# NATURAL RESOURCES MANAGEMENT PLAN

AND ENVIRONMENTAL ASSESSMENT

## HAWAII VOLCANOES

## NATIONAL PARK
## HAWAII

REVISED JANUARY 1985

UNITED STATES DEPARTMENT OF THE INTERIOR / NATIONAL PARK SERVICE

# NATURAL RESOURCES MANAGEMENT PLAN
# AND ENVIRONMENTAL ASSESSMENT
# REVISED JANUARY, 1985

Hawaii Volcanoes National Park

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# INTRODUCTION

Important changes in the January, 1985 update of the Resources Management Plan include a major revision of format and expansion of projects. The format now conforms with that of most other resources management plans in the National Park Service (NPS). It is a loose-leaf format in which individual projects are explained in detail, including the nature of the problem, alternative solutions and their impacts, and cost and staffing requirements to accomplish the task. In the body of the plan, project statements are arranged by logical groupings. Groups of statements are preceded by overviews. At the outset, project statements are summarized on a spread sheet which indicates priority, source of funding, and cost distribution over a five-year period beginning with Fiscal Year (FY) 1985. Project statements are identified according to research, monitoring, or management mode, and throughout the text the interdependence of research and resources management is indicated.

The Resources Management Plan (RMP) is a critical link between overall Park objectives, as expressed in the Park Master Plan and Statement for Management, and resources management and research activities. These activities are detailed in the Resources Management Plan and in other closely related documents such as cave, fire, and backcountry management plans. All of these plans identify natural resource problems, articulate management objectives, and recommend solutions. They are the primary points of reference for research activity, management action, and long range planning.

The main objective of any Park resources management and research program is to protect native ecosystems and the ecological processes which support them. In Hawaii Volcanoes National Park, introductions and spread of non-native animals and plants since the arrival of human colonizers have disrupted native ecological processes and severely degraded native plant and animal communities. This process began with the arrival of Polynesians in 500-800 A.D., but has accellerated with the arrival of Europeans since the late eighteenth century. The suppression and/or removal of the most disruptive plant and animal introductions is the primary resources management objective.

Feral goat (Capra hircus) control, carried out systematically since 1971, has been the most noteworthy success of the program, and is considered to be in its final stages. Fencing and removal of goats in areas above 6,700 feet elevation is the last major project to be undertaken. This project is expected to receive funding in FY-1985 or 1986. Long-term fence inspection,

cyclic fence maintenance, and periodic replacement of goat-proof boundary fences is an inherent and critical part of the goat control program.

Feral pig (Sus scrofa) research and management has begun in selected areas following the receipt of special funds during the FY-83 through 85 period. Although approximately 1500 acres have been cleared of pigs (Thurston Lava Tube to Bird Park) and another 3700 acres are nearly cleared (Kipukas Ki and Puaulu and the Puhimau control unit), the program is still experimental. A major pig control research program, closely allied to management, is underway.

Exotic plant control presents a complex problem which stems from overwhelming numbers of exotic species (approximately 400), vulnerability of native ecosystems to exotic invasion, lack of ecological knowledge about, and lack of specific control methods for, exotic species, and inadequate funding for research and management. This and previous RMP updates have attempted to identify species which are the most destructive and controllable. This update continues the previous focus on identifying, prioritizing, and controlling localized species, and provides more details and justification for assigning species to certain categories. Biological control efforts have received more funds, as manifest in a newly constructed insect quarantine facility and a functioning inter-agency team to identify, study, and evaluate potential insect releases in Park and State lands.

The nene or Hawaiian goose (Nesochen sandvicensis) restoration program has received substantial rejuvenation in 1983-84 as a result of inter-agency cooperation between Hawaii Volcanoes and Hawaii State Department of Land and Natural Resources (DLNR). Consequently the Park program now commits more time and effort than in years past in release pen and captive flock maintenance and in wild bird observation and long-term monitoring. New NPS funds for nene research have not been released, so NPS managers look toward State, U.S. Fish and Wildlife Service (USFWS), and previous NPS research for guidance in management and monitoring activities.

Re-introduction of native species is presently receiving less emphasis than in previous RMP updates. The native plant nursery and out-planting program has undergone file update and summary work, but propagation and out-planting activities have not been undertaken during the past two years. Future work in this program will be based on scientific research, and normally will be targeted for unnaturally rare species which need manipulation in order to survive. Out-plantings will be considered for selected lowland recovery sites where research indicates need, method, and reasonable chance for success.

Native plant management activities will consist mostly of inventory and long-term monitoring, with special emphasis on remnant and intact communities of native plants and on rare, threatened, and endangered species. Special emphasis efforts will include intensive control of alien plants and feral animals within these communities. Kipuka Puaulu and a portion of Ola'a Tract rainforest are likely to be the initial areas for such efforts.

The 1984 Resources Management Plan Update received the benefit of considerable criticism and advice from public, agency, and internal reviewers. The Park owes a large debt of gratitude to these astute and generous people for their keen interest and insistence on high standards by the managers of their park.

It was determined through public and NPS review of the 1973 Natural Resources Management Plan and Environmental Assessment and subsequent revisions in 1978 and 1982 that the proposed actions would not have significant environmental effects or adversely affect cultural resources. Since the projects described in this Revision fall within the purview of impacts of the 1973 Plan and Assessment and Section 106 clearance, no further documentation of impacts is necessary prior to implementation of projects.

Dan Taylor
Chief, Division of Resources Management
April 11, 1985

Approval:

David G. Adams — April 17, 1985
Superintendent, Hawaii Volcanoes — date

Boyd Harris — 4/25/85
Pacific Area Director — date

Howard L. Chapman — 6-10-85
Regional Director, Western Region — date

| Project Number | Project Title | Project Type | Priorities: RMP | Priorities: Park | 10-237 Number | 10-238 Number | Five Year Program Costs (in $1000) and Fund Sources FY85 Funded/New | FY86 Funded/New | FY87 Funded/New | FY88 Funded/New | FY89 Funded/New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Maintain Control of Feral Goats | Mit | | | | | 20 (PBO)<br>00 | 20 (PBO)<br>00 | 20 (PBO)<br>00 | 20 (PBO)<br>00 | 20 (PBO)<br>00 |
| 58 | Control Localized Exotic Plants | Mit | | | | | 30 (PBO)<br>00 | 30 (PBO)<br>00 | 30 (PBO)<br>00 | 30 (PBO)<br>00 | 30 (PBO)<br>00 |
| 5 | Conduct Feral Pig Control Research | Res | | | | | 35 (NRP)<br>00 | 100 (NRP)<br>00 | 100 (NRP)<br>00 | 00<br>00 | 00<br>00 |
| 33 | Monitor Wild Nene Population | Mon | | | | | 25 (PBO)<br>00 | 25 (PBO)<br>00 | 25 (PBO)<br>00 | 25 (PBO)<br>00 | 25 (PBO)<br>00 |
| 62 | Remove Misplaced Native Plantings | Mit | | | | | 7.5 (PBO)<br>00 | 7.5 (PBO)<br>00 | 7.5 (PBO)<br>00 | 00<br>00 | 00<br>00 |
| 17 | Study Status of Pathogens on Native Plants | Res | | | | | 15 (RNR)<br>00 | 15 (RNR)<br>00 | 15 (RNR)<br>00 | 15 (RNR)<br>00 | 15 (RNR)<br>00 |
| 68 | Implement Photo-Point Monitoring System | Mon | | | | | 00<br>00 | 10 (PBO)<br>00 | 10 (PBO)<br>00 | 10 (PBO)<br>00 | 10 (PBO)<br>00 |
| 8 | Remove Deteriorating Fences From the Backcountry | Mit | | | | | 00<br>00 | 00<br>00 | 5 (PBO)<br>00 | 00<br>00 | 00<br>00 |
| 22 | Control Trespass Cattle | Mit | | | | | 2.5 (PBO)<br>00 | 2.5 (PBO)<br>00 | 2.5 (PBO)<br>00 | 2.5 (PBO)<br>00 | 2.5 (PBO)<br>00 |
| 72 | Build Goat and Pig Fences | Mit | 1 | 1 | | 83-179 | 00<br>00 | 00<br>390.1 (NRP) | 00<br>800 (NRP) | 00<br>800 (NRP) | 00<br>00 |

Funding source: PBO - Park Base Operating; PBI - Park Base Increase; SAQ - Service-wide Air Quality; NRP - Service-wide Natural Resources Preservation Program; RNR - Region-wide Natural Resources Base; CYC - Region-wide Cyclic Maintenance Program

| Project Number | Project Title | Project Type | Priorities: RMP | Priorities: Park | 10-237 Number | 10-238 Number | Five Year Program Costs (in $1000) and Fund Sources: FY85 Funded/New | FY86 Funded/New | FY87 Funded/New | FY88 Funded/New | FY89 Funded/New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Maintain Goat and Pig Fences | Mit | 2 | | | 85-239 | 40 (PBO)<br>00 | 00<br>40 (CYC) | 00<br>40 (CYC) | 00<br>40 (CYC) | 00<br>40 (CYC) |
| 26 | Eliminate Feral Goats in High Elevation Areas | Mit | 3 | 1.1 | | 84-250 | 00<br>00 | 00<br>00 | 00<br>20 (RNR) | 00<br>00 | 00<br>00 |
| 35 | Extend Pig Control to Additional Areas | Mit | 4 | 1 | 84-121 | | 165 (NRP)<br>00 | 00<br>226 (PBI) | 226 (PBI)<br>00 | 226 (PBI)<br>00 | 226 (PBI)<br>00 |
| 3 | Control Fountain Grass | Mit | 5 | 5 | 84-158 | | 42 (PBO)<br>38 (NRP) | 00<br>125 (PBI) | 125 (PBI)<br>00 | 100 (PBI)<br>00 | 90 (PBI)<br>00 |
| 34 | Maintain Captive Breeding Nene Flock | Mit | 6 | .9 | 83-051 | | 40 (PBO)<br>00 | 00<br>45 (PBI) | 45 (PBI)<br>00 | 45 (PBI)<br>00 | 45 (PBI)<br>00 |
| 42 | Maintain Control of Exotic Plants | Mit | 7 | | 84-170 | | 42 (PBO)<br>20 (NRP) | 42 (PBO)<br>58 (PBI) | 100 (PBI)<br>00 | 100 (PBI)<br>00 | 100 (PBI)<br>00 |
| 12 | Study Small Mammal Control | Res | 8 | 24 | | 84-226 | 00<br>00 | 00<br>45 (NRP) | 00<br>45 (NRP) | 00<br>45 (NRP) | 00<br>00 |
| 20 | Study Ecological Role of Fire | Res | 9 | 7 | | 84-215 | 00<br>00 | 00<br>50 (RNR) | 00<br>50 (RNR) | 00<br>50 (RNR) | 00<br>00 |
| 23 | Delineate and Study Special Ecological Areas | Res | 10 | | | 84-225 | 00<br>00 | 00<br>40 (NRP) | 00<br>40 (NRP) | 00<br>40 (NRP) | 00<br>00 |
| 60 | Manage Special Ecological Areas | Mit | 11 | | 84-177 | | 20 (PBO)<br>00 | 20 (PBO)<br>20 (PBI) | 40 (PBI)<br>00 | 100 (PBI)<br>00 | 100 (PBI)<br>00 |

Funding source: PBO - Park Base Operating; PBI - Park Base Increase; SAQ - Service-wide Air Quality; NRP - Service-wide Natural Resources Preservation Program; RNR - Region-wide Natural Resources Base; CYC - Region-wide Cyclic Maintenance Program

Hawaii Volcanoes National Park

Natural Resources Projects
Programming Sheet

March, 1985

| Project Number | Project Title | Project Type | Priorities: RMP | Priorities: Park | 10-237 Number | 10-238 Number | Five Year Program Costs (in $1000) and Fund Sources FY85 Funded/New | FY86 Funded/New | FY87 Funded/New | FY88 Funded/New | FY89 Funded/New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | Study Exotic Plant Control Treatment Methods | Res | 12 | | | 84-227 | 25 (NRP)<br>00 | 00<br>50 (RNR) | 00<br>50 (RNR) | 00<br>50 (RNR) | 00<br>50 (RNR) |
| 18 | Study Nene Habitat | Res | 13 | 13 | | 84-224 | 00<br>00 | 00<br>40 (NRP) | 00<br>40 (NRP) | 00<br>40 (NRP) | 00<br>00 |
| 2 | Map and Monitor Exotic Plants | Mon | 14 | 18 | 84-166 | | 20 (NRP)<br>00 | 00<br>30 (PBI) | 30 (PBI)<br>00 | 30 (PBI)<br>00 | 30 (PBI)<br>00 |
| 1 | Study Biocontrol of Selected Exotic Plant Species | Res | 15 | | | | 34 (RNR)<br>00 | 34 (RNR)<br>10 (RNR) | 45 (RNR)<br>00 | 45 (RNR)<br>00 | 45 (RNR)<br>00 |
| 57 | Control Kahili Ginger | Mit | 16 | | 84-172 | | 00<br>00 | 00<br>75 (PBI) | 50 (PBI)<br>00 | 30 (PBI)<br>00 | 30 (PBI)<br>00 |
| 53 | Control Kikuyu Grass | Mit | 17 | | 84-173 | | 4 (NRP)<br>00 | 00<br>25 (PBI) | 15 (PBI)<br>00 | 15 (PBI)<br>00 | 10 (PBI)<br>00 |
| 11 | Monitor Air Quality to Establish Baseline | Mon | 18 | | | 84-217 | 6 (PBO)<br>00 | 00<br>50 (SAQ) | 00<br>26.3 (SAQ) | 00<br>26.3 (SAQ) | 00<br>00 |
| 52 | Control Nasturtium | Mit | 19 | | 84-174 | | 5 (NRP)<br>00 | 00<br>15 (PBI) | 10 (PBI)<br>00 | 7.5 (PBI)<br>00 | 7.5 (PBI)<br>00 |
| 54 | Control Olive | Mit | 20 | | 84-175 | | 00<br>00 | 00<br>00 | 00<br>50 (PBI) | 25 (PBI)<br>00 | 10 (PBI)<br>00 |
| 51 | Control Koa Haole | Mit | 21 | | 84-176 | | 00<br>00 | 00<br>00 | 00<br>75 (PBI) | 50 (PBI)<br>00 | 35 (PBI)<br>00 |

| Project Number | Project Title | Project Type | Priorities: RMP | Priorities: Park | 10-237 Number | 10-238 Number | Five Year Program Costs (in $1000) and Fund Sources FY85 Funded/New | FY86 Funded/New | FY87 Funded/New | FY88 Funded/New | FY89 Funded/New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | Control Rubus glaucus | Mit | 22 | | 84-178 | | 00 / 00 | 00 / 00 | 00 / 15 (PBI) | 8 (PBI) / 0 | 5 (PBI) / 00 |
| 41 | Map and Inventory Lava Tube Caves | Res | 23 | 23 | | 84-216 | 00 / 00 | 00 / 00 | 00 / 30 (NRP) | 00 / 30 (NRP) | 00 / 30 (NRP) |
| 13 | Eliminate Remnant Pigs | Mit | 24 | | 84-171 | | 45 (NRP) / 00 | 00 / 00 | 00 / 00 | 00 / 83 (PBI) | 83 (PBI) / 00 |
| 70 | Study Control Methods for Yellow-Jacket Wasps | Res | 25 | | | 84-240 | 00 / 00 | 00 / 40 (NRP) | 00 / 40 (NRP) | 00 / 00 | 00 / 00 |
| 71 | Control Yellow Jacket-Wasps in Localized Areas | Mit | 26 | | 84-179 | | 1 (PBO) / 00 | 1 (PBO) / 4 (PBI) | 5 (PBI) / 00 | 5 (PBI) / 00 | 5 (PBI) / 00 |
| 59 | Manage Endangered, Threatened, and Rare Plant Species | Mit | 27 | | 84-180 | | 1 (PBO) / 00 | 1 (PBO) / 00 | 1 (PBO) / 40 (PBI) | 40 (PBI) / 00 | 40 (PBI) / 00 |
| 27 | Study Exotic Plant Ecology | Res | 28 | | | 84-241 | 00 / 00 | 00 / 40 (NRP) | 00 / 40 (NRP) | 00 / 40 (NRP) | 00 / 00 |
| 16 | Study Status of Endangered, Threatened, and Rare Plants | Res | 29 | | | 84-242 | 00 / 00 | 00 / 30 (NRP) | 00 / 30 (NRP) | 00 / 30 (NRP) | 00 / 00 |
| 55 | Control Silky Oak | Mit | 30 | | 84-181 | | 00 / 00 | 00 / 00 | 00 / 15 (PBI) | 7.5 (PBI) / 00 | 2.5 (PBI) / 00 |
| 56 | Control Christmasberry | Mit | 31 | | 84-182 | | 00 / 00 | 00 / 00 | 00 / 20 (PBI) | 15 (PBI) / 00 | 10 (PBI) / 00 |

