HAKALAU FOREST NATIONAL WILDLIFE REFUGE
ANNUAL NARRATIVE REPORT
Calendar Year 1991

REVIEW AND APPROVALS

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2/12/93
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ASSISTANT REGIONAL DIRECTOR
REFUGES AND WILDLIFE

HAKALAU FOREST NATIONAL WILDLIFE REFUGE

Hilo, Hawaii

ANNUAL NARRATIVE REPORT

Calendar Year 1991

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

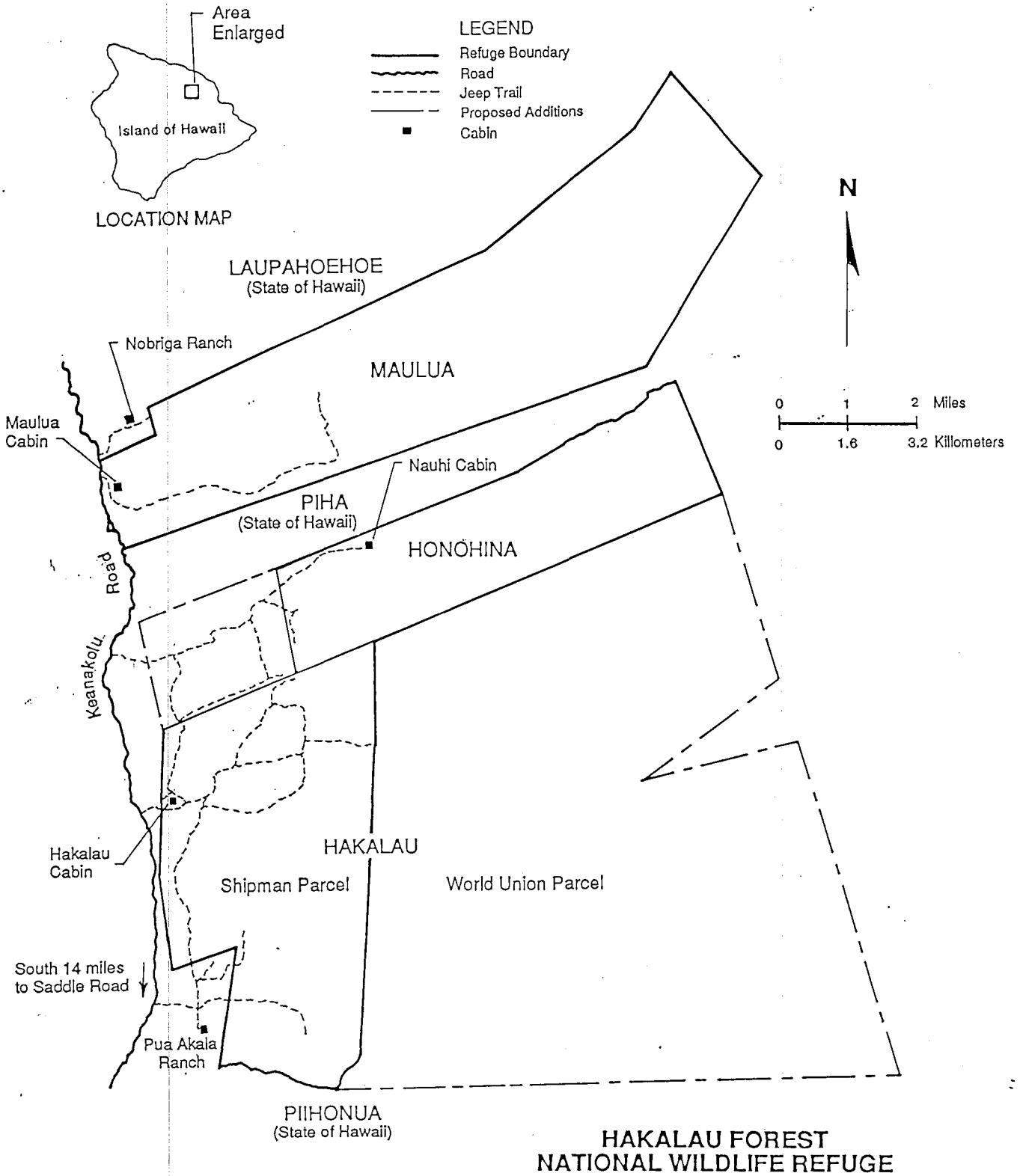
INTRODUCTION

Hakalau Forest National Wildlife Refuge was established October 29, 1985 with the purchase of two properties totaling 8,313 acres. Four additional parcels have subsequently been acquired bringing the current total area to 15,484 acres. Negotiations toward the purchase of two additional parcels totaling approximately 17,000 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 endemic (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 154 Waianuenue Ave., Rm. 219, Hilo, HI 96720. The phone number is (808) 969-9909. The FAX number is (808) 934-7473.

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 Killometers
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. A Sport Hunting Plan was approved which will open the 7,240 acre Maulua Tract to pig hunting and other public use on February 1, 1992. (Section D.2.)

2. Dr. Leonard A. Freed, University of Hawaii, and his graduate students, continued their research project on the refuge. Their efforts focused on behavior and population studies (which included banding as many native birds as possible), genetic and disease studies (which included collecting blood samples), a study of the evolution of sexual dichromatism and cavity-nesting in the Hawaii 'Akepa, a study on the foraging strategies of 'Elepaio in different habitats and a study of temporal arthropod abundance in the koa/ohia forest. During their four year study at Hakalau, Dr. Leonard Freed and colleagues (chiefly Jaan Lepson) have banded a total of 2,008 birds of which 700 have been bled. This total includes 186 endangered birds. The presence of avian malaria and avian pox was also documented. (Section D.5.)

3. The volunteer program was greatly expanded. Fourteen groups visited the refuge for 1-3 day periods providing 1,418 person-hours of effort to assist the refuge staff picking and shucking koa seed pods, planting koa tree seedlings, fertilizing seedlings and grubbing and removing banana poka, gorse and other alien plants. Additionally, three Student Conservation Association volunteers spent the summer on the refuge assisting with cabin construction and maintenance efforts plus habitat monitoring and maintenance. (Section E.4.)

4. 72% of the koa seedlings planted in 1989 are still alive and their average height has increased from 12 to 49.6 inches. 5,000 koa tree seedlings were planted on the refuge during 1991. Six site preparation techniques, high and medium elevation seed sources and the use of fertilizer were tested in the effort to maximize survival and growth rate. (Section F.3.b.)

5. A Special Use Permit was issued to the Alfred Nobriga Ranch which allowed grazing to continue through 1991 within the Upper Maulua Tract. Grazing amounted to 216 AUY during the year for which $5,773 in grazing fees were collected. 1991 was the last year grazing was permitted on the refuge. (Section F.7.)

6. Honua Landscaping, Inc. was contracted to provide 240 hours of effort uprooting and cutting banana poka vines within the Maulua Tract. (Section F.10.a.)

7. Orchard Services was contracted to provide 258 hours of effort for foliar spray and basal bark applications of Garlon 4 herbicide on gorse. All of the large, mature patches of gorse on the refuge were sprayed and burned by the end of 1991. (Section F.10.b.)

8. Experimental plots were established to test the effectiveness of Roundup for controlling blackberry. Preliminary results indicate the "clip and drip" method is effective, though labor intensive. (Section F.10.c.)

9. Bi-annual bird censuses were conducted during the spring and fall. No consistent population declines for any species are evident during the five-year-period over which the refuge has collected data and no marked declines have occurred since the 1977 survey. (Section G.2.)

10. The Hawaii Volcanoes National Park was contracted late in 1990 to assist the Refuge with feral cattle eradication in the 5,000 acre Shipman Parcel. Late in 1991, Mr. Ernest Pung and his catahoula hounds were contracted to "clean up" the few cattle that remained. By the end

of 1991, 94 cattle had been shot during 4 helicopter hunts and 66 cattle were taken by ground hunters. Incidental shooting by refuge staff and contract hunters plus the use of snares also accounted for 45 pigs during the year. (Section G.15.)

11. Hakalau Cabin was enlarged by the addition of a 20 ft x 20 ft wing containing four rooms for staff who generally spend weeknights on the refuge. (Section I.1.a.)

12. The Kershaw Construction Company constructed 57,241 feet of pig/cattle fence around the perimeter of the 5,000 acre Shipman Feral Ungulate Management Unit at a cost of $284,747. Two feral ungulate management units have now been enclosed (17.2 miles of fence costing $421,114). (Section I.1.b.)

13. Steve's Ag Services was contracted to provide maintenance and rehabilitation services for refuge roads. The worst spots on most of the refuge roads were graded and graveled at a cost of $18,058. (Section I.2.)

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 five years, rainfall at Hakalau Cabin has varied between 58.29 and 159.56+ inches and averaged 96.28+ inches. At the higher elevations of the refuge, considerable moisture (perhaps as much as an additional 35%) 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.

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 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. These data are correlated with native plant survival, growth rate and life history data collected during the Forest Service's experimental reforestation studies on the refuge.

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.

Meteorological data from the three locations described above are summarized in Tables I and II.

Table I. Extreme and mean daily air temperatures (°F) recorded at Hakalau cabin and at the flat below the cabin and mean soil temperature (10 cm depth) during 1991.

	Cabin		Flat Below Cabin			
Month	Max.	Min.	Max.	Min.	Mean Daily	Mean Soil Temp.
Jan	68	38	71	34	51	54
Feb	70	40	75	36	51	54
Mar	70	38	70	34	51	54
Apr	-	-	63	36	52	57
May	70	38	65	37	52	60
Jun	71	40	67	38	53	60
Jul	76	40	71	37	55	62
Aug	74	43	71	41	57	63
Sep	74	44	70	42	56	61
Oct	70	44	70	41	55	57
Nov	69	44	71	41	56	55
Dec	-	-	66	35	51	53

Table II. Rainfall (inches) recorded at Hakalau cabin, the flat below the cabin and at the clearing below Pua Akala Ranch during 1991. A "+" after the rainfall figure indicates the rain gauge overflowed before it could be emptied. The true value is, therefore, higher than that listed.

	Hakalau Cabin		Flat	Clearing
Month	87-91 Ave. Rain	91 Rain	91 Rain	91 Rain
Jan	12.22	0.85	1.98	2.39
Feb	7.38	5.24	3.90	3.71
Mar	11.71	36.89+	44.04	48.42+
Apr	5.90	4.95	5.10	9.54
May	5.89	5.94	3.54	4.24
Jun	3.74	3.32	3.16	4.93
Jul	7.90	2.88	2.57	3.50
Aug	4.91	8.95	8.33	13.54
Sep	7.00	4.01	3.76	2.29
Oct	5.71	1.78	1.24	1.79
Nov	13.88	3.37	2.85	5.56
Dec	10.04	7.46	4.57	4.80
TOTALS	**96.28+**	**85.64+**	**85.04**	**104.71+**

Total rainfall for 1991 was close to the long term average and only half as wet as 1990 when Hakalau cabin received a record 159.56+ inches. About half of the 1991 rain, however, fell during the month of March so conditions were drier than normal for most of the year. This was partially due to the *El Niño* condition which began to influence Hawaii's weather in October and continued through the first half of 1992.

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 since 1987 are 0.72 inches for August 1987 and 39.09+ inches for November 1990.

Table II shows that the Pua Akala clearing receives about 15% more rain than Hakalau cabin. The slightly lower elevation (about 200 feet), and the fact that the clearing is surrounded by forest instead of open grassland, probably account for the difference.

C. LAND ACQUISITION

1. Fee Title

Hakalau Forest NWR currently encompasses six parcels totaling 15,484 acres. All of it is owned in Fee Title by the FWS.

During 1991, negotiations were ongoing toward the purchase of an additional 15,715 acres from the World Union Industrial Corporation, Ltd. A request to initiate condemnation proceedings for this parcel was forwarded to the Attorney General on June 22, 1989. Negotiations were also ongoing toward the purchase of an additional 1,034 acre parcel owned by the Liliuokalani Trust. During 1991, the refuge assisted with appraisals and inspections of this property through provision of information and guided tours for appraisers and FWS personnel. Both properties fall within the approved boundary of the refuge.

As part of the acquisition process, the Division of Realty funded an aerial photographic survey of the World Union Parcel and the entire refuge. Color photos at a scale of 1:12,000 (1 in = 1,000 ft) were taken of the lower elevations on May 2, 1991 and of the upper elevations on October 12, 1991. The photos have already proven very useful for mapping and planning purposes.

Realty also funded two surveys of the World Union Parcel to gather information for the appraisal. Michael Garcia, University of Hawaii, was contracted to document the presence and amount of aluminum ore (bauxite) on the property. Winkler Woods was contracted to estimate the amount and value of koa and ohia timber on the property.

In 1990, the Service learned that the W.H. Shipman Corporation was for sale and expressed interest in acquiring the 500 acres retained by the W.H. Shipman Estate (borders the SW corner of the refuge) when the 4,994 acre Shipman Parcel was sold to the FWS in 1985. The owners stated the property was not for sale as a separate entity, and that they would notify the Service if the situation changed.

D. PLANNING

2. Management Plan

A Sport Hunting Plan for Hakalau was approved by the Regional Director in 1991 which will open the 7,240 acre Maulua Tract to public use 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. Hunters will be allowed to hunt pigs on state holidays and during the first three weekends of each month. On the last weekend of each month, only non-hunters may enter Maulua for activities such as

birdwatching, hiking and photography. Reservations are required for all visitors and will be limited to a maximum of 12 during hunting days for safety reasons. State hunting regulations apply except there will be no limit to the number, size or sex of pigs taken because one of the program objectives is to maximize the control effort.

A sign plan was drafted for the refuge which calls for the placement of entrance signs at the upper entrances to the Pua Akala Tract, Hakalau Tract, Honohina Tract and the Maulua Tract. The entrance signs will be erected in 1992 when the Maulua Tract is opened to public access. Informational, regulatory and directional signs will also be erected at Maulua to facilitate public access.

