to keep them from running into the upper area of Piha and Laupahoehoe where state regulations prohibit the use of hunting dogs.

State Regulations Apply

State of Hawaii hunting regulations as set forth under Title 13, Chapter 123, Rules Regulating Game Mammal Hunting, are applicable. Highlights include:

— It is unlawful to hunt or possess game mammals without a valid State of Hawaii hunting license.

— A bright orange exterior garment at least 12 inches square on chest and back must be worn by all hunters and assistants in hunting areas.

— It is prohibited to have a loaded hunting arm on horseback, in any vehicle, or any other carrier, or to discharge a hunting arm from any carrier.

— Permitted Hunting Arms

Bows and arrows: Bows having at least 45 pounds of drawing tension for straight bows, 30 pounds for compound bows, and 35 pounds for full-recurved bows.

Firearms: Rifles of 1,200 foot pounds muzzle energy or more; shotguns of 20 gauge or larger loaded with 00 buckshot or rifled slugs; or muzzle loading rifles with a minimum of .45 calibre bore size.

Hunter Checkout

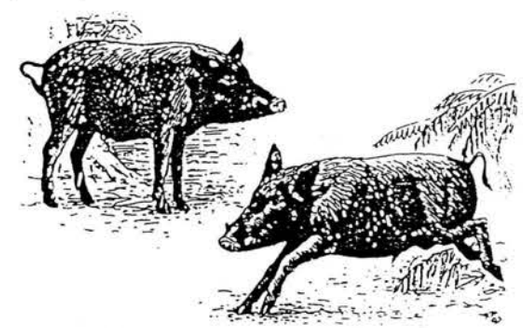
At the gate to the fenced Upper Maulua Management Unit, hunters are asked to deposite a form which records take and effort (even if no pigs were taken). Game may be inspected by enforcement officers or refuge personnel.

No-Hunting Zone

The area within 100 yards of the fence in the northwest corner of the Upper Maulua Management Unit is designated as a no-hunting zone.

Pig Hunting is a Management Strategy

The refuge was established to protect endangered Hawaiian birds and their rain-forest habitat. Because pigs eat native plants and damage the forest floor by their rooting and trampling actions, the population of this non-native animal must be greatly reduced or eliminated on the refuge. The hunting public is invited to assist with this action.



Alien Plants

Relatively few non-native plant species occur on the refuge. Prevent the introduction of weed species such as firetree, Himalayan raspberry, and gorse by cleaning mud and seeds from boots, gear, and vehicles before entering Maulua Tract.

Iiwi, Hakalau Forest Bird

Prohibited Activities

— Use or possession of alcoholic beverages or other drugs while hunting

— Removal of any plant or plant material

— Littering or dumping trash

— Removal or damage to numbered tags and colored flagging tape

— Disposal of lighted smoking materials

— Open fires

— Overnight parking and camping

— Damage to fences, signs or other structures

Vehicle Entry

Access to Upper Maulua is via Maulua Road which intersects with Keanakolu Road at Maulua Gate at the upper end of the tract. The main gate must be closed after entry or exit. Vehicles must be four-wheel-drive and must remain on Maulua Road or parked on the shoulder. Vehicles may be driven to the gate at the bottom of Maulua Road.