Funding source: PBO - Park Base Operating; PBI - Park Base Increase; SAQ - Service-wide Air Quality; NRP - Service-wide Natural Resources Preservation Program; RNR - Region-wide Natural Resources Base; CYC - Region-wide Cyclic Maintenance Program

Hawaii Volcanoes National Park

Natural Resources Projects
Programming Sheet

March, 1985

| Project Number | Project Title | Project Type | Priorities: RMP | Priorities: Park | 10-237 Number | 10-238 Number | Five Year Program Costs (in $1000) and Fund Sources FY85 Funded/New | FY86 Funded/New | FY87 Funded/New | FY88 Funded/New | FY89 Funded/New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | Update Plant Checklist | Res | 32 | | | 84- | 00<br>00 | 00<br>00 | 00<br>50 (NRP) | 00<br>50 (NRP) | 00<br>50 (NRP) |
| 44 | Study Ecosystem Restoration | Res | 33 | | | 84-243 | 00<br>00 | 00<br>10 (NRP) | 00<br>5 (NRP) | 00<br>5 (NRP) | 00<br>00 |
| 50 | Study Native Bird Reintroduction | Res | 34 | | | 84-244 | 00<br>00 | 00<br>00 | 00<br>40 (NRP) | 00<br>40 (NRP) | 00<br>40 (NRP) |
| 49 | Study Invertebrates | Res | 35 | | | 84-245 | 00<br>00 | 00<br>00 | 00<br>50 (NRP) | 00<br>50 (NRP) | 00<br>50 (NRP) |
| 25 | Study Control of Non-Native Birds | Res | 36 | | 84-246 | 00 | 00<br>00 | 00<br>00 | 00<br>40 (NRP) | 00<br>40 (NRP) | 40 (NRP) |
| 43 | Survey and Fence Eastern Park Boundary | Mit | 37 | | | | 00<br>00 | 00<br>40* | 00<br>00 | 00<br>00 | 00<br>00 |
| 69 | Study ADP Information Management | Res | 38 | | | 84-247 | 00<br>00 | 00<br>2 (RNR) | 00<br>2 (RNR) | 00<br>00 | 00<br>00 |
| 46 | Prepare Water Resources Management | Mit | 39 | | | 84-834 | 00<br>00 | 00<br>5 (RNR) | 00<br>00 | 00<br>00 | 00<br>00 |
| 24 | Study Recovery of Vegetation Following Removal of Feral Animals | Mon | 40 | | | | 00<br>00 | 00<br>00 | 00<br>20 (PBI) | 20 (PBI)<br>00 | 20 (PBI)<br>00 |

* Soecial Law and Order Project (Western Region)

| Project Number | Project Title | Project Type | Priorities: RMP | Park | 10-237 Number | 10-238 Number | Five Year Program Costs (in $1000) and Fund Sources FY85 Funded/New | FY86 Funded/New | FY87 Funded/New | FY88 Funded/New | FY89 Funded/New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | Study Causes of Reproductive Failure of Endangered, Threatened, and Rare Plant Species | Res | 41 | | | | 00 / 00 | 00 / 00 | 00 / 25 (NRP) | 00 / 25 (NRP) | 00 / 25 (NRP) |
| 63 | Study Native Animal Management Needs | Mon | 42 | | | | 00 / 00 | 00 / 00 | 00 / 30 (NRP) | 00 / 30 (NRP) | 00 / 30 (NRP) |

Funding source: PBO - Park Base Operating; PBI - Park Base Increase; SAQ - Service-wide Air Quality; NRP - Service-wide Natural Resources Preservation Program; RNR - Region-wide Natural Resources Base; CYC - Region-wice Cyclic Maintenance Program

## VEGETATION MANAGEMENT OVERVIEW

The 27 project statements that follow comprise a compendium of vegetation research and management projects proposed for the next five year period (1985-89). They contain a strategy to control disruptive non-native plants, study and protect key ecological areas, recover reduced rare plant populations, and restore lowland ecosystems. The total cost for the proposed vegetation management program over this time frame is $2,665,000 and would require 35 FTE, approximately 30 times the current funding and 10 times current staffing levels. The purposes of this overview are to express priorities, outline the vegetation management strategy contained in the project statements in the context of current insufficient budget and personnel ceilings, and relate projects to each other and to Park vegetation management objectives.

### EXOTIC PLANT MANAGEMENT

Exotic plants pose an immediate and serious threat to native Hawaiian ecosystems. Approximately 50 of the 400-odd exotic species in the Park are especially aggressive and persistent, displacing native species, dominating native plant communities, and disrupting native ecosystem processes. The magnitude of the problem exceeds the capability of current staffing and funding to solve completely; consequently, an approach that prioritizes control areas and target species has been developed. Higher priority is given to controlling disruptive non-native plant species in ecosystems which are relatively intact and biologically significant and also to suppressing potentially disruptive species which are still localized and controllable. Lower priority is given to controlling exotic species in ecosystems which are disturbed and/or exotic dominated and to suppressing widespread exotics on a Park-wide basis at considerable expense of funds and manpower.

Current funding and staffing permit control actions on approximately 30-40 highly localized species, two or three widely spread species, and control of all exotic plant threats in one to several intact plant communities designated as Special Ecological Areas. Work is urgently needed to control an additional six highly disruptive and rapidly spreading species which are relatively widespread but still localized enough to contain; these target species will require special funding and staffing (HAVO-3, HAVO-51 through 57).

Certain exotic species are targeted for biological control because they are beyond control by mechanical or herbicial methods. Research on these problems is underway. The biological control program is discussed in more detail in HAVO-1.

Preserving examples of native Hawaiian ecosystems in the Park is feasible, at least for representative portions of larger ecosystems, if intensive, corrective management is applied to mitigate sources of disturbance and check the spread of exotic plants in the Park. However, threats from outside the Park continue and additional educational efforts are needed. The application of integrated pest management principles to exotic plant management is a new approach at Hawaii Volcanoes. It has achieved some measure of success recently in controlling highly localized exotics, developing an information base necessary for successful control of the more widespread species, defining the process necessary for successful control efforts, and in establishing the monitoring systems to indicate if control is needed, feasible, or effective.

Target Exotic Species and Program Priorities

The approximately 50 introduced plant species targeted for control efforts can be grouped into six categories based on the magnitude of the threat they pose, the workload required to achieve containment, and the control strategy to be followed.

Category I (Highly Localized, Potentially Disruptive Species)

These species are potentially disruptive but localized enough for herbicidal or mechanical treatment methods with a modest manpower requirement and consistent follow-up. Some of these species have proven to be aggressive and displace native species in other localities in the State or in the Park; others are suspect because of their life form, e.g., vines, or taxonomic affinities e.g., members of the Melastomataceae. These species are not prioritized within the category because all have or can be treated with a moderate expenditure of manpower and funds. Most are now suppressed and require follow-up treatments of sprouts or seedlings. Some Category I species may be reclassified as Category II plants following completion of distribution mapping if they are found to be extensive. As new localized populations of suspect disruptive exotic plants are

discovered in the Park through reconnaissance work or incidental to other assignments, they are added to the list of Category I plants. Initial and maintenance treatments of these species are described in HAVO-58. Monitoring and surveillance are outlined in HAVO-2.

| Target Species | Mapping/Monitoring | Control Actio |
|---|---|---|
| Tropical ash (Fraxinus uhdei) | completed 6/84 | in progress |
| White ash (Fraxinus americana) | completed 6/84 | in progress |
| Squash (Benicasa hispida) | completed 6/83 | in progress |
| Wire vine (Muhlenbeckia axillaris) | completed 3/83 | in progress |
| New Zealand flax (Phormium tenax) | completed 3/83 | in progress |
| Castor bean (Ricinus communis) | completed 10/84 | in progress |
| Black wattle (Acacia decurrens) | completed 6/84 | in progress |
| Kudzu (Pueraria lobata) | completed 5/84 | in progress |
| Lupine (Lupinus sp.) | completed 6/82 | in progress |
| Paperbark (Melaleuca leucadendra) | completed 6/84 | in progress |
| Kiawe (Prosopis pallida) | completed 10/84 | in progress |
| Cactus (Opuntia megacantha) | completed 10/84 | in progress |
| Formosan koa (Acacia confusa) | completed 6/64 | in progress |
| Melochia (Melochia umbellata) | completed 5/83 | in progress |
| Trema (Trema orientalis) | completed 6/83 | in progress |
| Loquat (Eriobotrya japonica) | completed 6/84 | in progress |
| Eucalyptus (Eucalyptus sp.) | completed 6/84 | in progress |
| Ironwood (Casuarina equisetifolia) | completed 6/84 | in progress |
| Pine (Pinus sp.) | completed 6/84 | in progress |
| Maile pilau (Paederia foetida) | completed 3/85 | in progress |

| Target Species | Mapping/Monitoring | Control Actions |
|---|---|---|
| Pineapple guava (*Feijoya sellowiana*) | in progress | in progress |
| Pearl flower (*Heterocentron subtriplinervum*) | completed 10/84 | not started |
| Arthrostemma (*Arthrostemma latifolia*) | in progress | in progress |
| Tibouchina (*Tibouchina urvilleana*) | completed 10/84 | not started |
| Eleagnus (*Eleagnus* sp.) | completed 10/84 | in progress |
| Pittosporum (*Pittosporum undulatum*) | in progress | in progress |
| Bamboo (*Phyllostachys* sp.) | completed 5/83 | in progress |
| Sisal (*Agave sisalana*) | in progress | in progress |
| Century plant (*Agave americana*) | in progress | in progress |
| Koa* (*Acacia koa*) | in progress | in progress |
| Haleakala silversword* (*Argyroxiphium sandwicense* var. *macrocephalum*) | in progress | in progress |

*misplaced native plantings

Category II (Established, disruptive species)

These species are well established, somewhat localized and known to be highly disruptive and aggressive. Because they are more widespread than Category I species, they require considerable expenditures of manpower and highly effective treatment methods that maximize control efficiency. Only two or three species can be controlled at current levels of funding and staffing. These target species are ranked by their potential degree of disruptiveness to native plant communities. Therefore, target species disruptive only in the (mostly exotic) lowlands, such as koa haole and silky oak, are prioritized for treatment after species such as Kahili ginger which threatens more intact plant communities. Fountain grass is given top priority even though it is mainly a lowland species because of its potential to spread into many higher elevation, predominantly native plant communities. Because of the heavy workload requirement for controlling Category II

species, separate project statements have been written for the initial treatment of most species, (HAVO-3, HAVO-51 through HAVO-57). Follow-up maintenance treatments for all species are subsumed under one project (HAVO-42). All mapping and monitoring are described in HAVO-2 Category II species will be controlled, for the most part, on a Park-wi basis. Control efforts may be deferred or not taken in irreversibly disrupted areas.

| | Target Species | Mapping/Monitoring | Control Action |
|---|---|---|---|
| 1. | Fountain grass (*Pennisetum setaceum*) | completed 2/85 | in progress |
| 2. | Kahili ginger (*Hedychium gardnerianum*) | completed 11/84 | not started |
| 3. | Kikuyu grass (*Pennisetum clandestinum*) | in progress | in progress part of ran |
| 4. | Nasturtium (*Tropaeolum* sp.) | completed 6/83 | in progress |
| 5. | Koa haole (*Leucaena leucocephala*) | completed 11/84 | suspended |
| 6. | Raspberry (*Rubus glaucus*) | completed 10/83 | not started |
| 7. | Olive (*Linociera ligustrina*) | completed 11/84 | not started |
| 8. | Silky oak (*Grevillia robusta*, *G. banksii*) | in progress | in progress Ainahou |
| 9. | Christmasberry (*Schinus terebinthifolius*) | in progress | not started |

Category III. (Candidate species for biological control)

These species are targeted for biocontrol research and subsequent biological control methods if effective and suitable biocontrol agents can be found. These species are too widespread for conventional control measures.

| Target Species | Mapping/Monitoring | Control Actio (conventiona |
|---|---|---|
| Banana poka (*Passiflora mollissima*) | completed | planned for Spe Ecological Area |

| Target Species | Mapping/Monitoring | Control Actions |
|---|---|---|
| Fire tree (*Myrica faya*) | in progress | controlled in 300 acre block north of USGS Observatory[1] planned for Special Ecological Areas |
| Blackberry (*Rubus penetrans*) | not started | planned for Special Ecological Areas |
| Yellow Raspberry (*R. ellipticus*) | not started | planned for Special Ecological Areas |
| Raspberry (*R. glaucus*) | completed | planned if necessary |

Category IV. (Candidate species for localized control in Special Ecological Areas)

These species are too widespread to be controlled Park-wide. Because they are highly disruptive, they must be controlled locally in selected biologically important areas, Special Ecological Areas, to be designated (HAVO-23, HAVO-60). Funds have been requested for both the delineation and management of these areas. In the meantime funds will be provided from base monies and other funded projects. Some Category IV species are targeted for biocontrol research but will be controlled by conventional means until biological controls are available.

| Target Species | Mapping/Monitoring | Control Actions |
|---|---|---|
| Strawberry guava (*Psidium cattleianum*) | in progress | planned for special Ecological Areas |
| Banana poka (*Passiflora mollissima*) | completed | planned for Special Ecological Areas |
| Fire tree (*Myrica faya*) | in progress | see comments above |
| Molasses grass (*Melinis minutiflora*) | not started | planned for Special Ecological Areas |

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| Target Species | Mapping/Monitoring | Control Actio |
|---|---|---|
| Broomsedge/Bush Beardgrass (Andropogon virginicus, A. glomeratus) | not started | planned for Spec Ecological Areas |
| Blackberry (Rubus penetrans) | not started | planned for Spec Ecological Areas |
| Yellow raspberry (Rubus ellipticus) | not started | planned for Spec Ecological Areas |
| Palm grass (Setaria palmaefolia) | not started | planned for Spec Ecological Areas |
| Paspalum (Paspalum dilatatum, P. urvillei) | not started | planned for Spec Ecological Areas |
| Common guava (Psidium guajava) | not started | planned for Spec Ecological Areas |

Category V. (Species to be monitored)

The distribution and rates of spread of these species are to be monitored to establish a required management status (HAVO-2).

| Target Species | Mapping/Monitoring | Control Actio |
|---|---|---|
| Fuchsia (Fuchsia magellanica) | completed 11/84 | N/A |
| Black-eyed Susan (Abrus precatorius) | not started | N/A |
| Elephant grass (Pennisetum purpureum) | in progress | N/A |
| Chinese anemone (Anemone hupehensis) | not started | N/A |
| Jerusalem cherry (Solanum pseudocapsicum) | not started | N/A |

Category VI (Species to be reconnointered)

These disruptive species are known to occur in the Islands but are not yet found in the Park. A formal scouting and reconnaissance program will be conducted along trails and roads and selected disturbed sites to

detect these species and any other potential weed problems in the Park. Efforts will be made to encourage the State to control these plants outside the Park (HAVO-2).