On April 16, the Refuge Manager convened a meeting attended by 13 people from the National Park Service, State Division of Forestry and Wildlife, The Nature Conservancy, The Audubon Society and the Fish and Wildlife Service. The meeting was called to set priorities for construction of fences at Hakalau and to facilitate communication between agencies with feral ungulate control programs. The group felt that a fence dividing the 4,994 acre Shipman Feral Ungulate Management Unit was probably not necessary. Though the unit is large, hunting is relatively easy because much of the unit is open pasture. Highest priority was given to fencing the Honohina-Piha boundary and the creation of the lower Honohina Feral Ungulate Management Unit.

4. Compliance with Environmental and Cultural Resource Mandates

Section 7 consultations are required for refuge actions that may affect endangered species. Such consultations were completed during the year for four actions described elsewhere in this narrative. The actions are 1) opening the refuge to recreational hunting and other forms of public use; 2) construction and maintenance of jeep roads; 3) construction and maintenance of cattle/pig fence; and 4) construction and use of a temporary rain shelter.

Anan Raymond, Regional Archaeologist, visited Hakalau in February to conduct a cultural resources survey. His report, dated May 1991, documents the existence of three native Hawaiian sites on the refuge plus one site on the soon-to-be-acquired Liliuokalani Trust Parcel. The sites include a rock cairn on a forested ridge, a square stone platform almost obscured by thick sod, a rectangular enclosure of loosely stacked cobbles and boulder-sized basalt rocks, and a group of four rock cairns and raised stone enclosures. Further study in the form of more careful surface inventories, detailed mapping and test excavations is recommended for all four sites. Their presence is significant because few Native Hawaiian sites have been discovered on the middle slope of Mauna Kea and they represent prehistoric activity previously undocumented in Hawaiian archaeology.

The R.M. Towill Corporation was contracted to prepare a Conservation District Use Application for the construction of approximately 63.8 miles of pig\cattle fence and the eradication of pigs and cattle within the lower elevations of the refuge which are zoned "Conservation". If approved by the State of Hawaii, the Conservation District Use Permit will allow the six miles of fence construction planned for the lower Honohina Tract in 1992 as well as subsequent fence construction elsewhere on the refuge.

5. Research and Investigations

a. Forest Bird Research

Forest bird research was initiated in 1987 at Hakalau by Dr. Leonard A. Freed, Professor of Zoology, University of Hawaii. In 1988 he was issued a Special Use Permit (HAK-1-88) 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. His basic research techniques include capturing birds in mist nets, banding with numbered and colored bands, collecting blood samples for disease and DNA analysis, and behavioral observations of banded individuals. The bulk of his research occurred within a 20 acre area centered around an open meadow at the top of the Pua Akala Tract.

Seven University of Hawaii personnel were officially associated with the field studies at Hakalau during 1991. Drs. Leonard Freed and Rebecca Cann (Chief Investigators) were assisted by graduate students Scott Fretz, Jaan Lepson, Heather McSharry, Robert Peck and Eric VanderWerf.

Mr. Lepson camped in the Pua Akala meadow almost continuously, 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. Eric VanderWerf, a graduate student from the University of Florida, resided at the camp during his research on 'Elepaio, a native flycatcher. Robert Peck stayed intermittently at the camp while collecting insects.

In March, an undergraduate class (Quantitative Field Ecology) of nine students resided at the Pua Akala camp for nine days to conduct research on field problems relating to bird behavior and plant ecology, to learn ornithological techniques and to become familiar with native birds. John Maynard Smith, an evolutionary biologist from the University of Sussex, visited the camp for several days. And lastly, Yvonne Ching, a veterinary student form Washington State University, participated in the collection of bird blood samples to detect avian malaria.

The following species were captured, banded and sampled for blood during 1991 by Dr. Freed and colleagues:

Endangered Species	Newly Banded Individuals	No. Bled (Includes birds previously captured)
Hawaii 'Akepa	20	26
Hawaii Creeper	3	4
'Akiapola'au	0	0
Total	23	30
Other Native Species		
'Oma'o	12	14
'Elepaio	6	9
Common 'Amakihi	52	51
'Apapane	94	38
'I'iwi	124	91
Total	288	203
Introduced Species		
Red-Billed Leiothrix	19	19
Japanese White-Eye	30	30
House Finch	4	4
Northern Cardinal	2	2
Nutmeg Mannikin	0	0
Total	55	55
GRAND TOTAL	**366**	**258**

Five-Year Summary of Bird Banding By University of Hawaii Research Team

	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
TOTAL	**2008**	**186**	**700**

Dr. Freed and colleagues found nests of all native bird species except Hawaiian Hawk during 1991 including 11 endangered 'Akepa nests of which at least 6 fledged young successfully. All 'Akepa nests were in ohia and koa tree cavities and in the same trees as used in previous years for nesting or in a another tree in close proximity. The nest trees were the largest (diameter) in the area. This sample of nests will enable a study of the extent to which cavities are re-used from one breeding season to the next. Introduced House Finches also nest in cavities allowing for possible interspecific competition for nest sites with 'Akepa.

'Akepa nesting studies reveal high fledging success (70-80%), but that juvenile mortality may be quite high shortly after fledging. This is evidenced by noting that many banded pairs fed fledglings for a much shorter period than the nine weeks normally observed and that relatively few juveniles were captured in nets during summer months. Causes of the high fledgling success and later massive fledgling mortality are unknown but some juvenile mortality may be due to predation as was observed on one occasion when an 'Akepa fledgling was captured and eaten by a Hawaiian Hawk.

The fate of endangered nests observed by Dr. Freed's crew at Hakalau during 1991 is indicated in the following table:

Species	Total Nests	Successful	Failed	Fate Unknown
Hawaii 'Akepa	11	6	3	2
Hawaii Creeper	4	2	1	1
'Akiapola'au	1	1		

The post breeding interspecific flocks of Hawaii Creepers, 'Akepa and 'Amakihi appear to be an association of different family groups before the termination of parental care. Flock size and number of flocks may serve as indicators of breeding success for the species involved. This information was gathered in July during a group science project in which 10 people worked in pairs separated by 100 meters. Each pair walked 1,000 meters in parallel, censusing flocks at 100 meter intervals. Synchronized stations ensured that flocks could be tracked across the entire study plot. The census was done on two different days, south of the Pua Akala meadow. One flock was detected on the first day and two or three on the second day. This suggests that flocks roam widely and do not have exclusive use of forest space. During the census, it was noted that Japanese White-Eyes were associated with the flocks. Perhaps this introduced species impacts native birds at this time through competition or serving as disease reservoirs.

Several years of recapturing and resighting color-banded birds have revealed that endangered species such as 'Akepa and Hawaii Creeper exhibit greater natal and breeding philopatry than non-endangered birds. This indicates that they may be less prone to colonize new habitats. Opening a new area for study at the northern part of the refuge will enable research to determine if endangered birds have several local populations.

Three bird species, all introduced, were newly recorded on or near the refuge during 1991. One male house sparrow was seen at the Pua Akala Ranch house. A spotted dove was observed near the Pua Akala barn and just above the refuge gate on Pua Akala Road. A large flock of yellow-fronted canaries was seen in the open areas of the Pua Akala Meadow. The canary is of particular interest because it has been known to serve as a reservoir for avian disease.

Avian malaria is definitely present on the refuge. Although Gaines stains on blood smears were all negative, a random sample of 20 'Apapane and 20 'Amakihi captured on the refuge indicated a 4-10% incidence of malaria using a newly developed molecular probe. The probe was developed by Dr. Rebecca Cann and associates from the University of Hawaii. It 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. If the disease was contracted on the refuge then the potential vector needs to be identified. 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 continue to be found in all species of native birds on the refuge, although rarely on the endangered birds. The survival and reproductive success of the 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.

Genetic studies of Hakalau birds are continuing under the direction of Dr. Cann. Research is underway to develop primers to exploit more rapidly evolving portions of the mitochondrial genome that will be useful in identifying specific lineages of the birds sampled. Current studies show that in a semi-conservative region of the mitochondrial genome, the Hawaii 'Akepa has the same level of genetic variation as do the non-endangered honeycreepers at the refuge. More samples of Hawaii Creeper and 'Akiapola'au are needed to assess genetic variation in these species. Surprisingly, the Common 'Amakihi has about twice the genetic variation of the other species.

Dr. Freed and his students noted that, despite the generator, power tools and high noise levels present during the construction of the rain shelter in the Pua Akala Meadow, a pair of Common 'Amakihi nested in a nearby ohia tree. The parents remained at the nest throughout construction but the nest failed during torrential rains which followed completion of the shelter.

University students investigated biomass and morphology of kikuyu grass in open and in shaded areas to evaluate the hypothesis that this introduced grass will be crowded out as the forest regenerates. Their results indicate that kikuyu grass has a lower relative biomass in well shaded areas and that root morphology may differ between areas. The lower internode interval in the shaded grass indicates the grass is growing more slowly in shade. There is also a greater diversity of grasses in the shaded area indicating that competition with other

grasses, rather than shadier conditions, may be responsible for the different root morphology. Variability among samples may also reflect heterogeneous soil conditions.

b. Soils Research

On July 2, Dr. H. Ikawa, Professor of Soil Science, University of Hawaii was issued a Special Use Permit (HAK-7-91) to describe and collect representative soil profiles and to map and verify soil units at Hakalau. This research will assist in understanding relationships between soils, vegetation and climate and provide valuable aid in the reforestation effort.

E. ADMINISTRATION

1. Personnel

Hakalau Forest NWR is part of the Hawaii/Pacific Islands Refuge Complex. The 1991 Complex staff was comprised of 31.1 FTE's broken down as follows:

Refuge Complex Administration	4.0 FTE
Remote Island Refuges	11.0 FTE
Oahu Refuges	3.7 FTE
Kauai Refuges	8.4 FTE
Hakalau Forest NWR	4.0 FTE
TOTAL	**31.1 FTE**

All positions at the refuge were fully staffed throughout 1991. The staff was comprised of the following individuals:

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

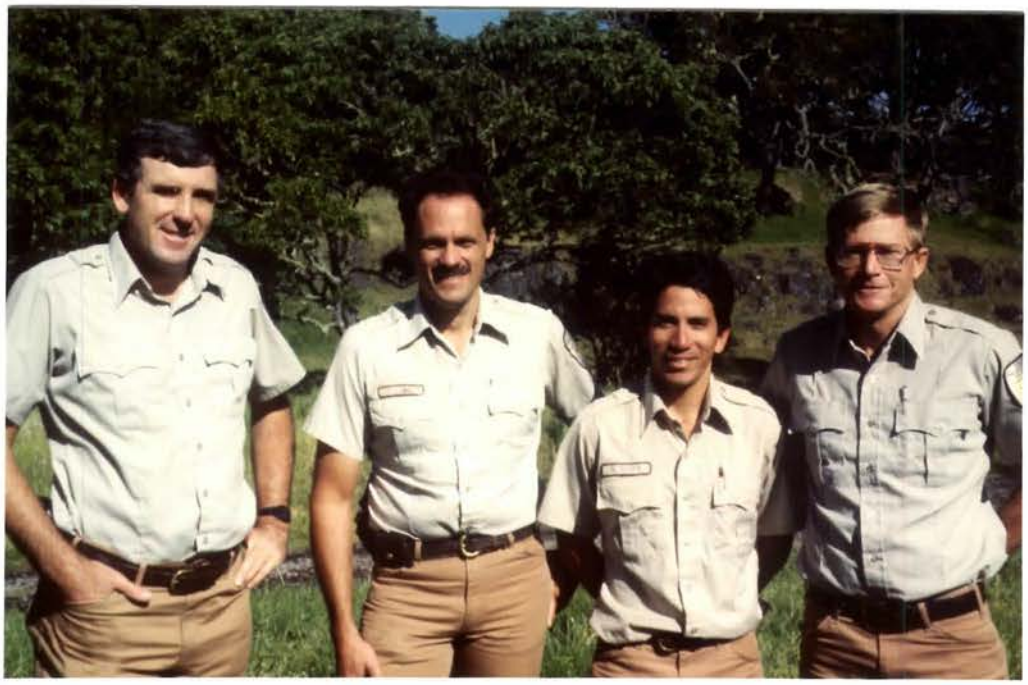
b. John J. (Jack) Jeffrey, Wildlife Biologist, GS-9, Permanent Full Time, entered on duty September 9, 1990.

c. Jon R. Emig, Maintenance Worker, WG-7, Permanent Full Time, entered on duty April 20, 1988 as Temporary Full Time, converted to Permanent Full Time May 5, 1991.

d. Anthony C. (Tony) Texeira, Maintenance Worker, WG-6, Temporary Full Time, entered on duty April 15, 1990.

In December, Lynne Hanzawa was selected for the position of Office Automation Clerk. She will transfer from a similar position with the Farmers Home Administration Office in Hilo and begin working January 13, 1992.

Also, Dick Bauer and Vanessa Gauger spent a week at Hakalau in November as paid employees picking koa seed pods.



The 1991 Hakalau staff. Jack Jeffrey (Wildlife Biologist), Jon Emig (Maintenance Worker), Tony Texeira (Maintenance Worker) and Dick Wass (Refuge Manager), left to right.

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

	Permanent			
Calendar Year	Full-Time	Part Time	Temporary	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

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, work supervision and tools to accomplish the job. For three-day trips, the group is usually given the last day to hike and observe birds accompanied by one of the refuge staff. The bird hike is a major incentive because the refuge is closed to the general public.

The volunteer program during 1991 was far larger than during previous years. Fourteen different work crews visited the refuge for 1 to 3 day periods and provided a total of 1,418 person-hours of effort. A brief description of each visit follows:

a. January 19-21. Nine Sierra Club members from Honolulu, who were training to lead future service trips, grubbed banana poka at Maulua (90 person-hours) and holly, German ivy and fuschia in Pua Akala Gulch (20 person-hours).

b. March 29-31. Nora Furuno's group of nine people from Honolulu spent about 108 person-hours grubbing banana poka at Maulua and in the Middle Honohina Feral Ungulate Management Unit.

c. May 25-27. Eight Honolulu Sierra Club members led by Marlene Lemke spent about 40 person-hours removing gorse in the Pua Akala Tract and 56 person-hours pulling banana poka at Maulua.

A group of volunteers weeds gorse from the upper edge of the forest. DW

d. June 8-10. Six Sierra Clubbers from Maui led by Anna Mae Shishido spent 72 person-hours grubbing banana poka at Maulua.

e. July 4-6. Nine folks from the Honolulu Sierra Club led by Bill Aoki and Gina Goodman spent about 117 person-hours planting 2,300 koa seedlings in Hakalau 2 and Hakalau 4 paddocks.

f. August 16-18. The Hilo Tax Office Hikers, consisting of 8 individuals led by Gloria Amaral, spent 158 person-hours picking banana poka at Maulua.

g. August 31-September 2. Twelve volunteers from the Honolulu Sierra Club led by Reese Liggett and Helen Sing planted 2,300 koa seedlings in Hakalau 4, Pedro and Hakalau 1 paddocks during 180 person-hours of effort.

h. September 28-29. Nine Boy Scouts and five adult leaders from Troop 23 of Hilo led by Eagle Scout candidate Keith Shimabokuru spent about 84 man-hours removing banana poka and picking koa seed pods at Maulua.

i. October 4-6. A Honolulu group of seven people led by Nora Furuno provided approximately 110 person-hours of banana poka control effort at Maulua.

j. October 26-27. Ten students and two leaders (Julie Williams) from the Hilo High School Hiking Club spent about 84 person-hours picking 2-1\8 trash bags full of koa seed pods.

k. November 9-11. Twelve Sierra Clubbers from Honolulu led by Anna Kaohelaulii and Robert Becker provided 144 person-hours of koa seedpod picking effort resulting in 8 bags of pods.

l. November 23. Eleven folks from the Hawaii Island Sierra Club (Moku o Loa Group) spent about 55 person-hours picking four bags of koa seedpods.

m. December 7-8. Eight volunteers from Hawaii Research Station and elsewhere spent approximately 60 person-hours of effort fertilizing experimental plots of koa seedlings.

n. December 23-26. Two volunteers spent approximately 40 person-hours hand shucking koa seed pods.

Three volunteers associated with the Student Conservation Association also provided a great deal of assistance to the refuge for a three-month period during the summer. Chris Johnson, Carolyn Garvey and Emma Loss resided at Hakalau Cabin while assisting with construction of the staff wing of the cabin, painting the cabin exterior, banana poka control, koa tree planting, monitoring growth and survival of koa seedlings, weed surveys, gorse control, native plant surveys, koa seed pod picking, fence inspection and feral ungulate surveys. In return they received roundtrip air tickets between their mainland residences and Hilo, $15 per day to cover living expenses and a very thorough orientation to Hakalau Forest NWR and its resources. All parties were pleased with the program and plans were made to bring out three more SCA volunteers in 1992.

5. Funding

Hakalau Forest NWR receives its funding through the Hawaii/Pacific Islands Refuge Complex. The FY 1991 funding for the Complex is broken down as follows:

Refuge Complex Administration	$250,100
Remote Island Refuges	713,700
Oahu Refuges	347,400
Kauai Refuges	482,800
Hakalau Forest NWR	525,800
TOTAL	$2,319,800

The refuge received $525,800 in funding for FY 1991 which included a special congressional appropriation in the amount of $251,000 for the construction of pig\cattle fence plus a donation of $3,507 from the Natural Resources Defense Council. The NRDC funds were designated for tree planting and were raised through NRDC's "Rescue the Rainforest Campaign" which focuses on actions that individuals can take to reduce rainforest destruction, starting with defending and restoring America's own tropical forests. For each new member who joins the NRDC during the campaign, $1.00 of the $10.00 membership fee is passed to the refuge to plant a koa tree.

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

6. Safety

One reportable accident occurred on the refuge during 1991. Volunteer Daniel Dinell was assisting with banana poka eradication and, while pulling banana poka vines down from a tree, a piece of debris lodged in his eye. A minor abrasion of the cornea required medical attention from a doctor at Hilo Hospital.

In April, potable water from the Hakalau cabin catchment system was retested to see if it remained safe to drink. The total coliform count was found to be slightly elevated (6\100 ml) though no fecal coliforms were present. Lead was well within safe limits. The coliform test was repeated by the State Health Department in September and none were found.

7. Technical Assistance

The Refuge Manager actively participated on the multi-agency Gorse Steering Committee and the Forestry Subcommittee of the Resource Conservation and Development Council. The Forestry Subcommittee is considering a project to solicit funds from the public for a reforestation project on the Big Island. Hakalau Forest NWR will likely be the first recipient of these funds. The same committee is also working with the Refuge Manager on a proposal to secure funding from the American Forestry Association for tree-planting efforts at Hakalau.

The manager was invited to participate on a committee convened by the Nature Conservancy of Hawaii. The 10-member committee met for the first time in August and was charged with the responsibility for compiling a prioritized list of research needs relative to native terrestrial communities throughout the state.

F. HABITAT MANAGEMENT

3. Forests

Formally, koa and ohia forests extended to 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 due to 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

On September 11, 1986 an Interagency Agreement between the FWS and the U.S. Forest Service's Pacific Southwest Forest and Range Experiment

Station was signed. The agreement transferred $15,000 to the Forest Service "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 the necessary field trials to determine what methods for regeneration of the native forest are most efficient and cost effective and to provide management prescriptions for future large-scale reforestation effort.

A second Interagency Agreement was signed with the U.S. Forest Service in August 1988 to continue and expand the original studies. $15,000 was transferred to the Institute of Pacific Islands Forestry to accomplish the following: 1) Determine if fertilizing enhances establishment and early growth of koa and other native seedlings. 2) Test the extent of koa seedling production from the soil seed bank along a gradient of decreasing koa tree cover. 3) Continue research on techniques for propagating seedlings and vegetatively propagated plantlets for various native forest trees and shrubs. 4) Evaluate survival of planted native understory species. 5) Plant rooted ohia cuttings in the Magnetic Hill exclosure to test the effect of established koa seedlings on rates of growth and survival for the cuttings. 6) Continue measurements of growth and survival on seedlings established within the Magnetic Hill and woodland exclosures. 7) Document baseline forest cover within the 40 acre woodland exclosure. 8) Assist with the preparation of a reforestation management plan for the refuge. This agreement extended through March 1991 but the Forest Service plans to continue to monitor the experimental plots and plantings at their own expense for an additional indefinite period. Accomplishments through 1991 under both agreements are summarized in the following paragraphs.

In May 1987, an experimental reforestation plot (termed the Magnetic Hill Exclosure) of about 6 acres was established in open grassland below Magnetic Hill at the 6,500 ft elevation. The area was fenced to exclude cattle and pigs. Seedlings of koa, mamane, and sandalwood as well as rooted ohia cuttings were planted in pure stands and in combination with each other. No weed control or fertilization was done. Koa survival after one year averaged 75% with minimal losses in succeeding years in most plots. Some microsite conditions led to higher mortality in a few plots. By 1991, almost all koa trees were thriving and the average height was over eight feet. The vast majority of mamane seedlings and ohia cuttings, however, were dead. The ohia was probably killed by frost. All of the sandalwood seedlings planted a year earlier were alive, but no growth occurred.

A second experimental reforestation plot (a 40-acre area termed the Woodland Exclosure) was established in July 1987. It is located at about 5,500 ft in the SW corner of the Honohina Tract (and within the Middle Honohina Feral Ungulate Management Unit). The understory has been heavily impacted by cattle and pigs and consists mostly of introduced grasses. There is a scattered overstory of koa, ohia, and other species, however, to produce seeds and root-sprouts. This plot was established to determine the efficacy of soil scarification for producing koa forest regeneration from the residual soil seed bank. A disc-harrow was used to turn over the sod to a depth of about 5 inches, thereby exposing the soil surface and allowing sunlight to penetrate and warm the soil to stimulate seed sprouting.

The early results from the soil scarification study were detailed in the 1989 narrative. The study showed that scarification will produce numerous seedlings in the vicinity of live and dead koa trees (if they have been dead for less than about 10 or 15 years). Three years after scarification, new recruitment in parent tree areas continued but none was seen in open treeless areas, possibly due to an exhausted seed bank. The seedlings in the Woodland Exclosure are growing faster than those at Magnetic Hill. Many were more than twelve feet tall by the end of 1991.

Conclusions drawn thus far from the two experimental plots include the following: Mamane seedlings and ohia cuttings have not done well at the higher elevation plot. Sandalwood has survived but shown no growth. Koa seedlings do well in both plots but grow more rapidly at the lower site, perhaps because of the warmer temperature and moister conditions. Scarifying the soil in woodland areas produces significant numbers of koa seedlings. Competition from grasses such as kikuyu is severe but, once established, koa seedling growth is vigorous. Most koa seeds are not far from the seed source. Beyond about 80 ft, the number of seedlings drops dramatically. Prevailing wind does not appear to have much impact on seedling distribution. Existing data do not allow a determination of how long koa seeds remain viable in the soil but it appears that dead tree skeletons remain long after their seed viability is lost.

Natural regeneration of native vegetation after removal of feral cattle and pigs was significant but varied by substrate. Mineral soil accounted for 97% of the potential seed bed in study plots, but less than 33% of all regeneration occurred there. In contrast, decaying logs made up less than 2% of the area but supported more than 50% of all regeneration. Organic seedbeds are, therefore, vitally important sites for recruitment of native plants. Ohia, ohelo and olapa are species that showed a strong preference for organic beds. In contrast to these woody species, hapu'u (tree fern) showed a strong preference for mineral soil.

As part of the Interagency Agreement, the Forest Service has also been working on the propagation of a number of native trees and shrubs in addition to koa, ohia and mamane. Germination and grow-out conditions have been established for a total of 11 species thus far.

180 seedlings and rooted cuttings from six of these species (kolea, kawau, olapa, ohia, *Clermontia* and pilo) were planted at Hakalau during May and June of 1990. They were planted in five areas under varied canopy cover, from shaded to open, within the 40 acre Woodland Exclosure for protection from feral pigs and cattle. The Forest Service is monitoring their growth and survival.

A number of general conclusions can be drawn from observations and studies by the Forest Service at Hakalau and elsewhere within the state:

1) Koa seedling survival and growth rate can be increased by application of herbicide to reduce competition from pasture grasses and weeds.

2) Koa stands are found to increase soil acidity, increase soil nitrates and increase soil water content. These soil conditions are also favored by other native trees and shrubs. It, therefore, appears that a healthy stand of koa may be needed to prepare pastureland for the reintroduction of other native plants.

3) An organic seedbed such as decaying wood or the trunk of a treefern is required for natural reproduction of many native plant species. Only a few individuals of some species will germinate and grow in mineral soil. It may, therefore, be necessary to create organic seedbeds in the pasture areas to establish a diverse community of native plants.

4) Logs and other coarse woody debris are not undesirable waste or trash. Organic debris plays a valuable role in the forest ecosystem by providing sites for natural plant regeneration as well as reservoirs for nutrients and water, energy sources for microorganisms, homes for forest invertebrates and structures for soil stabilization.

5) Growth rate and survival of koa seedlings and other native plants is far greater within enclosures which have been fenced to exclude feral pigs and cattle.

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 methodology is best known for this species. Additional species will be planted in the future as techniques for their propagation are better defined. In the meantime, the establishment of koa stands in open pasture will improve the chances for later success with other species because koa will add nitrogen to the soil, acidify the soil, add organic matter to the soil and provide shade.

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.

Survival and growth rates for about 2,500 of the seedlings in fifteen plots at elevations between 6,400 and 5,600 feet were re-measured in August 1991. Mean survival was found to be 72%. Survival varied from 43% at the higher elevations to 93% at the lower elevations. Much of the mortality at higher elevations resulted from frost. The rooting activities of feral pigs which were attracted to worms under the sod clumps produced by the discing also caused significant mortality at all planting elevations. Mean seedling height was 49.6 inches, an increase of 44% over the 1990 measurements. Height averaged 38.8 inches at the highest elevation and 56.8 inches at the lowest elevation. Higher temperatures, fewer heavy frosts, and greater moisture, therefore, enhanced survival and growth at lower elevations. Growth and survival data for the 1989-90 planting are summarized in Figures 2 and 3.

The full-scale koa reforestation program continued in 1991 with the planting of 5,000 seedlings below Hakalau Cabin and along the north side of Kolekole Stream above Middle Road. The following six site preparation methods (to reduce grass competition) were tested and compared: 1) Discing; a continuous strip about 2 meters wide was disced. 2) Burning; a patch of grass about one meter in diameter was burned away with a propane torch. 3) Scalping; a mattock was used to clear the vegetation within a 1 meter circle. 4) Weedwacking; a gas-powered weedwacker was used to clear the grass from a 1 meter circle. 5) No preparation; nothing was done to remove or kill the grass. 6) Herbicide; Roundup was sprayed several weeks before planting to kill the vegetation in a one meter diameter area. Labor, machine time and material costs were recorded for each method.

Six parallel continuous strips, one for each treatment, were laid out 12 feet apart from 6,400 ft to 5,500 ft elevation. During the first planting (July), the progeny from mid-elevation koa trees were planted at 24-foot intervals within the six parallel strips. During the second planting (September), seedlings from high-elevation parent trees were interplanted at 24-foot intervals alternating with July plantings. The resulting strips each contained one July tree and one September tree at 12-foot intervals throughout their lengths.