Clidemia (Clidemia hirta)
Rose apple (Eugenia jambos)
Velvet tree (Miconia bicolor)
Hilo holly (Ardisia crispa)
German Ivy (Senecio mikanioides)

Base funding levels can support control of all Category I plants (HAVO-58) at apparent invasion rates and minimal support of biocontrol, monitoring, and limited maintenance programs on treatment of fire tree and Kikuyu grass. At current levels of funding (base and special Natural Resource Problem funds), the following control programs are being carried out: treatment of Category I plants and three plants from Category II (fountain grass, nasturtium, and selected areas of Kikuyu grass); mapping and monitoring of all target species (HAVO-2); treatment methods research for Category II and some Category I species (HAVO-28); and, biocontrol research (Categrory III species) (HAVO-1). Reductions in current levels may require changes in the number and kinds of exotic species treated because of reduced capability of providing the necessary follow-up levels of treatments.

Current funding levels allow control of highly localized exotics but not of the most disruptive species in the Park: disruptive but still somewhat localized (Category II target species) such as Kahili ginger, koa haole, olive, Christmasberry, silky oak, and destructive and widespread species such as strawberry guava, fire tree, banana poka, molasses grass, and broomsedge. These funding limitations result in a management paradox in which localized exotics can be prevented from spreading but more widely spread species may overwhelm native communities and negate the effects of controlling the former. For example, a highly localized species such as loquat may be contained but olive, fire tree, and others may ultimately swamp native communities in seasonal submontane forest in which these plants grow. Similarly, the rainforest in Puhimau may be liberated of the threat of pearl flower but overwhelmed by palm grass or banana poka.

In order to deal with threats from widespread exotics not currently controllable on a Park-wide basis, these species will be controlled in key biological units of the Park or Special Ecological Areas (HAVO-60). In these areas, all

exotic plant threats (as well as exotic animal threats) can be addressed and Category I, II, III, and IV target exotic plant species will be controlled. These intensive management/research units will not only preserve the best assemblages of native organisms, but also serve as learning laboratories for successful management for larger areas of the same ecosystem and integrate exotic animal and plant control programs. Although Special Ecological Areas have not been designated, funding has been requested for delineating, researching, and monitoring (HAVO-23) as well as managing these areas (HAVO-60). Preliminary work on a limited number of areas is planned in FY-85. Management plans for each intensive management unit will be circulated among the research and conservation community for review and comment prior to management; once delineated, each area will be described in a separate project statement requesting additional funding for management and research needs.

Control of localized exotic plant species is not to be abandoned in emphasizing intact biological units and Special Ecological Areas. All Category I (localized exotic species) are to be controlled on a Park-wide basis to prevent the spread of additional exotics into the system (HAVO-58); Park roads and trails will continue to be inspected to locate (HAVO-2) and treat new introductions (Category VI species) (HAVO-58). Category II species that threaten mostly native ecosytems, such as Kahili ginger, fountain grass, Kikuyu grass, nasturtium, the Kalapana populations of koa haole, and Kikuyu grass, will be given higher priority than species which threaten semi-native or mostly exotic plant communities. Similarly, control of widespread, disruptive exotics (Category IV species) in significant native biotic communities (Special Ecological Areas) to be designated will be ranked above control of Category II species in mostly exotic ecosystems. Logistical considerations such as the availability of a treatment method, the proximity of a target species to another species currently being treated, or the workload requirement can modify this ranking system.

The prioritization of action on target exotic species at current funding levels can be summarized by species category as follows:

High Priority (pursued simultaneously)

Category I species (localized exotics): treat all species listed. Initial and maintenance species described in HAVO-58.

Category II species (established, disruptive exotics): treat as many species as funding allows, with highest priority given to those species impacting intact ecosystems; target Category II exotics found in lowland ecosystems are not being written off, but prioritized after control of threats to intact areas and key ecological units. Complete mapping, monitoring, and treatment method research for all listed species in order to develop an information base necessary for a successful control program. Initial treatment described in HAVO-3 and HAVO-51 through 57. Maintenance treatments for all Category II species are combined in one project (HAVO-42). The more labor intensive intitial treatments which reduce populations back to seedling stages are outlined in separate project statements in order to qualify these projects for special short-term funds. An increase in base funding is being requested for maintenance treatments.

Category III species (biocontrol candidates): conduct research.

Category IV species (candidates for localized control): confine control of widely spread exotics to significant biotic communities (Special Ecological Areas) to be designated. At current levels of funding work can commence in one to several areas. Localized control of widespread exotic species is described in HAVO-60.

Category V species (candidates for monitoring): determine distribution, rate of spread, and other basic data. Mapping and monitoring of exotic plants is described in HAVO-2.

Category VI species (candidates for reconnaissance): survey roads and trails for new introductions (HAVO-2).

Low Priority

Category II species (established, disruptive exotics): defer treatments on those highly labor intensive lowland species impacting mostly exotic ecosystems in Park. At most, conduct treatments at levels necessary until additional funds can be secured (HAVO-51 through 57).

## Integrated Pest Management

An integrated pest management (IPM) philosophy guides the non-native plant control program to the degree funding constrains acquiring sufficient ecological knowledge of target species and the kinds of control options feasible. Under the IPM approach, acceptable pest levels are assessed through monitoring and research, all control strategies are considered in terms of their ecological soundness and Park resource management objectives, and effectiveness of the control program is monitored and evaluated. Some population levels of pest species are inevitable. Acceptable levels of pest species are determined by distribution mapping, monitoring population structure, rate of spread, and relationship of the target species and surrounding vegetation (HAVO-2). Distribution mapping and monitoring are also essential for refining priority lists of target species, estimating workload requirements, relocating target plants in a rather featureless Park environment, and evaluating effectiveness of treatments.

Effective and ecologically sound control strategies are based on understanding the biology of the target pest and its relationship to other species and its environment. In addition to distribution, population structure, and relationship to other plant species (HAVO-2), it is important to know features of the biology of a target species such as phenological patterns of fruiting, flowering, and growth, seed dispersal mechanisms and seed set, germination, and viability features. These kinds of investigations are described in greater detail in HAVO-27.

Simple trial and error treatment methods, carried out by Resources Management personnel, are usually adequate for highly localized plant species. Even partially effective methods carried out consistently over time will suppress an exotic population, cut off contributions to the seed bank, and eventually exhaust food reserves and kill a target exotic. Trial and error may lead to effective treatment methods on larger populations. If this approach fails in intial stages, it is more time effective to carry out formal research on treatment methods to provide the most efficient and ecologically sound control method. In addition, ecological questions important for large populations such as the effects of treatment method on non-target native species, the invasion of treated sites by other vegetation, and soil seed bank status can be addressed with a level of confidence provided by a statistically sufficient research design. These kinds of

formal treatment method investigations are carried out by Research personnel (HAVO-28).

Accurate monitoring of the effectiveness of treatments is essential, not only to document the efficacy of a treatment program, but also to determine when control becomes unfeasible and a target species should be abandoned in order to avoid wasting limited manpower resources on a lost cause. The feasibility of control can be partially inferred before a treatment regime is started by distribution mapping, rate of spread monitoring, the efficacy of treatments as determined in treatment methods research, and the viability of seeds in the soil and other ecological data. In many cases, however, treatments must be initiated in order to determine workload requirements, the effectiveness of treatments under field conditions, and the feasibility of exhausting the soil seed bank. New invasions from outside the Park or establishment from the seed bank within the Park may expand population ranges and thereby increase the workload requirement. Post-treatment monitoring and updated distribution mapping will indicate the effectiveness of treatments and the scope of the project and are the essentail data needed in making decisions about abandoning species. Other subjective factors that are considered are the impact on Park ecosystems of terminating control work, the kinds of biological resources affected, the potential for dispersal into the Park in the future, and the relative merits of shifting manpower and funds to other target species. Control of Myrica faya on a Park-wide basis by mechanical means or pesticides was abandoned when it became obvious that armies of workers would be needed to successfully carry out this program.

## NATIVE PLANT MANAGEMENT

Native plant management focuses more at the ecosystem rather than the species level by emphasizing the mitigation of factors that disturb native ecosystem processes and by intensively managing selected important native plant areas (Special Ecological Areas). For example, the two most important native plant management activities are feral animal and exotic plant control. At the same time, sustained, low level efforts are directed to determining management needs of endangered, threatened, or rare species through vegetation monitoring, inventory summaries of target species, field assessments of the status of rare plants, and research of the causes of reproductive failure. Specific management actions are currently taking place with only one native species, Hibiscadelphus giffardianus, which is protected from rats using bait

stations and climbing barriers. As management needs become known, management of other rare species will be undertaken to the extent funding permits. Rehabilitative management will focus on mitigating habitat conditions that constrain reproduction, although outplanting of species reduced to precariously small populations is not precluded. Ecosystem restoration through widespread plantings is not envisioned, although limited, experimental plantings to test the feasibility of restoring depleted seed sources in the mostly exotic lowland environment would be attempted if funds permitted (HAVO-44). Mistakes in previous planting programs are being rectified by removing native plantings located beyond their natural ranges or in inappropriate habitats.

Rare Plant Management

More flowering plants in Hawaii are in danger of extinction than in any other state in the nation. In Hawaii Volcanoes 18% (43 of 240) of the native plants are listed as candidates under review for endangered or threatened status. An additional 39 species are considered to be rare within the Park. Fourteen other rare species are thought to occur within the Park but their abundance or reproductive success is not known because their current distributions are unknown. The vascular plant flora of Hawaii is highly significant because of its striking examples of adaptive radiation and high degree of endemism: eighty-five percent of the vascular plants in the Park are endemic to the Hawaiian Islands; seven species are found only within the Park; and a number of taxa have been reduced to a handful of individuals. Target candidate endangered and threatened and rare species targeted for management are listed in Table 1. Few lands in Hawaii outside the National Parks receive the kind of interventionist management needed to reduce threats to native plants; therefore, conservation of rare species in the Park, especially those relictual species unprotected outside the National Park, is critical. NPS policy mandates protection of candidate endangered or threatened species and requires definition of essential habitat and rehabilitative management if needed.

Most native plant depletions in Hawaii arise from the direct or indirect actions of man. These include the following: browsing and grazing of feral goats; rooting, trampling, and herbivory of feral pigs; girdling of stems or seed predation by various rodents; competitive exclusion by exotic plant species; loss of native pollinators; death or loss of vigor due to introduced diseases or arthopod pests; reductions through wildfires; and destruction of habitat by humans. These factors may directly affect

plants or modify light, soil, or nutrient conditions of the habitat to preclude successful establishment of seedlings. Small, isolated, and reduced populations may suffer from inbreeding depression or genetic drift and are especially vulnerable to disruptive influences.

The objectives of native plant management are to redress anthropogenic causes of population loss and to support populations at levels sufficient to maintain the genetic diversity they need to continue to survive, adapt, and evolve. It is not the intent of Resources Management to disrupt the natural process of extinction and colonization by artificially maintaining rare species in an arboretum setting. It is intended that rare species may be unburdened of human-caused sources of decline and allowed to survive or perish according to the dictates of natural processes.

Recent approaches to native plant management at Hawaii Volcanoes emphasized scattered plantings of a number of rare woody species and widespread plantings of a few common native species. This policy has been replaced by a program focused on reducing exotic plant and animal threats, permitting native ecosystem processes to occur, and encouraging native species to replace themselves unaided. If funding permits, a closely monitored, small scale experimental planting program in a lowland area will be carried out to determine the feasibility of reintroducing native seed sources depleted through many decades of disturbance by goats and historical Polynesian land use practices (HAVO-44). A research proposal for this investigation will be circulated for comment from the research and conservation community. It is recognized that a planting program in the lowlands is not a viable alternative to exotic plant control in the short run in that the natural open canopy structure of woodlands and forests in these areas does not prevent the establishment of introduced species such as fountain grass or koa haole. A measure of success in an experimental planting program will prompt the inclusion of a project statement outlining a lowland planting program of appropriate scale and direction in the Resource Management Plan.

Rare plant species are not ignored in an ecosystem approach to native plant management, although budgetary constraints preclude the level of research and management necessary to provide specific rescue management actions for every threatened species. A sustained, low level program is to be carried out concurrently with exotic threat management. Rare plant management currently consists of developing the information base necessary to identify threatened species and the nature of those threats as best as they can be

determined. In the past management actions have been mistakenly applied to species which are reproducing adequately; or these management actions have misidentified threats or used techniques whose efficacy is unknown. For example, much time was spent in applying untested rat control efforts to Pittosporum terminalioides, whose size class structure outside the control area suggests it is reproducing adequately without management of rats.

The first step in developing an information base to guide management of endangered, threatened, or rare plant species is to assemble available information about distribution, abundance, reproductive status, and perceived threats from local botanists, herbarium collections, and historical records (HAVO-16). This information base will be supported by updating the Park's plant checklist, upgrading the herbarium, and conducting systematic collections, particularily in poorly collected sections of the Park (HAVO-41). Because of the large number of taxa to be considered, target species (Table 1.) have been prioritized and will be considered in the following sequence: 1. endangered or threatened species (none known to occur in Park); 2. Candidate endangered or threatened species (List A); 3. Species of uncertain status in the Park (List C); and, 4. Species rare in the Park but not listed as candidate species (List B); species vulnerable to disturbance and competition (List D).

Native plant inventories serve as a guide to determining management actions in the more obvious cases or the need for further field studies for species whose status, threats, and management needs are uncertain. Inventories have been started on all candidate species and a number of taxa from Lists B and C. Field studies focusing on distribution, abundance, and population structure are conducted, either for single taxa or for several target species in a species rich biotic community. Distribution studies are to be designed to be comprehensive within the Park because of the inadequancy of sampling for the distribution of rare species. Permanent monitoring systems are established. Distribution, abundance, population structure, and long term monitoring will indicate the reproductive success of the species in the wild. Distribution studies and permanent monitoring system have been completed for one species at this time, Portulaca sclerocarpa. Distribution studies are the basis for determining essential habitat, a Park Service requirement for candidate and other rare plant species.

Species found to be reproducing adequately require no further work aside from monitoring. Obvious reasons for the lack of reproductive success and inferences about management needs may surface from field studies and corrective management actions can ensue. Species whose lack of reproductive success cannot be inferred from field studies of distribution, abundance, or population structure, will be targeted for research. This line of research will attempt to separate the various probable causes such as lack of pollinators, pests, disease, ungulates, rats (Rattus spp.), exotic plants, or other possible factors or combination of factors. Research on reproductive failure will be targeted on ecologically key species or selected "basket casé" species typifying the plight of many endemic Hawaiian taxa. Many populations of rare plants occur in very small populations which may suffer from inbreeding depression or genetic drift. Furthermore, rare island species may compete poorly against foreign invaders because of a genetic legacy of evolution involving passage through many bottlenecks in founder events which did not include strong competitors. Therefore, studies of the genetics and breeding systems of rare species may need to be addressed in research on reproductive failure. Such studies have been conducted for Hawaiian Drosophila but not for native Hawaiian plants; they may reveal information about the process of extinction of Hawaiian biota, the capacity of native Hawaiian plant species to survive, and the feasibility of preserving doomed species.