A fertilizer test overlaid a portion of the site preparation/parent elevation test. Three plots made up of 120 rows at three different elevations were established on December 7. Each plot was defined as six

Figure 2. Survival of koa seedlings planted in Triangle Paddock during 1989.

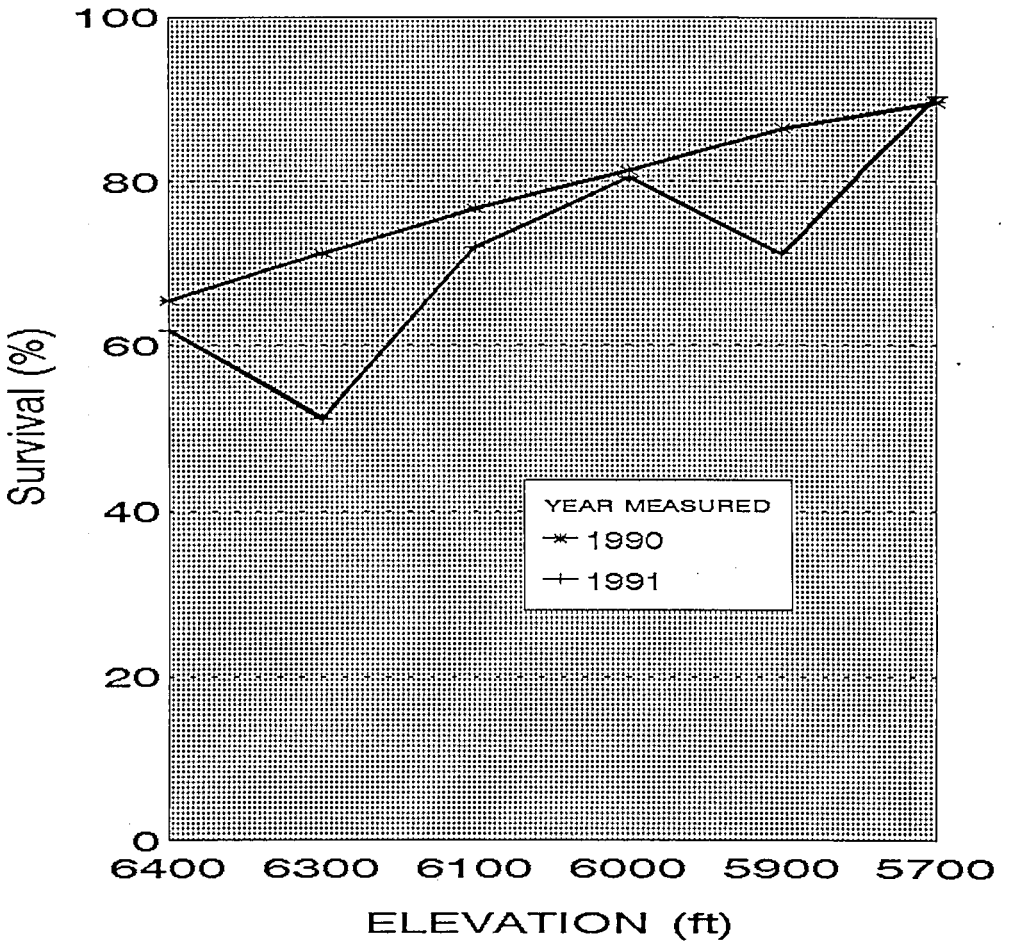
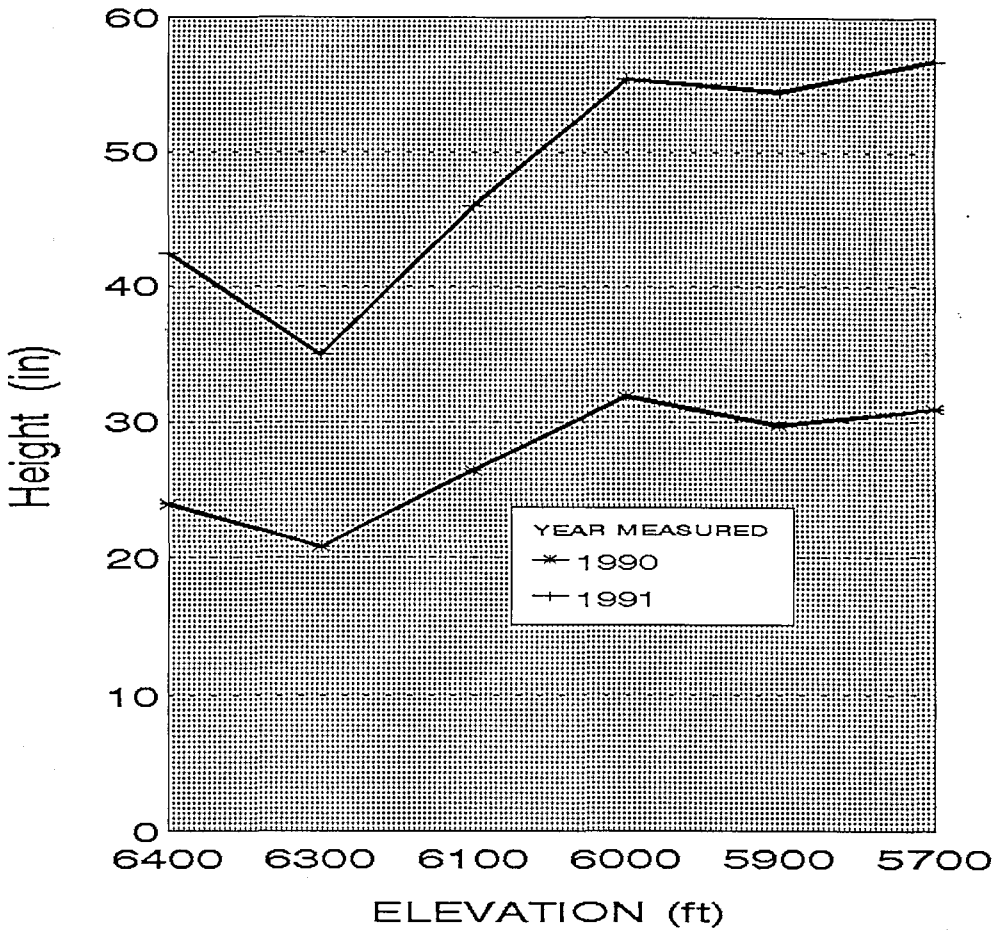


Figure 3. Average height of koa seedlings in Triangle Paddock. Seedlings were about twelve inches tall when planted in 1989.



strips wide and 120 rows long and each contained 720 plants. Since every other row was planted on a different date, two rows were fertilized and the following two rows were not. This continued, alternating two fertilized rows and two unfertilized rows, until 120 rows were included.

One of the six experimental site preparation methods (for koa tree planting) involves burning a one-meter-diameter patch of grass with a propane torch. DW

Two ounces (60 grams) of 10-30-10 granular fertilizer was placed in each of two holes made with a dibble stick at each test plant. Fertilizer placed in dibble holes is thought to leach out slower than broadcast applications and is less likely to burn the plants. It is also available sooner because it is closer to the roots. An earlier test using 20, 40, and 60 grams of 10-30-10 fertilizer on a small sample of seedlings showed that no burning of the young trees occurred at the 60 gram fertilizer level.

Survival and growth for trees within the experimental plots will be monitored to determine which site preparation is best, whether elevation

of parental stock affects resistance to frost and lack of moisture, and whether fertilization has a significant beneficial effect.

c. Koa Seed Viability Tests

Koa seeds collected in 1990 at and around Hakalau Forest NWR were hand shucked then germinated at the tree planting facility in Waimea. The end result was only 17% overall viability. Expecting 10-20,000 seedlings from 40,000 seeds, we were disappointed with the resulting 5,000 seedlings for the 1990 planting season. A test of seed viability was necessary during the seed collecting period to determine seed viability while seeds were still available for harvest. This test would allow us to know when enough viable seeds had been collected to produce adequate numbers of seedlings for future koa planting needs.

The 1991 koa seed collections began in late July and continued until late November. Twenty-two large (33 gallon) plastic trash bags of seed pods were collected. Seeds were shucked from the pods either by hand or by a mechanical shucker.

A test to determine the viability of hand-shucked vs. mechanically-shucked seeds was conducted in early December. Seed viability varied from lot to lot but averaged 29%. Although average viability was 11% higher with hand shucking (34.7% vs 23.3%), viability within subsamples (9-86%) showed wide variance. Amount of detritus was the major difference between the hand- versus mechanically-shucked samples. 46+% of the weight in the mechanically-shucked sample consisted of detritus while 5% of the weight in the hand-shucked sample was detritus. Seed loss due to mechanical shucking could not be assessed but the slightly higher weight/100 seeds for the mechanically-shucked sample with detritus removed indicates that smaller seeds are possibly being tossed out with the chaff. We conclude that hand-shucking results in a greater weight of viable seeds from a bag of pods but that the difference is usually not great enough to warrant the additional time and expense.

d. Heat Scarification Trial

It is well known that scarification of the soil under or in the vicinity of koa trees by a mechanical device such as a disc-harrow will cause numerous koa seedlings to sprout. We reasoned that heat might have the same effect because hundreds of young koa trees became established along the "Strip Road" at Hawaii Volcanoes National Park after the area was impacted by a wildfire. A heat scarification trial was, therefore, conducted at Hakalau on September 26.

A diesel-fired weed burner was used to burn the exotic grasses beneath two neighboring live, but senile, koa trees in the open pasture below Hakalau Cabin. Even though conditions were extremely dry for Hakalau, a natural fire would not burn the thick grass mat down to mineral soil due to the moisture content of the grass. Three degrees of heat scarification were used: intense, moderate and light. For the intense trial, the grass was burned away right down to the mineral soil, insuring that the soil was also heated to a significant degree. In the moderate trial, the grass was burned away to the point where some soil was exposed and some soil heating occurred. In the light trial, the burner was only used to ignite a fire which was allowed to carry naturally through the grass. The fire did not burn through the thick mat. No mineral soil was exposed and it is unlikely that soil heating occurred.

The burned patches were subsequently monitored for koa seedlings and root sprouts. None were found during the following twelve months. It, therefore, appears that heat scarification will not result in a significant number of young koa trees at Hakalau. There is a

possibility, however, that the relatively small areas selected for the trial had few viable seeds or surface roots. The weed burner was not found to be an efficient tool for large-scale scarification. It burned 55 gallons of diesel during the 1-1/2 hours it was used and only relatively small areas were burned.

A diesel-fired weed burner was used to scarify two areas beneath live koa trees to test the feasibility of using fire to stimulate germination and growth of koa seedlings and root sprouts in abandoned pasture. DW

e. Vegetation Plot Surveys

In 1987, C. P. Stone and assistants (NPS Technical Report 63) began the collection of detailed vegetation data at Hakalau to monitor forest recovery as intensive forest management progresses. Stone established six 20 x 20 meter semi-permanent plots and six 50 meter line-intercept transects at six locations on the refuge. Three heavily grazed areas and three less grazed areas were selected for sampling different elevations and different parcels of the refuge.

In 1991, with the help of Dr. Lani Stemmermann and several volunteers from the University of Hawaii at Hilo, two of Stone's plots on transect 5 in the Pua Akala area were found and detailed vegetation data were taken in the same manner as in 1987 survey. Stone's two plots on transect 13 in the Maulua Tract could not be found and were abandoned because transect 13 was repositioned in 1988. These two plots were re-established in 1991 along the new transect 13 and vegetation data were taken. Stone's plots on transect 10 will be resurveyed in 1992. All plots will be monitored every five years to assess ongoing management efforts and to monitor forest recovery.

f. Photo Plots

To aid in monitoring forest regeneration, 12 photo plots were established in pasture and forested areas of the refuge during 1991. These plots will be photographed every 2 years to monitor the results of

ongoing management efforts. The plots were marked by two, 4 foot by one inch diameter PVC pipes five meters apart in representative forest and pasture areas along existing transects. Two photos were taken, using the pipe closest to the transect as a camera rest, and the camera aimed so the second pipe was centered in the viewfinder frame. Using Kodachrome 64 film, one horizontal and one vertical photo was taken at each site. Also, two 6 foot folding rulers were bent 90 degrees and set on the ground to form a square directly in front of the pipe furthest from the transect for a closeup photo. The camera was positioned so that the frame filled the photo. An 8 1/2 in by 11 in sheet of paper with the date, area and photo plot number was set at the base of the farthest pipe to identify each photo.

g. Rare Plants

A number of rare native (candidate endangered species) plants are found on the refuge or on nearby State lands. The National Tropical Botanical Gardens (NTBG) is interested in collecting seeds from these species to add to their Rare Plant Seed Repository. Steve Perlman of NTBG visited the refuge in October to collect seed from *Clermontia lindseyana, Clermontia pyrularia, Phyllostegia macrophylla* and *Phyllostegia racemosa*. Some of these seeds will be germinated at NTBG and the plants grown to flowering for more seed. If plants from natural growing populations die off or are destroyed by feral ungulates, seeds and or plants from the NTBG will be available for re-establishment on the refuge as part of the ongoing reforestation effort.

h. Disease

During 1991, a "witches broom" like growth was seen on koa trees in the Maulua Tract. The disease appears as a multiple stemmed, poorly developed branch tip on koa. The leaves are undeveloped and appear as long and stringy tan-green bunches, giving the branch tip a broom-head appearance. Dr. Don Gardner, a plant disease specialist from the University of Hawaii at Manoa, visited the refuge to help identify the disease and determine the ramifications of its presence. The disease is a newly described endemic rust that is host specific to koa and was first described from Laupahoehoe and Maulua by Dr. Gardner. It does not cause significant damage to the tree and is unlikely to cause mortality.