Once management needs are established by native plant inventories, field studies of reproductive success, or formal research of causes of reproductive failure, specific management actions to deal with threats can take place. These may include techniques such as exlosure fencing to reduce ungulate depredations or localized rat or weed control. Highly depleted species may require rescue outplantings of local plant material or artificial pollination to promote outcrossing.

These types of rehabilitative management are labor intensive. For example, pesticide applications for rodents need to be reapplied regularly and are highly localized; exotic plants need to be treated frequently; and fences take much time to build and maintain. For this reason, it is unlikely that all rare species can be specifically managed, especially since the program emphasizes managing ecosystem-wide threats such as feral animals and non-native plants. Funds have been requested for rare plant management (HAVO-59) and critical problems will be minimally funded for the time being, but not to the detriment of control programs on non-native organisms.

Some rare species will be afforded protection through Park-wide ungulate and exotic plant control program. Others will probably receive more selective management in intensive management units in which specific exotic threats are controlled. (HAVO-60). Assemblages of rare native species or individual populations requiring management may be located outside intensive management units or areas in which threats to the target taxa are not controlled. Funding request have been made for these kinds of rare plant populations (HAVO-59) and high priority species will be dealt with on a case by case basis as funding permits or biological signficance warrants.

Misplaced Plantings

For many years Hawaii Volcanoes was used as a refuge for rare native Hawaiian plants from other parts of the island or from other islands. For instance, Pittosporum hosmeri var. St. Johnii, naturally occuring in Kona, was planted in Kikpuka Puaulu. In addition, species native to the Park have been planted in habitats in which they do not normally grow or at apparently unnaturally high densities in appropriate plant communities. Alphitonia ponderosa, for example, apparently native to dry forests, was planted in a seasonal montane forest; koa was planted in lowland areas below its natural range; mamane (Sophora chrysophylla) was planted over many acres of submontane seasonal forest at unnaturally high densities. Hybrids have resulted from some introductions and some misplaced plantings have the potential of expanding in inappropriate habitats. Hybridization at the species or varietal level between locally adapted and introduced congeneric or conspecies taxa is not acceptable. In order to correct artificial range extensions, eliminate deleterious gene flow and hybridization, and reduce the arboretum-like character of certain Park areas, misplaced plantings will be removed to the extent practicable and necessary. It is recognized that most misplaced native plantings are benign in that the number of individuals is limited and most are not reproducing. Highest priority for management will be given to species that are expanding, such as Acacia koa in the lowlands, Haleakala silverword, or to taxa that are hybridizing with naturally occuring taxa. Care will be taken to assure the survival of rare species native to other parts of the State and planted as range extensions in the Park. Table 2 lists misplaced plantings in the Park and proposed corrective management actions. Action has been taken on a number of species: Kau silversword, Mezoneuron kauaiense, Pittosporum confertiflorum and some individuals of Kokia drynarioides, and koa have been

removed; Hibiscadelphus hybrids have been removed as they appear in Kipuka Ki; and individuals of planted Pittosporum at Kipuka Puaulu are being identified.

Table 1. List of Rare Native Plant Species in Hawaii Volcanoes National Park Considered for Further Study and Management.

List A. Plants listed as candidates under review for endangered or threatened status in Federal Register, Decem 15, 1980.

Adenophorus periens
Argemone glauca var. inermis
Asplenium fragile var. insulare
Bidens skottsbergii var. conglutinata and var. skottsbergii
(note: varieties of this species not listed in Federal Register)
Bobea timonioides
Canavalia kauensis
Cyanea tritomantha
Cyrtandra giffardii
Cyrtandra ramosissima
Dodonaea eriocarpa var. skottsbergii
Draceaena hawaiiensis
Eurya sandwicensis var. grandifolia
Hibiscadelphus giffardianus
Ischaemum byrone
Labordia hedyosmifolia var. kilaueana
Labordia hedyosmifolia var. magnifolia
Neraudia ovata
Nothocestrum breviflorum
Nothocestrum longifolium var. rufipilosa
Ophioglossum concinnum
Pelea hawaiensis var. hawaiensis
(note: varieties not listed in Federal Register
Pelea puauluensis
Pelea zahlbruckneri
Peperomia lilifolia var. obtusata
Peperomia expallescens var. brevipilosa
Phyllostegia brevidens var. heterodoxa
Phyllostegia macrophylla var. velutina
Pittosporum hawaiiense
Portulaca sclerocarpa
Rauvolfia remotiflora
Reynoldsia hillebrandii
Scaevola kilauea
Sesbania tomentosa
Silene hawaiiensis
Stenogyne rugosa var. subulata

Stenogyne scrophularioides var. biflora
Tetraplasandra hawaiensis var. hawaiensis
Tetraplasandra kavaiensis var. grandis
Trematolobelia wimmeri
Zanthoxylum hawaiiense
Zanthoxylum maviense
Zanthoxylum dipetalum var. geminicarpum
(note: variety not listed in Federal Register)

List B. Plants rare in the Park, but not candidate endangered species.

Alphitonia ponderosa
Anoectochilus sandvicensis
Antidesma pulvinatum
Capparis sandwichiana
Cassia gaudichaudi
Charpentiera obovata
Clermontia hawaiiensis
Clermontia montis-loa
Cyanea densiflora (Syn: Cyanea pilosa var. densiflora)
Cyanea floribunda (Syn: Cyanea pilosa var. glabrifolia)
Cyrtandra montis-loa
Cyanea longipedunculata
Erythrina sandwicensis
Euphorbia celastroides
Exocarpus menziesii
Fragaria chiloensis var. sandwicensis
Gnaphalium hawaiiense
Lindsaea ensifolia
Liparis hawaiensis
Myrsine lanaiensis
Nototrichium sandwicensis
Panicum spp. (endemic)
Phyllostegio macrophylla var. macrophylla
Phyllostegia vestita
Phyllosegia villosa (Syn: Phyllostegia floribunda sensu Sherff)
Pisonia brunoniana
Pittosporum hosmeri
Pittosporum sulcatum
Pittosporum terminalioides var. macropus
Plumbao zeylanica
Pritchardia beccariana
Sicyos hillebrandii
Sicyos microcarpus
Sisyrinchium acre

Stenogyne rugosa var. rugosa
Stenogyne sessilis var. sessilis
Stenogyne kaalae var. coriacea
Trematolobelia sp.
Xylosma hawaiensis var. hillebrandii

List C. Uncertain of staus in the Park; known to be or to have been in the Park. Plants will be placed on appropriate list when additional information is obtained.

Clermontia coerulea
Clermontia peleana
Cuscuta sandwichiana
Cyrtandra paludosa
Embelia pacifica
Labordia baillonii
(Note: listed as extinct in Table 4, 1980 Federal Register)
Ochrosia kilaueaensis
Platydesma spathulata
Pritchardia affinis var. holphila
Rubus macraei
Rumex giganteus
Sicyos sp. (Olaa)
Spermolepis hawaiiensis
Stenogyne angustifolia var. salicifolia
(Note: removed from candidate endangered list because of taxonomic problem; 3B on Table 4 of 1980 Federal Register)

List D. Plant species not rare in the Park but vulnerable to disturbance and competition.

Cyanea pilosa
Cyrtandra platyphylla
Geranium cuneatum var. hypoleucum
Gnaphalium sandwicensium
Labordia hedyosmifolia var. grayana
Myoporum sandwicense
Pelea radiata
Santalum paniculatum

Table 2. Misplaced Plantings in Hawaii Volcanoes National Park

| Species | Location | Proposed Action |
|---|---|---|
| Acacia koa | Hilina Pali and Chain of Craters Roads, Crater Rim Dr, Kalapana and Napau Trails | Remove where reproducing |
| Alphitonia ponderosa | Kipukas Ki and Puaulu | Remove |
| Argyroxiphium kauense | Enclosure, 6,700 ft | Remove if found |
| A. sandwicensis var. sandwicensis | Possibly 9,000 ft | Remove |
| A. sandwicensis var. macrocephalum | 10,000 ft. | Remove |
| Hibiscadelphus X puakuahiwi | Kipuka Ki | Continue to remove seedlings |
| Kokia drynarioides | Kipuka Puaulu | Remove to arboretum |
| Ochrosia sp. | Kipuka Puaulu | Remove to arboretum if St. John's treatment of genus stands |
| Planchonella sp. | Kipuka Ki | Remove |
| Pittosporum hosmeri var. St. Johnii | Kipukas Puaulu and Ki | Remove to arboreta |
| Pritchardia sp. | Kipuka Puaulu | Remove |

HAVO-58 CONTROL LOCALIZED EXOTIC PLANTS

Statement of the Problem. Twenty-five localized non-native plant species have been targeted for control in Hawaii Volcanoes (Category I species listed in the Vegetation Management Overview). These species have the potential to spread and disrupt Park ecosystems as indicated by their aggressiveness and tendency to displace native species in the Park or in similar habitats in the State. Aggressive potential is also suggested by their taxonomic affinities to taxa characteristically aggressive in local environments, or by their growth form. The history of weed population dynamics in other tropical environments, for example, the invasion of Christmasberry in Florida, indicate that populations of highly aggressive and disruptive species may occur at very low numbers for many years prior to sudden expansion. Therefore, a prudent approach requires control and, at least, long-term monitoring of all suspect non-native species.

Localized, potentially disruptive exotic species vary in the Park from a few individuals or small populations to several hundred individuals or populations covering up to several acres. These species displace native vegetation and many can form monospecific stands or vegetation layers. Control of localized exotics is feasible because of their restricted distribution, limited numbers, and relatively modest seed banks. Treatments have been initiated on most Category I species and control efforts are now in a follow-up phase; treatments need to be initiated on other species. Some of these species have demonstrated remarkable persistence despite intensive herbicidal and mechanical control efforts and require vigilant and often long-term follow-up to eradicate seedlings or sprouts. New suspect species which invade the Park are to be included in Category I, mapped, and treated.

Alternative Actions and their Probable Impacts.

1. No action. By failing to treat localized, damaging non-native species, these plants can further invade Park ecosystems, displace native species, and convert native communities to exotic ecosystems. Control efforts become unfeasible as exotic populations expand.

2. Treat localized exotic species after they clearly demonstrate their aggressiveness and impact on Park ecosystems. Control is more problematical and certainly more expensive because populations and soil seed banks are larger.

3. Treat suspect localized non-native plant species as soon as possible, using herbicidal or preferably, mechanical means if effective. In this way, these populations are prevented from spreading and impacting native vegetation, the feasibility of control is greater, and costs are significantly reduced. Some impacts can be expected on soil and non-target organisms from mechanical or herbicidal treatments. However, these can limited by the small size of target populations, attempts to use target specific control techniques, and, if herbicides are used, the lowest effective dosages.

Recommended Course of Action. Treat potentially disruptive exotic plant species while they are still localized. Target species will be indentified by rate of spread monitoring and mapping (HAVO-2), relationships with plant groups characteristically agressive in local environments, life forms typically aggressive in Hawaii, and the advice of botanists familiar with the behavior of the subject exotic species in other parts of Hawaii. Although most of the approximately 400 non-native species in the Park are not aggressive, a cautious approach is the removal of suspect species while workload requirements are modest. Both initial and follow-up treatments are included in the project described in this statement.

Systematic reconnaissance of Park roads and trails and discoveries incidental to other projects in backcountry areas will indicate additional species to be targeted for control efforts. The monitoring aspects of localized plant control control, including surveillance for new introductions, distribution mapping, monitoring of the rate of spread, effectiveness of treatments, and relationship of exotics and native plants are delineated in HAVO-2.

Cost/workload. $30,000, 1.5 FTE per year indefinitely

## HAVO-42 MAINTAIN CONTROL OF EXOTIC PLANTS

Statement of the Problem. Exotic plant species pose an immediate and serious threat to native Hawaiian ecosystems. Without control, many aggressive exotics will displace native plants and native ecosystems. Effective control cannot be realized unless a deliberate and well organized program of maintenance eradication is implemented. This program would consist of systematic follow-up treatments of non-native plant populations which have received initial treatments and have thus been reduced to low numbers and to non-reproductive stages.

Initial treatments are currently in progress for three of the nine highly disruptive, well established non-native plants (Category II species) targeted for control efforts (HAVO-3, 52, and 53). Initial treatments are planned for the six other Category II target species (HAVO-51, 54 through 57), contingent upon funding and are anticipated to last three years. These initial treatments reduce populations to vegetative sprouts and seedlings and eventually to only seedling stages. They are often quite labor intensive because of the large numbers of mature plants requiring control efforts. Systematic maintenance treatments are needed to suppress sprouts and seedlings for all Category II species following initial treatments, in progress or planned.

HAVO-42 describes maintenance level control on all Category II species. Both initial and maintenance treatments of highly localized target exotic plants (Category I species) are covered in a single project statement, HAVO-58, because of the considerably smaller workload required for treatments of highly localized species.

The workload requirement for maintenance treatments of some well established species is often considerable and must be sustained for many years. Maintenance control strategies are complicated by scattered distribution and remoteness of target populations, rapid maturity, large seed bank, stimulation of seedling cohorts by removal of competition, persistence of most woody species, and recolonization from local or outside populations. Proper management of this project demands highly skilled and focused attention and a long term committment of funds and personnel, all insufficiently provided at present.

Alternative Actions and their Probable Impacts.

1. Delay or ignore follow-up work. By not maintaining control of non-native plant populations after initial treatment, plants will rapidly return to original population levels, money invested in effort will be wasted, and native ecosystems will not be protected.

2. Continue program at current level. Funding is available to perform maintenance treatments on 30 Category I species and initially treated populations of two Category II species. If control efforts are to expand to additional species, follow-up treatments must be planned and funded after initial treatments for these species; otherwise, initial work will be wasted and native biota not be safeguarded.

3. Extend the program by providing reliable and consistent follow-up for all species targeted for initial treatment. This course of action will establish regularity and reliability to all aspects of long term maintenance control, namely: careful long-term planning, proper interval between treatments, depletion of the soil seed bank, and prevention of further contributions of seed. The cost of control will be reduced and the take-over of native ecosystems precluded.

Follow-up treatments will often cause soil, vegetation, and wildlife impacts similar to those of initial treatments described in HAVO-51 through 57, especially because many treatments involve use of herbicides which affect the soil and non-target species. Impacts are mitigated as much as possible by preferring treatment methods utilizing non-persistent pesticides, target specific dosages, and application techniques.

Recommended Course of Action. Alternative 3 is selected because it recognizes that a very deliberate and thoughtful application of long-term planning, weed ecology, and persistence will make a more lasting contribution to the solution of exotic plant control problems.

Cost/workload. $100,000, 5 FTE per year, first through fifth years

HAVO-3 CONTROL FOUNTAIN GRASS

Statement of the Problem. Fountain grass poses one of the greatest non-native threats to Park ecosystems. As demonstrated by its behavior in Kona and Mauna Kea, this robust, introduced bunchgrass is capable of forming dense to monospecific stands or vegetation layers from sea level to at least 6,500 feet in all habitats except closed canopy rainforest. As a result, essentially all grassland, scrub, woodland, and forest communities are susceptible to infestation. Fountain grass colonizes all substrate types, including bare lava flows, thus obscuring significant geological features and interrupting natural successional processes on bare lava flows. Its capacity to invade areas with little soil allows it to occupy unusual lowland native, xeric plant communities in the Kau Desert which owe their native character to the lack of soil. If unchecked, fountain grass will undoubtedly invade Kilauea Caldera, the bare lava flows of the Kau Desert, Mauna Loa, and the East Rift and would interfere with natural recovery of native assemblages of organisms in these sites, thus obscuring the scenic value of features for which the Park was established or disrupt processes responsible for the Park's designation as an International Biosphere Reserve.

Fountain grass replaces native vegetation through direct competition for resources and preventing the reproduction of native species. Moreover, this highly flammable, fire-stimulated grass significantly increases fuel loadings and fire intensities, resulting in the loss of native species adapted to fires of low intensity and frequency and incremental increases in the biomass of fountain grass with successive fires.

To date, fountain grass has invaded most Park roadsides, including USGS jeep roads, predictable corridors of invasion used by vehicles which travel to parts of the Big Island infested by this non-native species. It is well established in a 1,000 acre site in the western lowlands of the Park adjacent to the Kamooalii lava flows. It also occurs in approximately 200 peripheral, outlying populations of 1 to 100 individuals. More outlying populations are expected to be found with additional reconnaissance and treatments. Finally, it is inevitable that fountain grass, well established in the western side of the island, will spread to the vicinity of the Park.

Resources Management workers routinely treat all roads and trails at three month intervals, including highways beyond Park boundaries, the main Kamooalii population, and outlying populations. Systematic searches by helicopter augment

ground crew efforts. Large populations are delineated, subdivided into manageable blocks, and worked by large crews. Small, disjunct populations are marked and eradicated by small groups on foot or horseback. The number of plants uprooted is recorded to assess the effectiveness of treatments.

Fountain grass is treated by destroying infloresences and uprooting the plants. This control strategy attempts to reduce and eventually deplete the soil seed bank. Ongoing research is determining the viability of seeds over time and the length of time from germination to flowering, two important factors affecting treatment regime and feasibility of control.

It is apparent that large, well established populations have a considerable reservoir of seed in the soil. The number of seedlings found during each treatment at Kamooalii, for example, has remained steady at about 4,000 plants over the last two years, although biomass has been signficantly reduced in this area. Preliminary treatment data suggest that it may be possible to deplete the seed bank of outlying populations with one or two treatments.

It is thought that a grass species with good dispersability would potentially be very difficult to control strictly within Park boundaries, especially if populations of significant density occur immediately outside the Park. Therefore, the Park is attempting to create a boundary buffer zone free of fountain grass through cooperation with adjacent landowners, survelliance of road corridors, treatment of known roadside populations, and treatment of selected populations by Park personnel, if required. Although distribution mapping within the buffer zone is incomplete, one population in Kalapana is known which could require approximately 60 man days per year to control.

Alternative Actions and their Probable Impacts.

1. No action; abandon fountain grass control program. This will allow fountain grass to proliferate, spread into all Park ecosystems except dense rainforest from sea level to at least 6,500 feet and form dense to monospecific stands in grasslands and bare lava flows or monospecific vegetation layers in scrub, woodland, and forest communities. Significant geological features would be obscured, fuel loadings considerably increased, native plants replaced, and many native ecosystems compromised or irreplacably lost.

2. Control fountain grass within the Park. This program will contain one of the most disruptive non-native plant species in Hawaii, preserve native assemblages of plants and animals, protect the scenic values of the Park's geological features, and help maintain natural successional processes on new geological substrates, features, and processes for which the Park was established and conferred international recognition. Because fountain grass currently infests exotic plant communities and is treated mechanically, control work involves essentially no impact on natural resources.

Recommended Course of Action. Regularly and systematically reconnoiter by foot, horseback, and helicopter all fountain grass habitat in the Park for new infestations. Relocate and retreat all known populations with ground crews at sufficiently regular intervals to prevent flowering and thus deplete the soil seed bank. Routinely treat all roadside populations outside the Park in the designated buffer zone. Cooperate with neighboring landowners in controlling fountain grass in their areas, even to the point of donating Park personnel to accomplish this task. Maintain accurate treatment data records and update distribution maps in order to develop the information necessary to determine feasibility of control.

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|---|---|---|
| Cost/workload. | $125,000, | 4 FTE first year |
| | $125,000, | 4 FTE second year |
| | $100,000, | 3 FTE third year |
| | $90,000, | 2 FTE fourth year |
| | $75,000, | 2 FTE fifth year |

HAVO-53 CONTROL KIKUYU GRASS

Statement of the Problem. Kikuyu grass is one of the more disruptive introduced plant species in Hawaii. Its establishment can ultimately result in community life form changes, converting woodlands and forests into exotic grasslands by directly competing with native species, precluding reproduction, or directly weakening or killing competitors through allelopathy. This non-native species forms dense, monospecific vegetation layers, and even climbs as much as ten feet into trees and shrubs.

Kikuyu grass has become established along Park roads and trails, whence it spreads vegetatively into otherwise intact plant communities. It also has spread into the Park from adjacent pasturelands. Although Kikuyu grass is found in many Park ecosystems, it most readily invades open woodland or rainforest which lacks a continuous tree fern layer.

A relatively effective treatment method developed from formal research is available for the control of Kikuyu grass. A control program is underway in a small portion of the range of this species in the Park, along approximately 10 miles of Park roads in some of the more vulnerable forest types around Crater Rim. Kikuyu grass especially threatens open, intact, and biologically diverse forests in the lower Mauna Loa Strip in which it occurs in extensive stands comprising approximately 100 acres. Kikuyu also occurs in a large infestation at Ainahou Ranch several times this extent. Current funding levels preclude control of Kikuyu grass in these areas.

Alternative Actions and their Probable Impacts.

1. No action. Failure to control Kikuyu grass will eventually result in the conversion of native forest or woodland to exotic grassland dominated by this non-native grass. One hundred acres of rich native montane forest in the Mauna Loa Strip area are immediately threatened and this non-native grass is capable of invading most montane seasonal forest in this area.

2. Control Kikuyu grass. This action will prevent the spread of Kikuyu grass into native ecosystems and help maintain their native character. Initial broadcast treatments with a non-specific herbicide (Roundup) results in a measure of damage to non-target species and soil contamination, impacts mitigated by the low rates required

to achieve control and the rapid breakdown of this pesticide. Negligible impacts occur in follow-up treatments of isolated individual sprouts.

Recommended Course of Action. Continue to control Kikuyu grass around Kilauea Caldera and expand current control program to lower Mauna Loa Strip forests using tested methods to prevent its spread into forests it threatens. Complete distribution mapping and monitor the spread of Kikuyu grass along roadsides and trails which are adjacent to rainforest with a dense tree fern understory to determine the need to control Kikuyu grass in this habitat.

Cost/workload. $25,000, 1.5 FTE first year
$15,000 .8 FTE second year
$15,000 .8 FTE third year
$10,000, .5 FTE fourth year
Project subsumed under HAVO-42 thereafter.

to achieve control and the rapid breakdown of this pesticide. Negligible impacts occur in follow-up treatments of isolated individual sprouts.

Recommended Course of Action. Continue to control Kikuyu grass around Kilauea Caldera and expand current control program to lower Mauna Loa Strip forests using tested methods to prevent its spread into forests it threatens. Complete distribution mapping and monitor the spread of Kikuyu grass along roadsides and trails which are adjacent to rainforest with a dense tree fern understory to determine the need to control Kikuyu grass in this habitat.

Cost/workload. $25,000, 1.5 FTE first year
$15,000 .8 FTE second year
$15,000 .8 FTE third year
$10,000, .5 FTE fourth year
Project subsumed under HAVO-42 thereafter.

HAVO-52 CONTROL NASTURTIUM

Statement of the Problem. Nasturtium occurs in 37 distinct populations varying from 30 square feet to five acres. This introduced herbaceous species is found in Kipuka Puaulu, one of the richest assemblages of native plants on the Big Island and one of the main foci of interpretation in the Park. It forms monospecific stands in open areas and grows into the canopy, thereby competitively excluding native species or precluding the re-establishment of natives in openings which are recovering from depredations of cattle (Bos taurus). Formal distribution mapping was completed in 1983 and revealed a ten-fold increase in the number of nasturtium populations found in informal mapping in 1980. Most of these populations are less than 1500 square feet in extent and occur beyond the periphery of the three larger, longer established populations. Three populations were found one-half mile from previously known populations. This distribution pattern suggests that a range expansion is taking place.

An effective treatment method is available for nasturtium. Treatments were started in 1984. Information that needs to be obtained before full scale management is implemented include the effects of the selected pesticide on non-target species, the potential for invasion of treated sites by other plants, and the feasibility of exhausting the soil seed bank. From initial mechanical and herbicide tests on limited areas, it is known that the soil seed bank is enormous, that nasturtium germinates rapidly following application of pesticides, and that it flowers within two to three months of germination. Therefore, numerous treatments at two to three month intervals will be needed to exhaust the soil seed bank.

Alternative Actions and their Probable Impacts.

1. No action; do not treat nasturtium. As a result, nasturtium will continue to expand, invade canopies of native forest and suppress native plants, colonize open areas and prevent the recovery of native species. These degrading processes will occur in one of the richest assemblages of native organisms on the island, a kipuka otherwise recovering perceptibly from the removal of cattle, goats, and pigs.

2. Control nasturtium. The above depreciative processes will not occur and native plant species in Kipuka Puaulu can continue to recover naturally. A modest degree of soil contamination and effects on non-target plants are inevitable because of the use of foliar applications of herbicide used in treating nasturtium. These impacts are mitigated by the use of a herbicide of modest persistence and at very low dosages.

Recommended Course of Action. Control nasturtium in Kipuka Puaulu. Implement control in two stages. Initially, treat one-third of the populations before control efforts are extended to other populations. In this way outstanding questions can be answered about the consequences of treatments. Perform treatments at two to three month intervals and monitor closely to determine impacts of treatments on non-target species, the seed bank, and successional changes in the treated site.

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| Cost/workload. | $15,000, | 1.0 FTE first year |
| | $10,000, | .5 FTE second year |
| | $7,500, | .5 FTE third year |

HAVO-57 CONTROL KAHILI GINGER

Statement of the Problem. Kahili ginger poses one of the greatest threats to native rainforests in the Park. It occurs in high to moderate densities in approximately 200 acres of the Kilauea Caldera area and in very low densities over many hundreds of acres in the Olaa Tract. Unlike a number of other non-native plant threats in the rainforest ecosystem, Kahili ginger is localized enough to achieve control with conventional control methods, provided funding levels are adequate.

Kahili ginger is capable of becoming established beneath dense tree fern understory and does not appear to depend on soil disturbance for establishment. Therefore, it can invade relatively intact rainforest and even sites from which feral pigs have been removed. This robust, herbaceous non-native can grow up to eight feet in height and individuals form tall, dense colonies with a massive rhizome system. This growth pattern enables Kahili ginger to form a monospecific vegetation layer beneath the tree fern or ohia canopy, thereby displacing understory vegetation, and ultimately tree species by precluding reproduction. It is ranked as one of the highest priority target exotic plant species because it impacts essentially native ecosystems.

Kahili ginger is a prolific seed producer, has been established for many years in the Kilauea area, and is stimulated to grow from seed when mature plants are treated; therefore, it is anticipated that soil seed bank problems will require persistent, frequent, and labor intensive follow-up treatments. The presence of closely associated native non-target species compounds control problems. Research to determine an effective and ecologically sound treatment method, as well as distribution mapping and monitoring, is underway.

Alternative Actions and their Probable Impacts.

1. No action. By failing to check the spread of Kahili ginger, most rainforest areas in the Park will undoubtedly be invaded over time and ultimately replaced by this highly aggressive and persistent species.

2. Control Kahili ginger. By doing so, native rainforest can be protected from a non-native species which has the capacity to bring about a life form change to this ecosystem. Implementation of control efforts now, while this species is still relatively localized, will be considerably less expensive than delaying control attempts

until a later time. It is expected that control of Kahili ginger will cause signficant soil, vegetation, and wildlife impacts in native communities. Mechanical treatments involve considerable soil disturbance and pesticide effects on non-target species are aggravated by the occurence of this non-native species in mostly intact forest. Treatment methods research is addressing the problem of impacts on non-target species by investigating highly specific application techniques.

Recommended Course of Action. Control Kahili ginger while it is still relatively localized. Complete distribution mapping, monitoring (HAVO-2), and treatment methods research (HAVO-28). Implement a control program in peripheral areas of this species' distribution to contain its expansion. Closely monitor results of treatments for undesireable effects on non-target native species and invasion of plants into treated sites. Ultimately expand treatments into core areas in the Kilauea area and biologically signficant resource sites in the Olaa Tract.

Costs/workload. $75,000, 5 FTE first year
$50,000, 4 FTE second year
$30,000, 2 FTE third year
Project subsumed under HAVO-42 thereafter.

HAVO-54 CONTROL OLIVE

Statement of the Problem. Olive presents a new exotic plant threat to the Park. Planted as a hedge row in Ainahou Ranch when this area was an inholding, this non-native tree population has exploded following the removal of cattle in the late 1970's. It currently occupies about 1,500 acres, varying from sparse to highly crowded. Seedlings and saplings are numerous, often in the hundreds per square yard, an age structure indicating exponential population growth. Olive is furthermore shade tolerant, which allows it to reproduce under itself or other forest trees. It forms dense to monospecific stands and competitively excludes native plants.

The distribution and population structure of olive have been assessed and treatment methods are under investigation. Olive is a prolific seed producer, and soil seed bank problems are expected to be challenging.

Alternative Actions and their Probable Impacts.

1. Delay or ignore the need for treatment. Olive can be expected to expand and form dense or single species stands, thereby eliminating native species. Olive is not a problem in similar habitats in the State; consequently the potential range is difficult to predict. However, if it expands in similar dry woodland habitat in the Park, it can be expected to invade and dominate thirty to forty thousand acres of Park land.

2. Control olive. In so doing, native species can be protected in an environment recovering from cattle grazing and supporting a number of candidate endangered/threatened or rare plant species such as Scaevola kilaueae, Exocarpus menziesii, and Alphitonia ponderosa, and the endangered nene. Impacts on adjacent plants, soil, and invertebrates are to be reduced by highly specific stump treatments.

Recommended Course of Action. Control olive. A control program will check the most serious woody plant threat to a Park ecosystem, the submontane seasonal forest, which is additionally plagued by a number of other woody exotics and fire adapated grasses that render its native character increasingly tenuous.

Cost/workload. $50,000, 3.0 FTE first year
$25,000, 1.5 FTE second year
$10,000, .5 FTE third year
Project subsumed under HAVO-42 thereafter.

HAVO-51 CONTROL KOA HAOLE

Statement of the Problem. Koa haole is a shrub or small tree introduced to the eastern and central lowlands of the Park. Formerly controlled by goat browsing, it has dramatically expanded its range in recent years following the reduction of these feral ungulates. The distribution of koa haole was mapped in 1983-84 and revealed 255 populations averaging 1,300 square feet in size and comprised of many, densely arranged, small diameter individuals. The age structure, density levels, and distribution pattern indicate rapid expansion of koa haole in the Park, a trend independently confirmed by local botanists.

Koa haole is particularily disruptive because it is capable of forming monospecific stands, thereby competitively excluding other species and precluding the establishment of native species. In the central lowlands, the spread of koa haole would prevent the recovery of native woody species and in the eastern lowlands, this non-native shrub grows as an understory tree and particularily threatens an unique and pristine lama dominated, dry forest, a community considered to be the finest representative of this vegetation type in the State. Koa haole dominates many lowland areas of Kau outside the Park and the leeward sides of many of the islands. It is capable of growing on all lowland substrates. Because populations are well established and seeds remain viable for many years, soil seed bank problems will require considerable attention.

An effective, ecologically sound, and NPS permitted treatment method is not currently available. The use of Tordon 10-K pellets was discontinued in 1982. Because a suitable substitute is not yet available, control efforts on koa haole have ceased. Effective treatment methods are under study at the present time. In the meantime, koa haole is expected to continue to expand rapidly.