7. Grazing

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

Four of the six 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 two of the parcels for at least three years to allow time for the ranches to phase out their operations and to allow the Service time to determine if the benefits of a limited grazing program might outweigh the adverse impacts.

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 cattle are no longer permitted to graze any portion of the refuge except when used as a tool by the Refuge Manager to assist with gorse control (see Section F.10.b. below).

When cattle are removed, young koas will sprout and grow in the vicinity of parent trees as shown in this photo taken two years after grazing was terminated. DW

Grazing by the Alfred Nobriga Ranch on the 1,542 acre upper Maulua Parcel extended from 1987 through 1991. The first three years were covered by a Cooperative Agreement under which grazing privileges were provided in exchange for equivalent value services relating to grazing and management. On April 11, 1987, a Cooperative Agreement was signed with the Alfred Nobriga Ranch which permitted grazing on the upper Maulua Parcel through the end of 1989. Grazing privileges were provided in exchange for equivalent value services relating to grazing and management.

A Special Use Permit (HAK-1-90) was issued to the Alfred Nobriga Ranch to allow continued grazing on the 1,942 acre Upper Maulua Parcel during 1990. The SUP was issued because Mr. Nobriga felt the Service had verbally agreed to allow him to graze for a five year period after the property was purchased and because the cattle would help to control banana poka until adequate funding and staff became available to fully address the problem. The grazing fee was set at $26.72 per AUY and maximum stocking density was set at one head per five acres. Grazing during 1990 amounted to 324 AUY for which $8,652.90 in grazing fees were collected.

Special Use Permit HAK-4-91 was issued in 1991 with the understanding this would be the last year grazing would be permitted at Maulua. The SUP also stipulated that grazing was permitted only on the upper 1,000 acres of the parcel (above the "halfway fence") after July 31. Grazing during 1991 amounted to 216 AUY for which $5,773 in grazing fees were collected. Nobriga Ranch cattle were still on the property at year's

end but preparations were underway to remove them during the first month of 1992.

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. The objective is to achieve the hottest possible fire in order to maximize consumption of gorse biomass and gorse seeds and to scarify as many of the remaining seeds as possible to cause early germination. The plan also called for the collection of data on a specially designed form to document fuel conditions, climatic conditions and fire behavior because there is no fuel model for gorse and there is little information on prescribed gorse burns.

Prescribed burns of gorse were conducted on October 29 and December 5, 1989, on March 27, 1990 and on January 10 and May 9, 1991. Burning occurred between 0900-1400 hrs during mostly sunny conditions. Temperatures ranged between 59° and 69° F., relative humidity between 56% and 88% and wind speed between 0 and 10 knots. A propane torch with the tank mounted on a backpack was used to ignite individual weed patches. The torch worked well enabling rapid ignition at several points along the upwind side of the patch perimeter.

The dead gorse patches averaged about 20 ft in diameter and burned almost explosively, being fully engulfed in flames 40-50 feet long within about one minute of ignition. Two minutes later, only the smoking stems remained. Live patches of gorse also burned fairly well, especially if the perimeter had been treated with herbicide. Areas between gorse patches consisted of kikuyugrass pasture. Occasionally the grass duff would catch fire and smolder but it was relatively easy to confine the fire to the gorse patches. Two fire trucks and four fire fighters were provided by the Hawaii State Division of Forestry and Wildlife to assist with the burns on the first day of the 1989 effort but it soon became obvious they were not needed. During subsequent burns, only the refuge staff comprised the burn team.
All of the larger patches of gorse remaining on the refuge were burned during 1991 including the largest patch which covered about 10 acres. This burn went exceptionally well considering that the interior was all live plants. It was estimated that 95% of the interior foliage was consumed by the fire. Further burning of gorse on the refuge should not be necessary unless the maintenance control effort ceases for a few years and gorse is allowed to regrow to the point where it again forms mature patches.

10. Pest Control

A major management concern 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*) and prickly Florida blackberry (*Rubus argutus*) are invading species that require control measures.

a. Banana Poka

On the refuge, only the Maulua area (which is bounded by Laupahoehoe and Piha) and the northern edge of the Honohina Tract (which is bounded by Piha) are presently infested with banana poka. Cattle grazing has helped to control this weed but, as grazing is eliminated, other means for control must be utilized. An experimental study conducted by refuge personnel indicated that most of the large vines (stem diameter greater

than about one inch) were killed by severing the stem near its base with a machete or pruning shears. In most cases the root did not re-sprout and the distal end died if it was not allowed to make contact with the wet ground. Smaller vines could be uprooted by hand as long as the root end was hung from a tree or otherwise positioned so as not to make contact with the ground or wet vegetation.

Flower, fruit and leaves of the introduced banana poka vine. Pigs eat the banana-like fruit and spread the infestation to other areas through defecation. DW

A contract was let to Honua Landscaping, Inc. for banana poka control at Maulua during 1990. They spent 317 hours severing stems and uprooting vines at a total cost of $10,312 ($32.50 per man-hour). Their effort was focussed in lower Maulua. Additional staff and volunteer control effort was also expended in lower Maulua and, by the end of 1990, it was estimated that approximately 90% of the larger vines in the area were eradicated.

The contract with Honua Landscaping, Inc. for banana poka control was extended in 1991. During this year they spent 240 hours severing poka stems and uprooting vines primarily in the upper Maulua area above the "halfway fence" at a cost of $9,000 ($37.50 per man-hour). The three Student Conservation Association volunteers plus seven groups of weekend volunteers and the Hakalau staff exerted over 500 additional person-hours of poka control in Maulua above and below the "halfway fence" in a major attempt to remove all the mature and fruiting vines from Maulua prior to the termination of grazing which occurred in December. It is thought that poka seeds are viable for only about a year so, if seed production is halted by the removal of all mature plants and a large portion of the young seedlings are eaten by cattle, significant control should be achieved.

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.

A gorse control effort was initiated at Hakalau during the summer of 1988 by the refuge staff. The restricted-use herbicide Tordon 22k was applied to gorse as a foliar spray by refuge staff. Good results were achieved but the magnitude of the infestation was too large to be addressed by the small staff.

In 1989, Honua Landscaping, Inc. was contracted for the spray application of herbicide on gorse. The company provided the equipment and 360 man-hours of effort for $16,680. The refuge provided 20 gal of Tordon 22K and surfactant (non-ionic and Silwet). The spray operation was conducted during late summer which is a relatively dry time of the year and a period when gorse is actively growing. Most of the gorse patches were small enough to be completely drenched by the hand-held spray wand. The interiors of patches larger than about 25 ft in diameter were not sprayed. With the exception of the core area of the gorse distribution at Hakalau (primarily a huge patch below Magnetic Hill which covered a few acres) the majority of all patches on the refuge (80-90%) were sprayed. A few months later, the dead and partially dead gorse patches were burned by the refuge staff. Burning is necessary to remove the dead plants and kill seeds on the surface of the ground, and to scarify remaining viable seeds in order to cause their immediate and simultaneous germination. If simultaneous and complete germination does not occur, some seeds will continue to sprout each year for the next 30 years resulting in the need for a long term major control effort.
Honua Landscaping was contracted again in 1990 to spray gorse during August and September. The company provided the equipment and 283 hours of effort for $15,848. The refuge provided the herbicide which consisted of 2 gal of Garlon 4 and 620 grams of Escort. The FWS would no longer permit the use of the "restricted use" herbicide Tordon 22K so Escort was used as a foliar spray. Garlon 4 mixed with diesel (4% solution) was applied as a basal bark treatment to the stumps of burned gorse bushes.

With the exception of the interior of the largest gorse patch (approximately 10 acres in size), all live gorse plants in the pasture areas, including the seedlings which had sprouted as the result of the prescribed burning, were treated with a foliar application of Escort. Escort was not found to be as effective as Tordon. Most of the plants that were drenched with Escort eventually died but many were only weakened to the point where they did not bloom and produce seed the following year. Garlon in diesel was applied to the stumps of all large gorse plants which had been burned a year earlier because the roots have a tendency to re-sprout if they are not completely killed by herbicide prior to burning. Most of these plants were at least partially killed by herbicide before burning but some were not sprayed before burning. The basal bark application worked very well, killing the roots of 95% of the plants to which it was applied. The 1990 spray effort was again followed with prescribed burning to kill and germinate seeds and to remove brush, thereby increasing accessibility for future basal bark treatment.

In 1991, a gorse control contract was let to Orchard Services which provided the equipment and 258 man-hours of control effort during August and September for $12,900 ($50 per hour). The refuge again provided herbicide and surfactant. Because Escort applied as a foliar spray did not work very well in 1990, a 2% formulation of Garlon 4 in water was

applied as a foliar spray in 1991. Satisfactory results were achieved and it was found to work almost as well as Tordon 22K. A 4% solution of Garlon 4 in diesel was again applied as a basal bark treatment with good success.

At the request of the Refuge Manager, the manager of Pua Akala Ranch placed about 70 head of cattle in the upper portions of Barn 1 and Barn 2 paddocks for about two months prior to the 1991 spray effort. The cattle ate some of the gorse seedlings which had been stimulated to sprout by the recent burn. They also did a great job of eating and tramping down the grass around the bases of the burned gorse plants which would have shielded the stems and root crowns from efficient application of herbicide.

Because much of the gorse was sprayed during the previous three years, there were sufficient resources to spray all gorse patches on the refuge during 1991. All remaining large patches were subsequently burned as well which is described above under Section F.9. Considerably less effort should be required during future years because 99% of the mature plants have already been sprayed and burned. The manager of Pua Akala Ranch also sprayed gorse on his property in 1991 (with Garlon 3A provided by the State) which should help to reduce the spread of seed onto the refuge.

Gorse prefers the open, sunlit pasture areas but it does occur within the forest, particularly in sunny openings and at wide spots in streambeds. During 1991, a considerable amount of staff time and effort by the SCA volunteers was spent manually removing gorse from the forest with a weed wrench and other hand tools because a foliar spray application of herbicide cannot be used when native plants are nearby.

c. Blackberry

In June, five 10 X 10 meter plots were established in the exotic grass/blackberry area of the fenced 550 acre feral ungulate management unit to test the "clip and drip" application of Roundup herbicide. Two plots were set up in blackberry with exotic grass ground cover and three in blackberry with exotic grass/native fern ground cover. Two plots of each ground cover type were used to test different concentrations of Roundup (50% and 100%). All blackberry stems were cut as close to the ground as possible and a drop of Roundup was dripped, using a small (250 ml) laboratory drip bottle, onto the stump end. The fifth plot (exotic grass/native ferns) was used as a control. Stems were cut, but the stump end was not treated with roundup. One month later, all plots were monitored for regrowth of the cut stumps.

The five plots were monitored for regrowth of the cut stumps one month after herbicide was applied. The following table summarizes the results:

Ground Cover	Roundup Concentration	Number of Stems Cut	Number of Stems Showing Regrowth	Percent of Stems Showing Regrowth
Grass/Fern	None	310	193	62%
Grass	50%	180	23	13%
Grass/Fern	50%	167	24	14%
Grass	100%	175	11	6%
Grass/Fern	100%	336	19	6%

Clip and drip with Roundup appears to prevent resprouting of blackberry stems after one month. Damage to surrounding plants was minimal. No ferns or other native plants were affected by the herbicide though some damage to exotic grass was noted within 5 cm of the treated blackberry stem. Clip and drip, therefore, appears useful for controlling

blackberry in situations where a foliar spray application has potential for damaging nearby native plants. The test plots will be re-monitored in 1992 to determine if "clip and drip" is equally effective in the longer term.

d. 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. 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 in the shelter area from March through December 1991. The catch during 187 trap nights was three Black rats (*Rattus rattus*), one Polynesian rat (*Rattus exulans*) and 5 house mice (*Mus domesticus*).

G. WILDLIFE

2. Endangered and Threatened Species

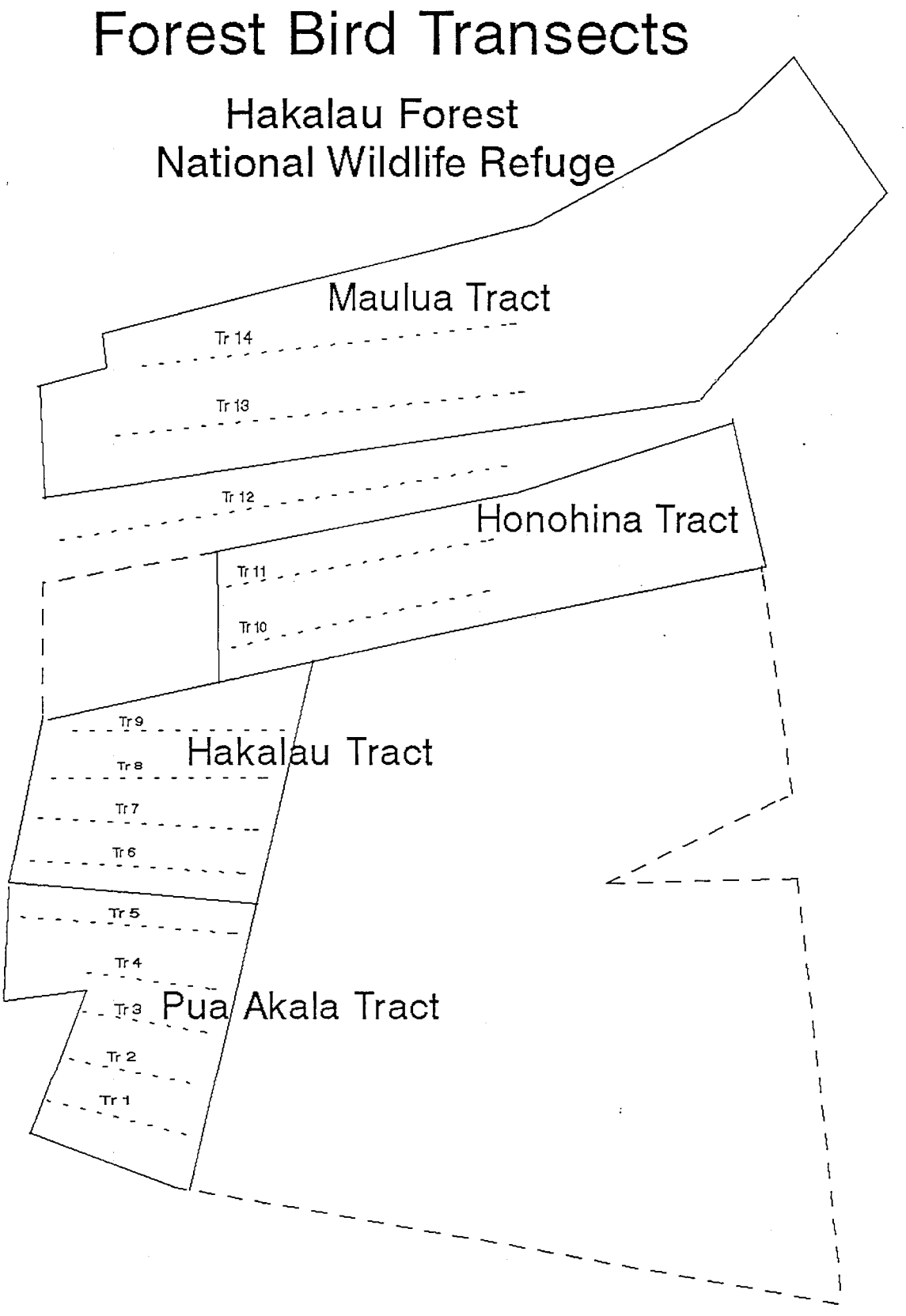
Hakalau Forest NWR was established for the purpose of protecting and restoring endangered forest bird populations and their habitat. The Hawaii 'Akepa, the Hawaii Creeper, the 'Io (Hawaiian Hawk) and Koloa (Hawaiian Duck) are relatively common endangered birds at Hakalau. Four other endangered birds, 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 but is very rare.

Systematic bird population surveys are required to ascertain the status of the various species, to track their population trends and to measure their response to management efforts. Accordingly, Dr. J. Michael Scott of the Cooperative Fish and Wildlife Research Unit, University of Idaho, was contracted in 1987 to develop a permanent bird monitoring program and to conduct the first three surveys. Since then, fall and winter surveys have been conducted annually by inter-agency teams from the Fish and Wildlife Service, National Park Service, Hawaii State Department of Land and Natural Resources and the University of Hawaii.

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. Transect locations are shown in Figure 4. 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 1991 spring census was conducted during the week of April 1-5. Principal observers included J. Jeffrey and J. Jacobi of the Fish and Wildlife Service; L. Cuddihy, L. Katahira, H. Hoshide, A. Kikuta of the National Park Service and J. Lepson of the University of Hawaii. Training in survey techniques and bird identification was conducted for other individuals with the hope that they could participate in future training sessions and, eventually, the actual censuses. Included in this group were K. Fruth, FWS; M. Fulton NPS; and D. Smith. P. Conry and C. Terry of the Hawaii State Division of Forestry and Wildlife.

Figure 4.


Forest Bird Transects
Hakalau Forest
National Wildlife Refuge
Maulua Tract
Tr 14
Tr 13
Tr 12
Honohina Tract
Tr 11
Tr 10
Tr 9
Hakalau Tract
Tr 8
Tr 7
Tr 6
Tr 5
Tr 4
Tr 3
Pua Akala Tract
Tr 2
Tr 1

A second census during the fall was conducted November 4-6. Principle censusors were J. Jeffrey, P. Banko, and S. Fancy of FWS; L. Katahira, L. Cuddihy, M. Morin, Z. Sarr and C. Atkinson of NPS; and J. Lepson of UH. Eighteen trainees from various Federal and State agencies as well as The Nature Conservancy also participated.

A singing male 'Amakihi. This is one of the most common birds at Hakalau. JJ

The data for the 1988-1991 spring forest bird surveys have finally been compiled and analyzed. Annual population estimates are summarized for each species in Table III.

Table III. Annual (Spring Census) bird population estimates for Hakalau Forest NWR.

Species	1987	1988	1989	1990	1991
'Akiapola'au	973	279	537	157	206
'Apapane	107,545	19,237	42,483	26,632	26,471
Common 'Amakihi	69,630	24,279	28,212	36,383	26,000
'Elepaio	8,920	9,007	5,806	8,246	3,404
Hawaii 'Akepa	4,255	3,218	4,366	2,297	2,227
Hawaii Creeper	4,761	1,704	1,419	4,400	3,477
'I'iwi	154,613	57,765	78,545	53,308	36,673
'Oma'o	13,007	7,154	6,412	5,839	2,939
House Finch	2,756	4,552	1,975	1,717	1,515
Japanese White-eye	36,552	8,815	10,546	14,044	5,777
Northern Cardinal	2,893	401	366	605	571
Red-billed Leiothrix	24,943	7,799	11,052	10,703	4,681

The population estimates for each species are graphically depicted in Figures 5 and 6.

Figure 5. Annual bird population estimates (Spring census) for Hakalau Forest NWR.

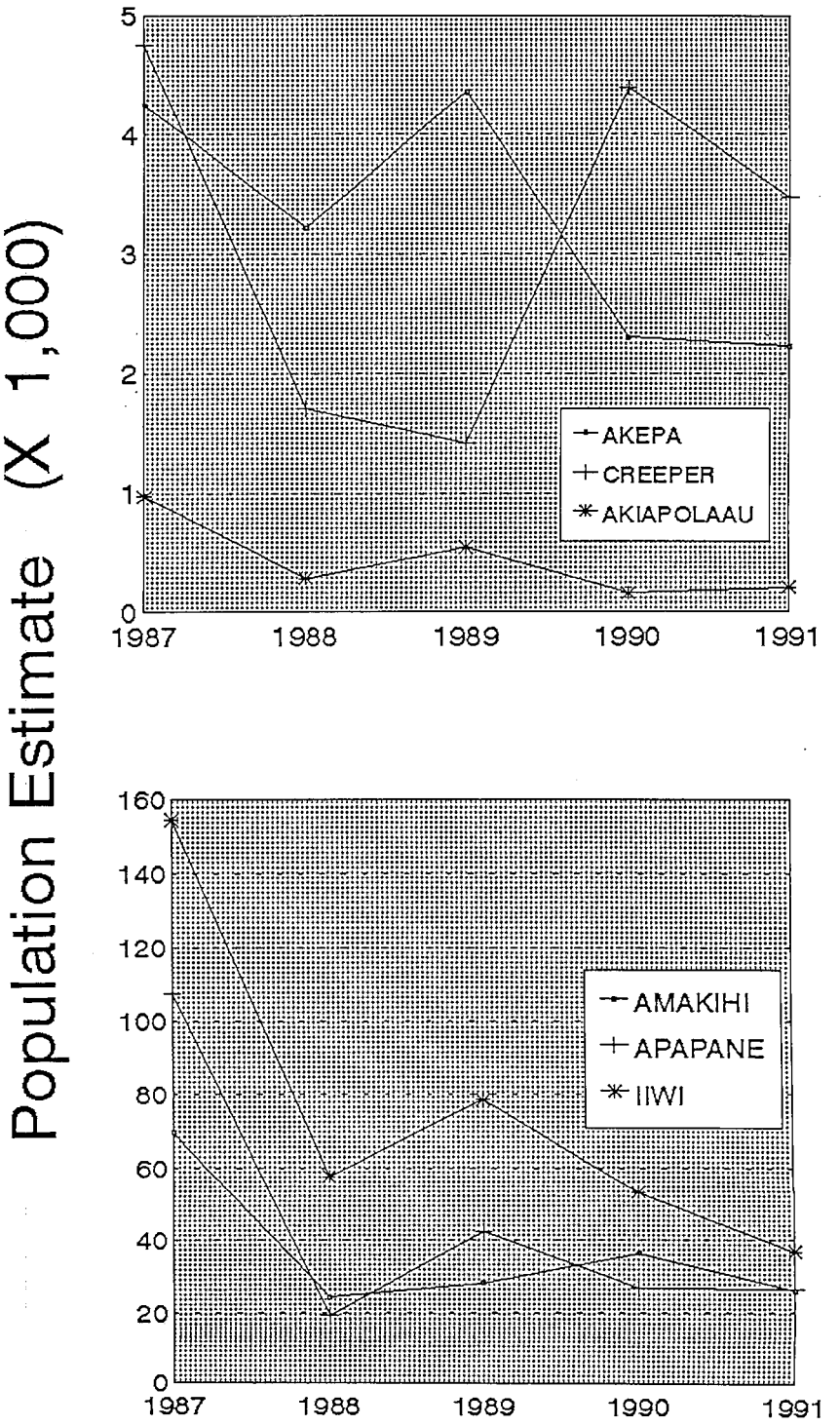
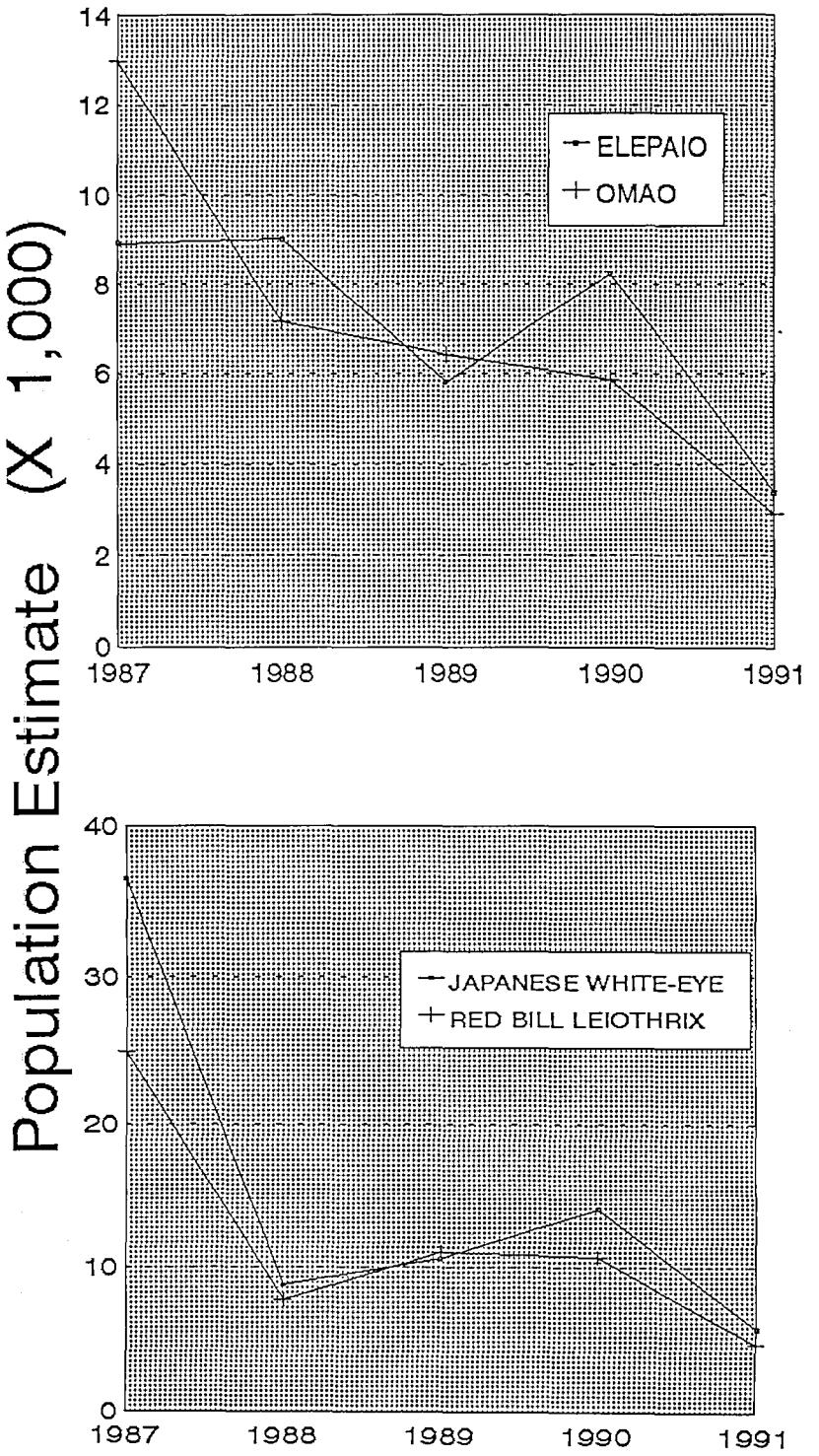


Figure 6. Annual bird population estimates (Spring census) for Hakalau Forest NWR.



Ten of the twelve estimates for 1988 are markedly lower than 1987. Much of this difference is probably due to a lack of training prior to the 1987 census which resulted in the observer over-estimating the distance between himself and the bird he heard or saw. The 1988-1991 estimates also fluctuate considerably from year to year. This is the result of real variations in nesting success and adult and fledgling survival due to varying weather conditions and food availability as well as differences in observer skills. The estimates should become more accurate over time as observers become more skillful and as calculation methods are refined.