Alternative Actions and their Probable Impacts.

1. No action; allow koa haole to expand unchecked. Much of the central lowlands will ultimately be converted from exotic grasslands to exotic brushfields or woodlands, thereby precluding the re-establishment of native woody plants, now recovering from goat depredations and hampering the lowland nene reintroduction program. Native scrub and pristine dry forest will be invaded in the eastern lowlands, thus threatening the native character of these plant communities.

2. Control koa haole. In doing so, native shrubs have an opportunity for re-establishment in the coastal lowlands, through natural means or assisted by planting. Native scrub and dry forest will be protected. Impact on native ecosystems will be minimal because koa haole mostly occurs in lowlands where exotic plant communities dominate. The only feasible treatment method is herbicidal. The impacts of herbicide application are mitigated by investigating target specific application techniques.

Recommended Course of Action. Control koa haole. Initial work has been completed in the preparation of distribution maps and establishment of pre-treatment monitoring. Once an effective treatment method and funding becomes available, treatments can commence. Because of the short interval from seed germination to flowering, treatments need to be frequent. Soil seed banks are expected to remain high for a number of years, requiring consistent follow-up. The remoteness and high number of target populations compound the workload requirement.

Cost/workload. $75,000, 5.0 FTE first year
$50,000, 3.0 FTE second year
$35,000, 2.5 FTE third year
Project subsumed under HAVO-42 thereafter.

HAVO-61 CONTROL RUBUS GLAUCUS

Statement of the Problem. Rubus glaucus is a potentially disruptive exotic plant pest in Park rainforest. This climbing raspberry is capable of invading forest canopies and in some areas grows at densities sufficient to competitively exclude native plant species. Other species of Rubus have proven to be disruptive in rainforest and are controllable only in localized areas. Rubus glaucus is still localized enough to be controlled over its entire range.

Currently, this non-native raspberry is confined in the vicinity of the Park to a State agricultural experiment station, from which it escaped, and neighboring agricultural lots adjacent to a 10,000 acre tract of Park rainforest; a few plants have been found in the Park adjacent to the area of infestation. If the plants can be controlled while localized, Park rainforest can be spared another disruptive Rubus species. The Park Service has not been successful in persuading State officials to control this non-native plant, for whose escape and spread they are directly responsible.

The distribution of Rubus glaucus has been partially mapped; treatment methods are targeted for research and some screening tests have been started. Landowners have been contacted prior to the distribution mapping phase of this control program and have informally agreed to allow control of this plant on their property by Park staff.

Alternative Actions and their Probable Impacts.

1. No action. Failing to check the spread of Rubus glaucus will result in the addition of another canopy smothering, impenetrable raspberry in Park rainforest. Control attempts at later dates would be possible only in localized areas; Park-wide control would be prohibitively costly.

2. Control Rubus glaucus. Containing this non-native raspberry would prevent the spread of a potentially disruptive exotic plant in the Park rainforest. Funds would be saved by effecting control while localized. Impacts on native forest vegetation, soils, and other organisms are anticipated and unavoidable. Impacts can be mitigated by target-specific herbicides application on the use of mechanical control methods. The most effective control methods has not been determined to date.

Recommended Course of Action. Control Rubus glaucus Park-wide while it is still localized. Complete distribution mapping. Continue treatment methods research. Revitalize contacts with the State to control this non-native plant, at least on their own lands where densities are highest. Re-establish contacts with landowners whose properties contain Rubus glaucus and encourage private control programs. Treat plants that the State and private landowners do not treat.

Cost/workload. $15,000, .8 FTE first year
$ 8,000, .5 FTE second year
$ 5,000, .3 FTE third year
. . Project subsumed under HAVO-42 thereafter.

HAVO-55 CONTROL SILKY OAK

Statement of the Problem. Silky oak (Grevillea robusta) is expanding in the central and western portions of the Park and require control efforts. Silky oak are found in ohia (Metrosideros polymorpha) woodlands from Ainahou Ranch to the western Park boundary. The precariousness of these plant communities, threatened by a number of exotic plants and high fire potential, is compounded by the expansion of silky oak, capable of establishing itself in the understory of ohia woodlands and forming dense stands. Another silky oak, Grevillea banksii, recently established along the Kau boundary of the Park, also threatens lowland ohia woodlands in the Park. The high proportion of individuals of younger age classes of this non-native species indicates that it is expanding rapidly. Its tendency to grow in dense stands within open ohia woodland demonstrates its capacity to disrupt this ecosystem within the Park lowlands.

A tentative treatment method has been recommended by Research for the control of Grevillea robusta; distribution mapping and population structure assessments are in progress and scheduled for completion in the Fall, 1985.

Alternative Actions and their Probable Impacts.

1. No action. Failing to control silky oak will allow additional disruptive woody plants to spread and form dense stands in a Park ecosystem already threatened by other exotic plants and fire. Silky oak have formed single species forests immediately outside the Park and are capable of transforming similar habitats within the Park.

2. Control silky oak. A control program will prevent the spread of these threatening species and help preserve native communities and natural processes in dry ohia woodlands of the Park. Herbicides are required to control this species because it resprouts where cut. Use of a target specific basal bark herbicide will mitigate impacts on soils and non-target species.

Recommended Course of Action. Control silky oak. Complete distribution mapping, population structure, and pretreatment monitoring. Assess effectiveness of recommended treatment method on a portion of the population before trying to control entire Park population. Treat Grevillea robusta within the Park with Park crews and encourage adjacent landowner in controlling localized population of G. banksii on his land. Follow-up treatments will be required to deplete the seed bank and control those dispersing into the Park from seed sources beyond Park boundaries.

Costs/workload. $15,000, .8 FTE first year
$ 7,500, .5 FTE second year
$ 2,500, .2 FTE third year
Project subsumed under HAVO-42 thereafter.

HAVO-56 CONTROL CHRISTMASBERRY

Statement of the Problem. Christmasberry threatens recovery of lowland plant communities in the cental and western portions of Hawaii Volcanoes. This tall non-native shrub forms extensive monospecific stands west of the Park. At the present time, populations of Christmasberry in adjacent portions of the Park are small and widely scattered, and therefore controllable. Although population structure data is not currently available, the presence of numerous small individuals suggests rapid population growth.

Christmasberry is relatively common in the eastern lowlands of the Park but appears to be in equilibrium with recovering native plant communities. Area-wide control is therefore not currently feasible or required in the eastern lowlands. However, localized control in Special Ecological Areas may be necessary, depending upon site specific conditions.

An effective treatment method is available for Christmasberry; mapping and monitoring in the western section of the Park is underway and targeted for completion in the Fall, 1985.

Alternative Actions and their Probable Impacts.

1. No action. Failure to control Christmasberry will allow the spread of a woody exotic capable of forming monospecific stands and thereby displacing all native ecosystem components or preventing the establishment of native species in areas recovering from goat depredations.

2. Control Christmasberry. This will prevent the expansion of this exotic and protect native ecosystems. The treatment method for Christmasberry is by herbicides. This will result in impacts on surrounding vegetation, mostly exotic grasses, and some soil contamination. These impacts will be mitigated by the localized nature of the target populations, relatively target specific application techniques (basal bark), and relative lack of persistence of the herbicide to be used.

Recommended Course of Action. Control Christmasberry. Complete distribution mapping, population structure assessments, pre-treatment monitoring in the central and western Park lowlands, and rate of spread monitoring in the eastern Park lowland (HAVO-2). Treat all isolated

populations in central and western lowlands. Treat selected population in eastern lowlands that threaten significant biological resources.

Cost/workload. $20,000, 1.0 FTE first year
$15,000, .75 FTE second year
$10,000, .5 FTE third year
Project subsumed under HAVO-42 thereafter.

HAVO-62 REMOVE MISPLACED NATIVE PLANTINGS

Statement of the Problem. Native plantings in the Park which have been artificially extended beyond their natural range need to be removed in order to restore native assemblages of plant species and prevent unnatural hybridization with locally adapted and naturally occuring taxa. From 1920 to 1980 Hawaii Volcanoes was used as an arboretum for rare species native to other parts of the the State. Many of these misplaced plantings were located in one of the most diverse and biologically important kipukas in the Park, Kipuka Puaulu. In addition, a number of rare species native to Hawaii Volcanoes have been deliberately established in plant communities in the Park to which they are not native. Furthermore, during the outplanting program of the 1970's, koa was extensively planted in inappropriate ecosystems and mamane was established at apparently unnaturally high densities in plant communities in which it is indigenous, ostensibly from an inappropriate seed source.

Although most misplaced plantings are not reproducing at this time, some species such as koa are expanding in the habitats to which they have been inappropriately introduced. Other misplaced plantings have the potential to hybridize with closely related and naturally occuring taxa, for example, Hibiscadelphus and Pittosporum hosmeri var. St Johnii. Most misplaced plantings in the Park have been identified and located, and strategies for their removal have been formulated (see Table 2 in Vegetation Management Overview). Some misplaced plantings are quite rare and must be relocated to local arboreta for their perpetuation.

Alternative Actions and their Probable Impacts.

1. Take no action by leaving inappropriate native plantings in place. This alternative will allow some species to spread, in many cases displacing naturally occuring species, or permit hybrids to form. In both cases, naturally occuring assemblages of native species will be disrupted.

2. Remove misplaced plantings. This action will preclude the replacement of species native to the Park or specific ecosystems of the Park by species inappropriate to these areas and prevent the establishment of unnatural hybrids. Most misplaced plantings can be removed mechanically.

Consequently, little impact on native ecosystems is anticipated. Herbicide treatments of misplaced koa will be confined to stumps and therefore have minimal effect on the habitat.

Recommended Course of Action. Remove misplaced plantings following recommendations outlined in Table 2 of the Vegetation Management Overview. Treat taxa which are actively spreading first. Unnatural range extensions represent a form of genetic contamination unacceptable in a National Park and International Biosphere Reserve.

Cost/workload. $7,500 per year for three years
Part-time Biological Technician

HAVO-2 MAP AND MONITOR EXOTIC PLANTS

Statement of the problem. The introduction, spread, and persistence of exotic plants present the most serious long-term threat to the Park ecosystem. The Park's exotic plant control program is hampered by a lack of accurate distribution mapping and baseline monitoring. Distribution mapping and population monitoring address three key elements of an integrated pest mangement approach to weed control: determining the extent and location of the target pest, assessing acceptable levels of the pest population, and evaluating the effectiveness of treatments or the control program. Precise, detailed distribution maps are also needed for a thorough treatment program in that they are essential to the relocation of target populations, an especially critical factor in a local landscape characterized by dense vegetation or lack of notable landmarks. Distribution maps also provide a baseline for assessing range expansions. Population structure studies determine densities of individuals and the proportions of different age classes and thereby suggest the workload requirement of a control program and indicate the reproductive status of a pest population. Rate of spread monitoring quantifies range expansions and can be modelled to evaluate the replacement of existing plant species by target exotic species.

The data from distribution mapping, population structure analysis, and rate of spread monitoring provide the information base needed to assess the magnitude of the threat posed by exotic plant populations, estimate the workload required to achieve control, prioritize control efforts on different weed species or populations, and develop management strategies. Pre- and post-treatment monitoring demonstrate the effectiveness of treatment methods used, the effects of treatments on non-target species, and the invasion of treated sites by other species.

Baseline distribution mapping and monitoring will have been completed for all target exotic species in Hawaii Volcanoes during 1984. Follow-up distribution mapping, population structure analyses, and rate of spread monitoring will be needed on a recurring basis. Pre- and post-treatment monitoring are conducted as integral elements of treatment regimes and therefore are required on a continuing basis. Many weed species tend to enter Park ecosystems along predictable invasion routes such as roadsides and trails. A systematic survey of invasion sites by trained staff is needed to detect the establishment of species new to the Park.

Alternative Actions and their Probable Impacts.

1. No action. Under this alternative, treatments would be applied without adequate baseline mapping, population structure analyses, and monitoring. As a result, pest species or populations posing a threat to Park ecosystems may be ommitted from treatment and follow-up, the magnitude of the threat posed by exotic species cannot be assessed, acceptable population levels cannot be determined, and the effectiveness of treatments cannot be evaluated. Consequently, essential elements of an IPM approach cannot be applied, manpower and funds may be squandered on inappropriate species, and native ecosystems will suffer from the invasion of exotic species.

2. Continue the present mapping and monitoring program. The information base developed from distribution mapping, rate of spread monitoring, population structure analyses, and pre- and post-treatment monitoring will indicate the scope of the threat posed by non-native species, aid in prioritizing species for treatment, facilitate treatments, and evaluate the effectiveness of treatments. By making treatment efforts more directed and efficient, funds and manpower will be utilized more efficiently and native ecosystems will be protected. Minor aesthetic impacts will result from flagging tape and aluminum markers used to mark permanent monitoring plots or transects, and limited, temporary damage to native vegetation will be sustained through trampling by botanists.

Recommended Course of Action. Continue present mapping and monitoring programs and establish a formal scouting program along Park roads and trails. Complete baseline mapping and monitoring of target exotic species. Repeat mapping and monitoring as needed to determine rates of spread and priorities for exotic plant control work. Establish pre- and post-treatment monitoring for species under treatment.

Cost/workload. $30,000 per year
2 part-time Biological Technicians and support

HAVO-28 STUDY EXOTIC PLANT CONTROL TREATMENT METHODS

Statement of the Problem. The introduction, spread, and persistence of exotic plants present the most serious, long-term threat to Park ecosystems. Highly localized exotics (Category I target species) can usually be effectively controlled by Resources Management personnel with consultation from specialists or on a trial and error basis. These methods may also be adequate for some of the more disruptive, more widely spread, and longer established Category II target species. However, effective and ecologically sound treatment methods are usually not available for the most troublesome Park weeds as many of these species are not considered to be pests except in the Park environment. Research on the Hawaiian weed species by range and agricultural interests have emphasized control using pesticides, highly destructive mechanical control measures, or cultural techniques prohibited, inappropriate, or not sufficiently effective for national parks or native ecosystems. In a Park environment, it is especially important to recognize the effects of weed control methods on surrounding native biota, depletion of the soil seed bank of well established plants, retreatment of seedlings or sprouts, and the invasion of vacated sites by other exotic species. In most cases, these factors need to be studied before treatment methods are actually applied and they certainly need to be integrated with treatment methods experiments.

Management has relied in the past on label recommendations, short-term trial and error, or anecdotal evidence as the basis for treatment methods. Methods derived in this way have not always worked, and as a result much labor and pesticide has been wasted. These experiences have taught that effective treatment methods need to have the reliability conferred by long-term, statistically sufficient research with large sample sizes reflecting the variety of plant material or habitat conditions. Efficiency of effort is especially critical because of funding and manpower limitations, the seriousness of the threat of exotic plants to the native biota, the explosive expansion of some weed species, and the rapid growth of sprouts and seedlings in a tropical environment.

Formal research has been completed on nasturtium and preliminary tests have been started on Rubus penetrans, silky oak, olive, and koa haole, species targeted for herbicidal control research. Prior research on Kikuyu grass, fire tree, and Christmasberry has been useful in indicating effective treatment methods, but some issues

about effects remain to be studied. Initial work indicates that long-term monitoring and research is required to develop treatment methods which are both effective and ecologically sound.

Alternative Actions and their Probable Impacts.

1. Continue weed treatment without intensive study of methods. Label recommendations, trial and error, antecdotal evidence, or consultation with specialists often is adequate for developing effective treatment methods for some target exotics, particularily localized species which can be controlled at sprout and seedling levels. However, without effective and ecologically sound treatment methods derived from formal research studies much time and money will be wasted in ineffectual control measures on more widely spread and longer established species. In addition, important questions of pesticide effects on native biota, soil seed bank reduction, and invasion of the site by other exotics will not be addressed. As a result, treatments may be inefficient or misdirected, non-target native species may be damaged, and greater weed problems may be created.