6. Raptors

A nestling Hawaiian hawk, still covered with down, was found in July on the ground below a nest positioned 50 feet above in a large ohia tree. The young bird had either jumped or was knocked out of the nest, possibly by the older sibling that still remained in the nest. It was impossible to return the fallen chick to the nest. On contacting other Federal and State personnel experienced in hawk nesting, it was agreed that keeping the bird at the nest site was preferable, if the parents would feed it. The nestling was placed in a 20 in x 20 in x 4 in wooden box filled with grasses and shredded bark which was nailed to the nest tree about six feet above the ground. During the first few observations, the parents fed the nestling regularly at the artificial nest site. Later in the month, however, after a week of heavy rains, the nestling was found dead. Though being fed, the nestling may not have been brooded by the female which would have protected it from the cold and inclement weather. The second nestling fledged from the tree nest in August.

A second nest (in the Maulua Tract near Station 6 of Transect 14) is also known to have fledged a single hawk in 1991.

14. Scientific Collections

The refuge was 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. In November, Paul Conry and assistants from the Division of Forestry and Wildlife collected and necropsied three species of game birds at the refuge under a Special Use Permit (HAK-11-91). Two of the five birds collected were found to be infected with avian malaria. The necropsy results are summarized as follows:

Species	I.D.	Condition	Necropsy Results
Erckel's Francolin	92-57	Good	Malaria plasmodium, *Eimeria* sp.
Ring Neck Pheasant	91-58	Good	Unidentified small ova
Ring Neck Pheasant	91-60	Good	*Eimeria* sp., blood cells ruptured
Ring Neck Pheasant	91-61	Good	Unidentified small ova, blood cells ruptured
Turkey	91-59	Good	Malaria plasmodium

15. Animal Control

Feral pig and cattle control is a high priority forest management objective at Hakalau. 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. Hawaiian plants are not adapted to the grazing pressure of these introduced ungulates (the only

native mammals are a bat and a seal) so they are easily suppressed by cattle and pigs.

An Interagency Agreement with the Cooperative Park Studies Unit, National Park Service, University of Hawaii was signed on September 26, 1986 to document the extent of the feral ungulate problem at Hakalau and to recommend measures for reducing the damage. The resulting report recommended that: 1) Cattle should be removed as soon as possible with priority given to the lower elevations and northern portions of the refuge which are not as dominated by alien plants in the understory. 2) Feral pigs should be controlled through establishment of fenced units ranging in size from about 700 to 2,100 acres. Priority should be given to the lower units where forest integrity and reclamation potential are highest. 3) Pigs should be eradicated from each unit by systematic hunting with dogs where hunters are required to return to hard-to-hunt areas. Public hunting reduces pig populations in accessible areas and is a good public relations tool but is no substitute for a systematic program where hunters are paid and a variety of innovative methods such as snaring, trapping, baiting, use of exit gates and ramps, and wing fences are utilized to reduce pig populations to near zero. 4) Transects should be systematically surveyed to monitor abundance and distribution of feral ungulates and the spread of alien plants.

Progress has been made toward implementing these recommendations. By the end of 1991, grazing by domestic cattle was completely eliminated on the refuge. However, a few feral cattle (perhaps a couple dozen head) still occurred within the forested areas of the Shipman Estate Parcel, and about 100 head were still present within the Honohina Tract and the Maulua Tract at elevations below the Forest Reserve boundary (about 5,100 feet elevation).

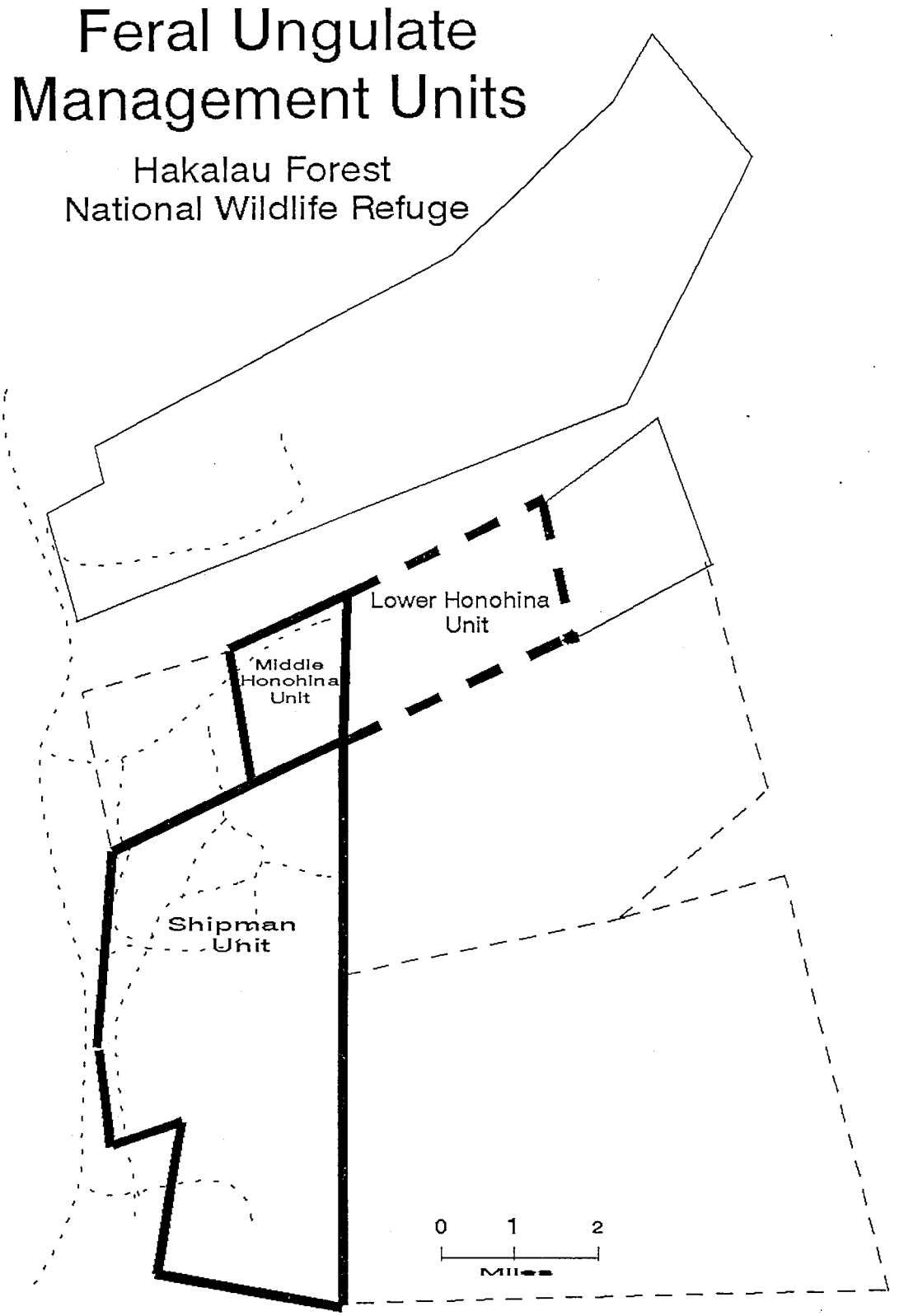
Two feral ungulate management units were established and fenced by the end of 1991. (Figure 7.) The 550 acre Middle Honohina Unit (formerly known as the Liliuokalani Trust Unit) was fenced in 1988 and all cattle and all but about two pigs were removed in 1989. The perimeter fence around the 5,000 acre Shipman Unit was completed in 1991. Most of the feral cattle (160 head) and almost 100 pigs were removed (shot or snared) from this unit by the end of 1991.

Feral cattle eradication within the Shipman unit 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 there are fewer of them (our initial estimate was about 200 head); and 3) cattle had the potential for breaking through the new fence when frightened by gunshots or the sight and smell of humans so we wanted to remove as many as possible before the fence was constructed.

Professional hunting expertise and manpower from the Resources Management Branch, Hawaii Volcanoes National Park (HAVO) was contracted for $12,000.00 through the Cooperative Park Studies Unit, University of Hawaii. The HAVO team agreed to remove as many cattle as possible and to test the effectiveness of aerial and ground hunting techniques. The Hakalau staff assisted the effort which began in December 1990 and extended through 1991.

Aerial hunting was conducted from a Hughes 500D helicopter with the doors removed. The OAS-trained rifleman was strapped and seated in the rear of the aircraft on the pilot's side to give the pilot and him the same field of view. A spotter/recorder sat forward next to the pilot to assist with the search for cattle and to record the number and location of kills. Aircraft crew members were in continuous communication with each other and with ground crews who also helped locate target animals. From 200-400 feet above the forest, the helicopter would systematically

Figure 7.


Feral Ungulate
Management Units
Hakalau Forest
National Wildlife Refuge
Lower Honohina
Unit
Middle
Honohina
Unit
Shipman
Unit
0
1
2
Miles

search an area. Upon sighting cattle, the aircraft would descend to a level just above the canopy or even into holes within the canopy to give the best vantage point for shooting. Usually the animals were shot in the forest but in some instances they could be driven into more open areas where they made easier targets.

Four aerial hunts were conducted. The first occurred on December 4, 1991 when 53 cattle were shot by the aerial gunner. Subsequent helicopter hunts occurred on February 5, July 16 and November 20, 1992 during which 26, 14 and 1 cattle were taken from the air.

Considerable hunting for cattle was also done from the ground. Fourteen cattle were taken by ground hunters in 1990 and 52 were taken in 1991. Together, aerial and ground hunters took 67 cattle from the Shipman unit in 1990 and 93 in 1991 for a total of 160 head.

Shooting from the helicopter proved to be an effective method for killing cattle when the population was high. A large area can be searched quickly and efficiently from the air (the Shipman Unit contains approximately 3,000 forested acres) and most of the animals in a herd could be followed and eventually shot. In one hour, a helicopter covers more area (though sometimes less thoroughly) than a ten-person ground crew can search in two days. When a herd is found by ground hunters, some animals are shot and some usually escape. Fewer animals in a herd escape the helicopter.

As cattle numbers declined, a coordinated effort between helicopter and ground crews proved most effective. After the first aerial hunt, the cattle became wary and learned to hide in thick vegetation at the sound of the helicopter. Ground crews were able to see or hear cattle in thick vegetation and call in the helicopter for assistance in shooting or following the animals. We conclude that aerial hunting and ground hunting are both effective at removing cattle and are best used in conjunction with each other.

A different cattle control method was initiated in December 1991 with the award of a contract to Ernest Pung, a retired State forester and experienced hunter. By this time helicopter hunting was no longer effective and the few remaining cattle were very wary and difficult to find by ground hunters. Mr. Pung agreed to search the Shipman parcel with two catahoula hounds which were trained to hunt cattle, and to shoot any cattle that were found. He was paid $200 per day for his effort plus $50 per head for cattle kills. Mr. Pung and assistants shot eleven cattle during two days of hunting during late December. Hunting with trained cattle dogs appears to be a good method to "clean up" an area when other methods are no longer effective. Mr. Pung's effort will continue during 1992.

In addition to the 93 cattle removed from the refuge in 1991, 45 pigs were taken. Twenty-five were shot, four removed by snares, and 16 by other means including dogs and archery. Of the four snare catches, three were caught alive and given to Hawaii Volcanoes National Park for a special film project on Hawaiian ecosystems.

A Special Use Permit (HAK-8-91) was issued to Wayne Mathews representing a group called "Sportsmen Against Hunger". The SUP permitted Mr. Mathews' presence on the refuge during the helicopter hunt conducted on July 16 and allowed him to take meat from cattle and pass it to the Salvation Army for distribution to the poor as part of their free meals program. Mr. Mathews butchered two cows shot near the lower portion of Pua Akala Road and delivered the meat to the Salvation Army kitchen in Hilo. The Salvation Army is one of the few charities that can accept "uninspected" meat because it receives no monetary support from government agencies.

16. Marking and Banding

As noted above under Section D.5., Dr. Leonard Freed and colleagues banded 366 birds during the year including 23 endangered 'Akepa and Hawaii Creeper. No 'Akiapola'au were captured or banded this year. The totals for his five years of study are 2,008 banded birds of which 186 were 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 they 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

No portion of the refuge was open to public entry in 1991. Visitors gained access only through Special Use Permit, through the volunteer process or during guided tours conducted by the Refuge Manager and staff.

In response to the need for a general refuge brochure describing resources and management objectives, the narrative was drafted by the staff and reviewed by EPIC in the Regional Office. EPIC expects to complete the layout, map, art-work and photo selection and to publish 5,000 copies of the full color brochure in time for the opening of the refuge to public hunting on February 1, 1992.

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 1991 included:

Jan. 16. Lola Gannon and Rich Johnson from the Regional Office and Dan Kershaw, Fence Contractor helicoptered over the fence construction site as part of the preconstruction meeting.

Jan. 25. Sharon Takeuchi, Assistant U.S. Attorney representing the FWS in the World Union condemnation action and Ted Wrobel of John Child & Co. who has responsibility for the World Union appraisal, overflew the World Union Parcel and the refuge by helicopter.

Jan 28-29. Eugene Conrad and Paul Scowcroft, U.S. Forest Service; Chris Smith, U.S. Soil Conservation Service; Jim Fones, U.H. professor of Agriforestry; and Kevin Grace and Paul Melaspina, U.H. graduate students; collected soil samples and discussed the need for a soil survey at Hakalau to facilitate reforestation.

March 27. Kathy Costello and Noreen Bautista visited Hakalau in conjunction with the annual imprest fund review. Nelson Ho, past president of the Hilo Sierra Club, and Guido, an Italian birder also accompanied the orientation tour.

April 2. Congresswoman Patsy Mink overflew the refuge in the company of Eugene Conrad, U.S. Forest Service. They were not accompanied by refuge staff.

April 10. Don Weathers and Bill Striplin of the Regional Office overflew Hakalau and landed at the cabin. Their primary interest was in inspecting the fence construction project.

April 15. Ron Nagata, Resource Management Specialist at Haleakala National Park and Mark Tobin, Department of Agriculture, viewed the new fence, met with the contractor (Dan Kershaw) and discussed Ron's fencing efforts at Haleakala. Ron had some good advice for Hakalau regarding fencing tips, techniques and planning.