2. Conduct formal research on most disruptive, well established species for which control measures are not known. This will result in the most efficient use of manpower and funds and will control target exotic plants, thereby preserving native ecosystems threatened by these species. Treatment methods research results in damage to non-target organisms and soil contamination. These effects are minimized by small sample sizes.

Recommended Course of Action. Conduct formal research on the most disruptive, long established target exotic plant species for which treatment methods not currently available. Direct research toward developing practical, labeled applications of herbicides within agency constraints. Develop effective and ecologically sound treatment methods and well documented evidence for methods which require special authorization. Address problems of retreatment of sprouts and seedlings, invasion of sites by other exotics, pesticide effects on non-target native species, and soil seed bank potential. The output of any research should be an integrated weed management program that addresses the various ecological situations in which the weed is found in the Park.

Cost/workload. $50,000 per year for 5 years

HAVO-1 STUDY BIOCONTROL OF SELECTED EXOTIC PLANT SPECIES

Statement of the Problem. Some of the most disruptive non-native plant species in Hawaii Volcanoes, such as fire tree, strawberry guava, molasses grass, broomsedge, and banana poka, are too widespread to control Park-wide by mechancial or herbicidal means. Control of these species is currently carried out in selected small areas or not at all. In addition, controlling simultaneously all widely spread exotic species currently targeted for control (Category II species in Vegetation Management Overview) is not possible at current funding levels. Furthermore, the lack of effective and ecologically sound treatment methods for many target species magnifies the workload requirement and would result in undesireable disturbance to Park ecosystems if control efforts were initiated at the current state of knowledge. Because of the difficulties in controlling widespread and persistent non-native plants, a control program utilizing available biological agents is necessary, an approach NPS pest management policies require considering before the use of herbicides.

Biological agents have been used to achieve partial to highly effective control of several exotic species occurring in Hawaii Volcanoes, for example, lantana (Lantana camara), cactus, and Hamakua pamakani (Eupatorium riparium). Effective biocontrol agents are not known for other disruptive and well established exotic plant species in the Park. Therefore, an intensive research effort, involving the use of quarantine facilities and considering the effectiveness of the biocontrol agent and its impact on economic and native plant or animal species has been started. Biocontrol quarantine facilities have been constructed at Hawaii Volcanoes for entomological investigations and at the University of Hawaii at Manoa for pathogen studies. A US Forest Service (USFS) entomologist and a NPS plant pathologist are primarily concerned with biocontrol research. Field reconnaissance trips to identify potential biocontrol agents have been conducted for fire tree and banana poka. Preliminary investigations have been started on Rubus.

Economic, political, and ecological considerations preclude the acceptability of biocontrol for many candidate species. Some species or their congeners are noxious in native ecosystems but are considered to be desireable outside the Park. Permits to import biocontrol agents are controlled by the State Department of Agriculture which defines weeds in terms of agricultural, horticultural, or range interests. Therefore, biocontrol cannot be extended to likely target species as Christmasberry (a favorite

plant of beekeepers), koa haole (used as forage by cattle and erosion control), Kahili ginger (closely related to the commercially exploited species), or fountain grass and broomsedge (concerns of the sugar industry). As a result, only banana poka, fire tree, and Rubus spp. are currently targeted for biological control research at Hawaii Volcanoes. Gorse (Ulex europaeus) and Clidemia (Clidemia hirta) may also be candidates in the future.

Alternative Actions and their Probable Impacts.

1. No action. Under this alternative, biocontrol studies are not made. As a result, species too widespread to control Park-wide will invade most Park native ecosystems and form monospecific stands, thus replacing native communities with exotic ones. Because of the lack of funds and/or effective or ecologically sound treatment methods, attempts to control a number of highly disruptive species mechanically or with herbicides may be suspended. Without the possibility of biocontrol, these species will expand unchecked and degrade native communities.

2. Continue present biocontrol research program. Expand the program to additional species if ecologically safe and if importation permits can be secured. With the current level of effort, effective biocontrol agents may be found for some of the most widely spread and disruptive non-native plant species beyond current staff resources to control. If constraints on importing biocontrol agents for other candidate species are lifted, research on additional species will be undertaken, thus contributing to checking the expansion of these species. Although the impact of potential biocontrol agents on non-target native and/or economically important species is assessed in quarantine prior to release, there is a possibility that native plants, insects, or economic species may be affected. It is possible that a released biocontrol agent may behave differently in a natural setting than in the laboratory; not all potential non-target species can be tested; and some insects are capable of switching hosts. For example, it is possible that there will be some kind of impact on horticultural passion fruits and native Rubus, whose congeners are targeted for biocontrol research.

Recommended Course of Action. Continue present biocontrol research program and expand to additional target species as opportunities allow.

Cost/workload. Interagency project in which USFS performs most staff work, with support from NPS plant pathologist. Hawaii Volcanoes Resources Management funds running costs of quarantine building: $5000 per year.

Plant Pathologist's needs: $40,000, 2.4 FTE

AVO-27 STUDY EXOTIC PLANT ECOLOGY

Statement of the Problem. Considerable information on the ecology of weed species is collected in preparing distribution maps, assessing population structure, and monitoring the rate of spread of exotic plants. These data indicate how rapidly weed species are expanding and reproducing and, in some cases, assess the replacement of existing vegetation by the expanding pest species. Pre- and post-treatment monitoring evaluates the effectiveness of treatments and, for most target species, vegetation changes in treated sites following treatment.

Additional ecological information is generally needed to develop effective and ecologically sound management strategies and to establish priorities for control efforts and target species; this information is rarely available in the literature. Additional ecological data necessary for exotic plant control include life history studies and an evaluation of the role of the weed in the Hawaiian environment. Studies on seed viability, seed set, germination and establishment requirements, methods and rates of reproduction, seed dispersal, and phenological as well as other autecological and synecological characteristics of the target exotic plants are typically necessary. The objective of all of these studies is to find a point in the biology of these organisms where they are especially vulnerable. The studies are also very important in the development of biological control strategies.

Strategies to deplete the seed bank of the target species and appropriate methods for their accomplishment are important in control programs for almost all exotic species. For example, seed viability characteristics indicate how long follow-up treatments are needed, or if pre-emergent herbicides, prescribed fire, or other soil treatments could be used. The magnitude of the soil seed bank needs to be characterized in terms of the number of seeds present and their distribution in various strata. Germination and establishment requirements are central to an understanding of the method by which the target species invades an ecosystem. This phase of the life cycle is frequently the one in which the species is the most vulnerable. For instance, a target species may require soil disturbance or highlight conditions for establishment and control efforts to preclude reproduction and spread may be confined to removing sources of soil disturbance.

The reproductive mode of an introduced plant may indicate how seriously these plants threaten other vegetation. For example, some disruptive exotics may be spreading vegetatively and not by seed. They will, therefore, remain confined to that immediate area and are much more amenable to control. Dispersal distances and vectors have a bearing on the feasiblility of controlling a species geographically adjacent to a source of disseminules and permit the prediction of patterns of range expansion. This type of information is essential when considering species whose center of distribution is areas adjacent to the Park.

Phenological information may indicate control strategies, seasonal timeliness of treatments, and length of treatment intervals. For example, treatments can be confined to plants of one sex in strictly dioecious species, systemic herbicide applications generally are more effective during periods of active growth, and treatment regimes can be timed to preclude fruiting and further contributions to the seed bank.

Understanding the ecological role of exotic species, interactions with existing vegetation, and impacts on biogeochemical cycling or other ecosystem processes is important in targeting species for control and developing effective and ecologically sound control strategies. An equilibrium between exotic and native species may be all that can be hoped for in Hawaiian ecosystems and some exotic species may have to be tolerated. Assessing acceptable population levels of exotics must be based on their ecological impacts in the plant community. This approach does not conflict with the strategy of controlling highly localized exotics before range expansions occur or the elimination of exotics from selected areas. The ecological role of exotic species may vary by ecosystem and approaches to management may differ accordingly. Assessing the ecological role of target exotic species in different ecological settings may help shape ecosystem specific management strategies.

Alternative Actions and their Probable Impacts.

1. Develop control strategies without understanding the ecological characteristics and role of weed species. In this approach critical information about the seed set, viability, and dispersal, soil seed bank, germination and establishment requirements, phenological characteristics, and ecological role of exotic species will not be available. Management will be based on distribution mapping, population structure studies, and rate of spread monitoring and intuitions about ecological features of the

pest species. As a result, target species may be prioritized incorrectly or inapproriate control strategies may be taken, wasting manpower and funds and failing to control exotic plant species and safeguard native ecosytems.

2. Collect relevant ecological information about weed species. The biology of the weed species will be studied with a view to understanding the role of the weed in the ecosystems which it infests. Its life history will be investigated and in conjunction with the managers the potential of the species for biological, herbicidal, or mechanical control will be evaluated and cooperative studies using the best control approach developed. Using this approach, it is hoped that a integrated management program can be developed, weed species can be controlled, and native ecosystems protected. Most weed ecology studies are non-manipulative; therefore, no significant impacts are anticipated.

Recommended course of action. Weed control in national parks in Hawaii is in its infancy. More information is needed before effective control strategies can be developed. There is little likelihood that outside agencies will develop this information base for us. The Park will therefore have to obtain most of the information for itself. Cooperative efforts with the State Department of Agriculture personnel are already underway but these contacts have highly biased interests. We must therefore develop a dual program. The first, the evaluation of the distribution and impact of weeds and the concurrent development of herbicidal control techniques, must continue. However, the second, a research program to develop a greater understanding of the biology and ecology of the important weeds, must be initiated. This second program will work interactively with the first so that herbicide use is kept to the minimum.

Cost/workload. $40,000 per year, duration dependent on number of species studied and nature of these studies
CPSU contract

HAVO-24 STUDY RECOVERY OF VEGETATION FOLLOWING REMOVAL OF FERAL ANIMALS

Statement of the Problem. The vegetation of the drier, woodland, scrub, and grassland communities in the Park is recovering following the nearly complete removal of feral goats from these areas. Small sections of rainforest and mesic forest communities are recovering following the removal of feral pigs. Studies of the recovery of vegetation released from feral animal depredations are needed to evaluate patterns of plant succession, indicate future management needs in these areas, and provide a model of zero impact levels.

The flora of the Hawaiian Islands has evolved in the absence of mammalian herbivores and thus has not undergone selection for resistance to herbivory and is particularly vulnerable to depredations by feral animals. Feral goats and pigs have been present in Hawaii for more than 150 years. Goat populations have been reduced from levels of above 20,000 in 1972 to probably less than 100 in 1984 in areas below 6,000 feet. Funds to fence subalpine and alpine areas between 6,000 and 8,500 feet have been requested. Populations of feral pigs have been successfully reduced through exclusionary fencing and systematic hunting in two control units comprising approximately 1,700 acres of rainforest. Control efforts are in progress in two other fenced units and fence construction is in progress or planned for two additional units involving a total of 8,900 acres.

Although a successful control program has reduced depredations by goats on native plants, it has also released exotic plant species, formerly held in check by grazing or browsing. Exotics compete with native species and create hazardous wildfire conditions. Lowland vegetation has noticeably recovered in areal cover and biomass since the removal of goats. Rapid successional changes have taken place in some grassland communities. The success of the scattered individuals or groups of the few native species found in the exotic grass and shrub dominated lowlands of the central and western sections of the Park, the area most heavily impacted by goats, is uncertain. In the eastern section of the Park's lowlands, native vegetation appears to be doing well, although several exotic species have the potential for disrupting this recovery. Exotic grasses have invaded the understory of dry woodlands above the coastal lowlands, competing with native understory plants, presumably disrupting the reproduction of native trees, and creating dangerously high fuel loadings. Native vegetation appears to be recovering

and competing successfully with exotics in the dry upland, mountain parkland communities. Successional changes and the capacity of native plants to compete with exotics in areas recovering from goats need to be monitored in order to develop management strategies for these areas which may include exotic plant control and ecosystem restoration through planting. This information will also be used to prioritize resource management efforts in these areas relative to other ecosystems in the Park.

Sixteen permanent transects were established in the late 1970`s in areas of the Park liberated of goats and these have been periodically re-evaluated. These transects were established after most goats were removed and a preliminary analysis indicates there has been little vegetation change since establishment and that long-term monitoring is necessary to assess vegetation changes.

The results of exclosure studies in the lowlands have been published by Mueller-Dombois and Spatz (1975). Williams (pers. comm.) has established permanent plots in the Kalapana lowlands. These studies require periodic re-evaluation and expansion of sample size.

Pig populations have been substantially reduced in four management units to date. Study plots have been established to monitor changes which result from control efforts. In addition, pig exclosures have been established in five rainforest areas. Most of these exclosure studies indicate marked recovery of native vegetation inside exclosures and continued degradation of vegetation outside. Pig exclosure studies document recovery of vegetation and indicate management needs that result from ungulate control. They furthermore provide a zero impact level with which to assess recovery and acceptable pest levels in control units, where low levels of pigs may have to be tolerated in even the most successful control program. Pig exclosure and vegetation transect studies need to be expanded to other rainforest communities and vegetation types impacted by pigs.

Alternative Actions and their Probable Impacts.

1. No action. Do not assess recovery of vegetation following removal of ungulates. In this way the success of the program cannot be documented and additional management needs will be based on intuition or casual observation. This approach will lead to inappropriate actions, wasted funds, and the failure to address threats to native ecosystems.

2. Continue the program at current levels. The sixteen goat recovery transects, five pig exclosures, and study plots in pig control units will continue to be monitored and valuable data with management implications will be collected. However, these studies are inadequate to address questions about the variety of plant communities for which information is needed, especially as pig control activities expand into different kinds of mesic and rainforest communities.

3. Expand vegetation recovery monitoring and exclosure studies to provide a more adequate information base necessary for appropriate, efficient, and ecologically sound management of areas liberated of goats or pigs. In areas freed of goats, vegetation recovery studies will indicate successional patterns, the capacity of natives to compete with exotics, and appropriate management strategies to deal with exotic threats and restore native vegetation. In pig control units, vegetation monitoring can assess the recovery of native vegetation and indicate further management needs, especially in terms of exotic plant control. Exclosure studies will predict vegetation changes and suggest management needs prior to unit-wide management and provide a base level for comparing success of management strategies and pig control efforts. Vegetation monitoring has essentially no lasting impacts on Park ecosystems. Exclosures result in limited and temporary damage along fencelines constructed.

Recommended Course of Action. Expand vegetation recovery monitoring and exclosure studies by taking the following actions: analyze and interpret data from all existing studies; continue to monitor existing exclosures and transects on a yearly or biennial basis; and standardize methods and quantify to make studies statistically sufficient. Expand and replicate exclosure studies in rainforest communities in Puhimau, Olaa, and Mauna Loa Strip, where pig control work is planned. Long-term monitoring of vegetation should be established or augmented in the following plant communties: subalpine scrub and mountain parkland on Mauna Loa; open, wet ohia-hapuu (Cibotium glaucum) forest of Olaa Tract; closed, wet ohia-hapuu forest of the East Rift east of Napau Crater; mesic lowland forest of the Kalapana Extension; drier, open ohia woodland near the Kalapana Trail; closed mesic forest in Kipuka Ki; closed wet ohia forest and open ohia-uluhe (Dicranopteris linearis) scrub in the Puhimau/Puu Huluhulu areas: and dry, open ohia woodland in the cinder fall areas below Puu Puai and in Kipuka Kahalii. Map and quantify scattered populations of native plants in the coastal lowlands for re-evaluation.