May 4. Joel Kaplan, Office of Management and Budget; Virgil Frizzell, U.S. Geological Survey; Robert Smith, FWE and Jerry Leinecke toured the refuge by helicopter.

May 15. Colin Bassett, Hawaii Conservation Biology Initiative and his wife Anne viewed the rain shelter erected by the University of Hawaii and the U.H. research area. The need for a biological field station was discussed and potential on and off refuge sites for the station were viewed.

May 23. George Hao of Raymond A. Lesher and Co. helicoptered over the World Union Parcel and nearby properties as part of the information gathering process for the second appraisal of the World Union property.

June 4. Norm Berggren, Acting Chief of Surveys tested Global Positioning System equipment at Hakalau by attempting to find the lower corners of the Upper Maulua Parcel. Most of the time, the equipment was unable to receive transmissions from the required four satellites while under the forest canopy. In open pasture areas, however, four satellite signals were usually detected and the system worked fine.

June 5. Norm Berggren; Tamra Swerdlik, Contracting Officer; and Russ Figueroa and Marius Fischer, R.M. Towill Engineering Co., helicoptered over the Honohina Tract and other portions of the refuge as part of the planning for the Honohina boundary survey and fence construction to occur in 1992.

July 20. Deputy Director Richard Smith, Jim Jacobi and Jerry Leinecke helicoptered to the refuge for a general orientation, briefing, and discussion of management issues.

Nov. 13. Patrick Walsh, the U.S. Attorney who had been reassigned the World Union condemnation case and John Ford and Phyllis Ha helicoptered to Hakalau and then received a ground tour as part of their orientation and briefing to prepare for the condemnation trial.

Dec. 12. Margaret Cummisky, Legislative Assistant to Senator Daniel Inouye, and Jennifer Casey, Legislative Assistant to Representative Neil Abercrombie visited Hakalau to view the refuge and discuss management issues, strategies and funding needs.

Dec. 31. Congressman Pete Stark (California) and his wife helicoptered over the refuge (and around the island). Various problems concerning native animals, plants and habitats were discussed.

7. Other Interpretive Programs

On May 6 the Refuge Manager met with Hawaii County Mayor Lorraine Inouye and William Takaba, County Director of Finance to present the 1991 Revenue Sharing Check in the amount of $40,217 from the FWS and to brief her on objectives and activities at Hakalau. A Press Release was also distributed at this time which was subsequently published in the Hilo Tribune Herald. The Refuge Manager has met with four different mayors during the last four years for check deliveries and briefings.

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 1991:

For the third year in a row, a Special Use Permit (HAK-2-91) was issued to Jack Jeffrey to allow him to take 35mm photographs of birds, plants and Hakalau scenery for possible publication and sale. Jack has given the refuge some very nice photos.

Special Use Permit HAK-6-91 was issued to Neil Goodwin, Peace River Films, to film Jaan Lepson's research efforts near the Pua Akala meadow and to film birds and habitat as opportunities arise. Mr. Goodwin's film is commissioned by the Public Broadcast System and produced by NOVA. It will profile scientists working in and around Hawaiian forests and volcanoes.

Peter La Tourrette was issued a Special Use Permit (HAK-9-91) to take 35mm photographs of birds and scenery for possible publication and sale. He donated several slides to the refuge which resulted from his efforts.

On June 25, Ginney Staley, Hawaiian Electric Industries, interviewed and photographed the three Student Conservation Association volunteers for a publication she is doing. Hawaiian Electric is a corporate sponsor for the Student Conservation Association.

Each year refuge personnel spend some time "off-refuge" making presentations to conservation, student and special interest groups. Following is a summary of presentations made during 1991:

Dec. 4. Wildlife Biologist Jack Jeffrey presented a slide talk titled "Hawaii's Forest Treasures" at Hawaii Volcanoes National Park's "After Dark in the Park" series. Approximately 100 people were in attendance.

11. Wildlife Observation

A Special Use Permit (HAK-3-91) was issued to H. Douglas Pratt to allow him to conduct guided bird-observation tours at Hakalau Forest NWR. On March 12, he led a party of fourteen people on a four-hour visit to the Pua Akala Tract. Most were amateur naturalists but one was the noted ornithologist Dr. Kenneth Parkes of the Carnegie Museum of Natural History. Their visit was marred by bad weather. No endangered birds were seen but numerous 'Akepa were heard.

A Special Use Permit (HAK-5-91) was issued to Mark Collins, Hawaiian Sunrise Excursions to allow him to conduct forest bird observation tours in the Pua Akala Tract. He led a group of three birders to the refuge on May 7 and another group of three to the refuge on December 19. Both groups observed 'Akepa as well as the more common species.

On July 30, two groups of approximately 20 people each visited two areas of the refuge to view birds and habitat and to learn about management strategies. One group was led by Dr. Leonard Freed and the other by Refuge Manager Wass and Wildlife Biologist Jeffrey. Participants were in Hilo to attend a joint meeting of the American Society of Naturalists, the Society of Systematic Biologists and the Society for the Study of Evolution at the University of Hawaii's Hilo Campus.

17. Law Enforcement

Late in the year, Maintenance Worker Jon Emig attended Federal Law Enforcement Training School in Georgia. He graduated with honors at the head of his class. He will have responsibility for monitoring the public hunting program scheduled to begin in February 1992.

I. EQUIPMENT AND FACILITIES

1. New Construction

a. Hakalau Cabin Staff Quarters Addition

Hakalau Cabin is the on-site base of operations for the refuge. Built as a single room outpost in 1986, the cabin has been upgraded regularly to meet expanding usage demands. A bathroom, kitchen and extra bunkroom were added in 1989-90. A photovoltaic power system to provide electricity for lighting, communications and water pressure; and a propane system for heating, cooking and refrigeration, were also installed.

In response to increased use by volunteers and a larger staff, Hakalau Cabin was enlarged in 1991 by the addition of a 20 ft x 20 ft wing which increased the cabin living area to 832 sq ft. The addition provides four 8 ft x 9 ft rooms used as private sleeping areas for four to six employees or long term volunteers and brings the permanent bunking capacity of Hakalau Cabin to sixteen. The private staff quarters provides secure storage for personal items and is a boost to employee morale.

Construction of the new wing began in April and the staff and volunteers moved into their rooms in July. Built on a post-and-pier foundation, the double wall construction has plywood exterior, fiberglass insulation and decorative wood paneling interior. Vinyl floors, double pane

insulated windows and metal roof are other features of the new wing. The addition was built by refuge staff with assistance from Student Conservation Association Volunteers, for a total materials cost of $10,969.14.

b. Fence Construction

On January 22, the Kershaw Construction Company of Oakland California began work on the contract awarded them in August/September 1990 to provide materials and labor to construct approximately 55,000 feet of pig/cattle fence around the perimeter of the Shipman Parcel for a modified bid cost of $272,055. This fence completes the enclosure of the 4,994 acre Shipman Parcel, connecting with the shorter section previously completed along the boundary with Pua Akala Ranch and with the Middle Honohina Feral Ungulate Management Unit at the Parcel's north-east corner.

The contract called for a five-foot tall fence of heavy galvanized hogwire mesh with a strand of barbed wire six inches above the hogwire and another strand immediately below the hogwire within two inches of the ground. Galvanized steel T-type fence posts and pressure treated wood posts at the corners and other stress areas support the hogwire.

Special features of this fence are the use of steel anchors (short pieces of fence post) between the regular fence posts to hold the fence wire down so pigs cannot dig under; and the use of breakaway panels at stream crossings designed to break free in a flash flood leaving the main fence undamaged.

The fence route follows older fence lines for the most part. Approximately 32,700 feet along the south and north boundaries (the wettest area) were cleared with a bulldozer by the Sonomura Contracting Company in 1990.

Though hampered by wet weather and delivery delays, construction was completed on November 27, 1991. A total of 57,241 feet of fence (10.8 miles) was erected by the Kershaw Construction Company at a cost of $284,747 ($4.97/foot or $26,265/mile). Since the refuge was established, 90,741 feet (17.2 miles) of pig/cattle fence have been constructed at a total cost of $421,114 ($4.64/foot or $24,484/mile). Two feral ungulate management units (the 5,000 acre Shipman Unit and the 550 acre Middle Honohina Unit) have now been enclosed. Work will begin in 1992 on third unit (Lower Honohina Unit) which will encompass approximately 1,800 acres (Figure 7.)

c. Temporary Rain Shelter

Early in the year, a temporary wooden rain shelter was constructed by Dr. Leonard Freed and students within Pua Akala Meadow. The structure has three sides and measures 12 ft x 16 ft. It is used by students, researchers, camera crews, birders and other refuge visitors as a dry place to eat, work and store gear. Its construction enabled the elimination of plastic tarps and the food preparation/dining area previously situated at the edge of the meadow, but under the forest canopy. By May 26, sleeping tents previously situated in the same area were also moved into the meadow next to the rain shelter where there will be less potential for adverse impacts on birds and native plants.

2. Rehabilitation

a. Roads

Steve's Ag Services was contracted to provide maintenance and rehabilitation of roads at Hakalau with provision for extension of the

contract through 1992. The first increment of the contract allocated $15,000 and called for Steve to provide two crawler/dozers, a loader and an Athey wagon (a tracked wagon to haul gravel) with operators.

1) Pua Akala Road

Access to the Pua Akala Tract of the refuge crosses a 500 acre parcel owned by the W.H. Shipman Estate. The old road followed an extremely muddy and steep quarter-mile route that was impassable in rainy weather. Several short stretches of the same road within the refuge boundary, totaling another quarter mile were also difficult to pass in wet weather. Regular use of this entrance by researchers and refuge staff focused priority on its rehabilitation.

With concurrence from the Shipman Estate, a better route roughly following an existing pasture crossing was chosen to replace the old access road. Work began on January 24. Construction is graded gravel over road-bed prepared by clearing with dozer blade. In especially muddy or soft areas, Mirafi 600 brand road stabilization fabric was laid over the prepared ground to help hold the road gravel in place. About 400 feet of roadway was prepared with the fabric.

This is the Refuge's first experience with road fabric, so its performance will be monitored closely. As of the end of 1991, the stabilized areas seemed to be holding up well.

On April 8th, an allocation of $3,000 was added to this increment of the contract for completion of the Pua Akala Road work, repairs to the Middle Road gate area at its Pua Akala boundary and drainage work at Hakalau Cabin. A Bobcat loader was added to the contracted equipment in use. In spite of the usual wet weather and mechanical problems, work totaling about 120 machine hours was completed on April 14, at a total cost of $17,930.00

2) Honohina and Hakalau Tract Roads

The contract with Steve's Ag Service was renewed in FY92 and road work started in the Honohina Tract area on October 7.

Nauhi Road crosses the 1,000 acre parcel owned by the Liliuokalani Trust, enters the refuge at the upper gate to the Middle Honohina Feral Ungulate Management Unit, and then continues on down to Nauhi Camp. The buildings at Nauhi Camp will be refurbished for staff use during planned fencing of the lower Honohina Tract, so access for maintenance crews and later for fencing staff is critical.

Nauhi Road is over two miles long, often steep and slippery, with stretches of deep mud that are impossible to cross in wet weather. Only the worst areas were tackled on this effort, using construction similar to that used at Pua Akala area. About 400 feet of stabilization fabric was laid. The Honohina Cross Road was improved and the old road through the Alleyway to the eastern boundary of the Shipman Parcel was regraded. This route provides access for maintenance of the eastern boundary fence and will provide access to the lower Honohina fence to be constructed in 1992 or 1993. Other roads receiving Steve's attention were Pedro Road down to Pedro Paddock, the loop past the toe of Hakalau 4 below Triangle Paddock and back up to the cabin, and the cabin entrance road.

To conclude this increment of the contract, the driveway and parking area at Hakalau Cabin were resurfaced with gravel and graded to provide better drainage and gravel pads were laid for the planned horse shed and bulldozer shed. About 130 machine hours were expended by completion on December 10, at a cost of $18,058.35.

A tracked "Athey Wagon", towed by a tractor is used to haul gravel for road maintenance at Hakalau. DW

3. Major Maintenance

The refuge's 1989 Chevrolet diesel pick-up truck received service and repairs totaling $1,718.66 in 1991. Eight separate service appointments kept the truck out of service for 23 days. Maintenance and repair included new tires, charging system repair, new batteries and four front end repairs for loose parts and non-functioning four-wheel drive.

4. Equipment Utilization and Replacement

In order to keep up with needs of increased visitor and staff use, the photovoltaic charging capacity at Hakalau Cabin was increased 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. Plans call for an additional storage increase in 1992 based on the system's performance during periods of high use and Hakalau's frequent overcast weather.

On June 21, the 1985 Ford Bronco Sport Utility Vehicle (SUV) was returned to GSA after providing three years of dependable service to the refuge. Two new 1991 Chevrolet Blazer SUV's were received from the GSA Office to accommodate our growing staff and volunteer program. They were enhanced by offroad tires and a bumper winch on one of the vehicles. At the end of 1991, the Hakalau fleet included a 1989 Chevrolet diesel pickup, a 1990 Ford Bronco SUV and two 1991 Chevrolet Blazer SUV's. All are leased through GSA.

6. Computer Systems

During the summer, a second computer and printer were added to the Hakalau inventory. The new computer is an IBM compatible Everex Tempo 386/20 and the printer is a Panasonic KX-P4420 Laser. The new computer is used primarily by the Wildlife Biologist for word processing and data storage and analysis.

J. OTHER ITEMS

4. Credits

This narrative was written by Dick Wass, Refuge Manager, Jack Jeffrey, Wildlife Biologist and Jon Emig, Maintenance Worker. The photographs were taken by Jack Jeffrey (JJ) and Dick Wass (DW).