Cost/workload. $20,000 per year
Biological Technician

HAVO-23 DELINEATE AND STUDY SPECIAL ECOLOGICAL AREAS

Statement of the Problem. Despite generally deteriorated Park ecosystems, managers are aware of the presence of essentially intact native ecosystems. Some of these areas are representative of broader ecosystems; others are biologically rich or unique biotic communities. Since there are budgetary, manpower, and technical limitations in controlling introduced species on a Park-wide basis, intensive management of smaller, intact areas within the Park is needed. Intensive management will preserve remnant ecosystems and relatively intact assemblages of native plants and animals and conserve genetic material. These areas would also serve as models of successful management and as baseline areas for evaluation of native ecosystem processes in other areas.

In order to manage effectively and intensively in biologically important areas of the Park, these areas must first be delineated with care, taking into consideration biological, research and education values, and the capacity to recover and be managed. Intensive investigations and monitoring are needed to determine site specific management needs and to assess the effectiveness of management programs. Relative agreement exists for selecting certain biologically rich remnant areas which meet most criteria described above; however, information needed for selecting other areas is not readily available, especially because conditions change rapidly with feral animal disturbance and exotic plant invasion and all areas of the Park have not been adequately studied. Intensive monitoring and research have not been systematically conducted to the extent necessary to develop site specific management plans in any candidate Special Ecological Area.

Alternative Actions and their Probable Impacts.

1. Continue present management course which can be briefly summarized as control of feral pigs in units established for geographic or research needs and control of localized exotic plant species. This management approach fails to integrate exotic animal and plant control and neglects many intact native communities threatened by one to several exotic plant species not controlled in the Park because they are too widely spread for Park-wide control efforts. As a result, valuable and manageable biological resource areas are not targeted for the kinds of management they require to preserve their essentially native character.

2. Delineate areas for intensive study and management. Select high value resource areas to be targeted for intensive study and management and monitor natural processes and effectiveness of management programs in these areas. Integrate this program with established exotic plant and feral animal control programs. Monitoring programs may result in the minor aesthetic impact of plot and transect markers. Manipulative research will have similar impacts to those described in more detail in exotic plant and animal control project statements; in brief, these are minor soil disturbance, introduction of weeds, and loss of some native plants along constructed fencelines, and damage to non-target native plants in exotic plant treatment sites.

Recommended Course of Action. Delineate areas for intensive study, monitoring, and subsequent management. Develop criteria for selecting representative areas of Park ecosystems and unique or biologically rich biotic communities. Conduct field reconnaissance and update previously conducted surveys to assess current status of Park ecosystems and compare biological conditions and values. From these field studies, delineate units for intensive study and management. Investigate site specific management needs through monitoring programs and manipulative research addressing all threats to the biotic community selected. Establish baseline monitoring to assess the effectiveness of management programs.

Cost/workload. $40,000 per year for 3 years
2 Biological Technicians

HAVO-60 MANAGE SPECIAL ECOLOGICAL AREAS

Statement of the Problem. Representative and biotically diverse areas of native ecosystems in the Park require intensive management to preserve native assemblages of plants and animals and maintain native ecosystem processes. Control of all highly disruptive exotic plant species and feral animals is not possible throughout the Park without substantially increased funding and staffing; therefore, an intensive level of management not possible on a Park-wide basis must be targeted for the most biologically significant representative or species rich sites. These Special Ecological Areas will not only preserve the most valuable and representative biological resources and genetic material, but serve as models to evaluate management strategies and assess changes in less intensively managed areas. The rationale for delineating and intensively managing important biotic communities is outlined in greater detail in HAVO-23.

In Special Ecological Areas, exotic plant control efforts can extend to species such as banana poka and fire tree, while biological control is being researched, species such as broomsedge which cannot be controlled by any means over the entire Park, and species such as fountain grass or koa haole, which may prove to be intractable to Park-wide control programs. Successful feral pig control can take place in units small enough for current control practices and exotic animal control can include programs for other disruptive introductions such as mongoose (Herpestes auropunctatus), rats, and yellow-jackets wasps (Vespula pennsylvanica).

Intensive management of important biological areas supplements, rather than supplants, current management strategies to control localized exotic plants Park-wide while populations are small enough to be contained. This management approach parallels that taken with feral animals which can be controlled feasibly only in small units. The current approach emphasizes management of high value resource areas.

Management of Special Ecological Areas is based on an understanding of site specific biological conditions and management needs. An intensive research and monitoring program accompanying delineation of Special Ecological Areas (HAVO-23) will provide the information base for effective management. It is not expected that all introduced organisms will be removed; research and monitoring will indicate what population levels of each exotic can be tolerated without disruption of native ecosystem processes or significant replacement of native biota.

Alternative Actions and Their Probable Impacts.

1. No action. By limiting exotic control strategies to current approaches, the following outcomes are expected: only those exotic plant and animal species localized enough to be controlled by herbicides or mechanically will be controlled; the most disruptive exotic plant species too widespread for localized control will overrun important native plant areas, displace native biota, and destroy the most valuable assemblages of native organisms and biotic communities in the Park; and control of exotic plants and animals will not be integrated and applied to the most biologically important areas in Park.

2. Intensively manage Special Ecological Areas. Exotic plants and animals not controlled or controllable on a Park-wide basis will be controlled in the biologically most significant areas in the Park. Integrated exotic animal and plant management will protect native assemblages of organisms and native ecosystem processes in the most biologically valuable resource areas. Managing Special Ecological Areas will result in negative environmental impacts similar to those resulting from feral animal and exotic plant control described in project statements concerning these activities.

Recommended Course of Action. Intensively manage Special Ecological Areas. Representative biotic communities and biologically diverse and unique areas will be delineated by prior study (HAVO-23). Feral animal and exotic plant control will be integrated and focused on these biologically valuable areas and populations of exotic species not controllable on a Park-wide basis will be reduced to acceptable levels. Management strategies and tolerance levels for exotics will be determined by research studies on ecological processes and ongoing monitoring of community trends and the impact and effectiveness of management programs.

Cost/Workload. $ 20,000, 2 FTE first year
$ 40,000, 2 FTE, per year second and third years
$100,000, 2 FTE, per year fourth and fifth years

HAVO-44 STUDY ECOSYSTEM RESTORATION

Statement of the Problem. Efforts to restore the altered and disturbed coastal lowland ecosystems in the Park have been stymied by the completeness of the disruption of native ecological processes and communities in these areas. These ecosystems have been disturbed by feral goats and weeds for so long that the seed banks of native plants has been highly depleted or have disappeared. Management strategies in more intact ecosytems of the Park emphasize the removal of the disturbance sources; once the disruptive introduced plants and animals are controlled, natural ecological processes can resume and native assemblages of organisms recover. This approach is inadequate in severely modified and disturbed central and western lowlands characterized by depleted native plant seed banks and seed sources. Native plant species need to be reintroduced to these areas and their ability to compete with non-native species subsequently assessed.

Alternative Actions and their Probable Impacts.

1. Continue present approach. Current management strategies in severely disturbed lowland areas focus on feral goat control and containment of the most disruptive weeds such as fountain grass and koa haole whose dominance would most assuredly preclude the reestablishment of native biota and perpetuate the exotic character of the lowlands. The distributions of rare native plant species in the lowlands are being mapped incidental to mapping the distributions of fountain grass and other exotics. Many plantings of native species have been mapped and their success monitored.

2. Reestablish a planting program to reintroduce native plants to lowland areas. Without the proper information base which remains to be developed, this program would probably not be ecologically sound or successful, resulting in wasted funds and poor environmental management.

3. Study ecosystem restoration in the coastal lowlands. In this way the feasibility and proper techniques of restoring native ecosytems in the lowlands can be studied on a small scale before larger management programs are initiated, thereby avoiding wasteful or unsound programs and facilitating the restoration of lowland ecosystems. Outplantings may suppress some exotic plants. Damage to cultural sites will be avoided by selecting areas without cultural resource significance.

Recommended Course of Action. Study the feasibility and proper techniques of ecosytem restoration in the coastal lowlands to establish an information base for a management program in this Park habitat. A small-scale, closely monitored experimental planting program using seeding and other techniques will be conducted to determine if ecologically appropriate desired native plants can become established from seed and survive under existing habitat conditions. It is recognized that plantings will not substitute for the control of feral goats and alien plant species. Naturally open woodlands and forests, for example, are not sufficient to preclude the establishment of exotic species such as fountain grass and koa haole; therefore, plantings are not viewed as a viable alternative to exotic animal and plant control. Ecologically appropriate species will be used within the constraints of limited knowledge of the historical composition of lowland ecosystems. A research proposal outlining the proposed experimental planting program will be circulated for comment before proceeding.

Cost/workload. $10,000, first year
Part-time Biological Technician
$ 5,000 per year, second and third years
Part-time Biological Technician

HAVO-47 STUDY CAUSES OF REPRODUCTIVE FAILURE OF ENDANGERED, THREATENED, AND RARE PLANT SPECIES

Statement of the Problem. Many of the 43 candidate endangered/threatened, and 39 rare plant species in Hawaii Volcanoes are not reproducing adequately to replace themselves. Some of these species require formal research studies to determine the causes of reproductive failure so that corrective management actions can be taken.

More flowering plants in Hawaii are in danger of extinction than in any other state in the nation. In Hawaii Volcanoes, 18% (43 of 240) native vascular plant species are listed as candidates under review for endangered or threatened status. An additional 39 species are considered to be rare within the Park. Fourteen other rare species are thought to occur within the Park but essentially nothing is known about their current distributions and reproductive success.

Human introductions are the root cause of reproductive failure in Hawaiian native plants. Introduced organisms are responsible for the following problems: depredations of goats and pigs; girdling of stems and the predation of seeds by rodents; loss of pollinators; competition from exotic plants; loss of vigor resulting from disease or arthropod pests; reductions through unnaturally intense wildfire; and loss of vigor or adaptability due to inbreeding depression or genetic drift.

An assessment of the status of endangered, threatened, and rare native vascular plant species has been started (HAVO-16). In determining distribution and reproductive success, these assessments will identify rare species not reproducing adequately to sustain viable populations. A triage approach will distinguish species suitable for perpetuation only in arboreta, species reproducing adequately, and those taxa requiring further management and research. Effective management is predicated on an understanding of the causes of reproductive failure. This understanding may surface in preliminary assessment stages or may require formal research to separate the various probable causes of reproductive decline outlined above.

Alternative Actions and their Probable Impacts.

1. No action. Continue current program in developing corrective management programs based on intuitions about the causes of reproductive failure developed through rare plant inventory work and field assessments of reproductive status. This approach is probably adequate for plant

species in which causes of reproductive failure are easy to separate and management strategies are obvious. For other species, it may lead to wasted efforts, inappropriate or counterproductive management actions, and the continued decline or extinction of species.

2. Study reasons for reproductive failure of selected declining species. Formal research will result in positive management of rare species either in applying effective, ecologically sound, and economically efficient corrective management actions or understanding why all management efforts are doomed to failure and further actions are pointless. In-depth studies of several species will probably provide insights into conservation of other rare species not formally researched and enhance the understanding of extinction in island biota. Although investigation of the reproductive failure of rare plant species may include some manipulative research, a significant impact on native organisms is not anticipated because of the limited scope of the research.

Recommended Course of Action. Conduct formal research on reproductive failure of selected declining species identified by preliminary plant inventory work and field assessments of reproductive status. This kind of research must be targeted to threatened and endangered species, ecologically important species, or species significant to understanding the problem of extinction in Hawaii. Because small populations may experience inbreeding depression and genetic drift, genetics and breeding systems may need to be addressed in a research program on rare plants.

Cost/workload. $25,000 per year
CPSU contract

HAVO-16 STUDY STATUS OF ENDANGERED, THREATENED, AND RARE PLANTS

Statement of the Problem. More flowering plants in Hawaii are in danger of extinction than in any other state in the nation. In Hawaii Volcanoes alone, approximately 18% (43 of 240) of the native plants are listed as candidates under review for endangered or threatened status; Park Service policy mandates management of these species as endangered. An additional 39 species are rare, at least within the Park. Fourteen other species are of uncertain status in the Park in terms of presence, abundance, or reproductive success. Seven species are known only from the Park. Eighty-five percent of the native plant species found within Hawaii Volcanoes are endemic to the Hawaiian Islands and therefore of special biological significance.

Native plants have suffered from the direct or indirect effects of man. The threats include: browsing by feral goats, disturbance by feral pigs, girdling or seed predation by various rodents, competitive exclusion by non-native plants, loss of native pollinators, introduced diseases, several problems associated with exotic arthropods, and wildfires. Habitat degradation due to one or a number of these threats is also significant.

A comprehensive assessment of the status of endangered, threatened, and rare plants has been started. In this assessment, 96 rare plants have been identified (Lists A, B, and C) and prioritized for study; the results of propagation efforts in the lowland dry forest and coastal lowlands have been summarized; a computerized system of rare plant locations has been developed; and standardized inventory summaries have been started for plants most frequently propagated in the past and for a number of candidate endangered/threatened plant species. The most critical task in evaluating the status of rare plant species is assessing distribution, abundance, and reproductive status. Distribution mapping indicates essential habitat for candidate species to be treated as endangered. Once distribution, abundance, and reproductive status have been determined by field studies, those plants requiring further research can be identified and appropriate management strategies developed.

Alternative Actions and their Probable Impacts.

1. No action. Under this alternative, endangered, threatened, and rare plant populations will not be assessed. As a result, threats to plants will not be systematically identified and informed, planned corrective

management actions cannot be taken. As a result, rare plant populations could decrease to the point where they cannot recover and become extinct. Efforts to restore these species could be wasted on ineffective programs.

2. Conduct research on the reproductive failure of rare native plants. Under this alternative, considerable effort will be expended which may not be of benefit to management if studies are undertaken on species which are common elsewhere, or are naturally rare and declining, or are without hope of recovering.

3. Conduct research on the distribution, abundance, and reproduction of rare plants. Under this alternative, species can be screened initially for suitability for further study, field studies can be carried out on appropriate taxa, and research needs and management strategies identified. Manpower will be applied efficiently by targeting research for appropriate species and developing the information base for effective management, concentrating particularly on areas where other management activities will enhance the recovery program. The ultimate objective of the research program is to produce a recovery plan for each target species.

Recommended Course of Action. Conduct research on the distribution, abundance, and reproduction of endangered, threatened, and rare plants. Develop a list of rare plants and establish priorities for further study based on the following categories: candidate endangered or threatened plant species, rare plants of uncertain status in the Park, species rare in the Park but not listed as candidates, and plants not necessarily rare but apparently threatened by competition, disturbance, or other factors. Write an inventory summary for target rare species based on field experiences of local botanists, herbarium collection data, and available botanical literature, and include the following items of information: name, taxonomic considerations, description, status in the Hawaiian Islands, present distribution, former distribution, habitat and ecology, current reproductive success in the wild, propogation efforts and techniques, and known and potential management problems. The inventory summaries will be used to recommend management strategies for some species and recommend other species for field studies to assess distribution, abundance, and reproductive success. These studies will be modelled for long term monitoring. Following inventories and field studies, target rare plant species can be sorted into three groups using a triage approach: those plants suitable only for continuation in arboreta, (e.g., those species where the pollinators are

extinct, species in which only one sex is extant, species ravaged by pests or diseases which need constant human intervention); those requiring no further studies or management; and those needing further study of factors underlying lack of reproductive success. Field studies will be used to complete native inventory summaries and will be consolidated into technical reports. A particular emphasis will be placed on developing a program to maintain and enhance the natural genetic diversity in the all of the managed species. Assessing the reproductive status of rare plant species is non-manipulative research and will therefore not have negative impacts on Park ecosystems.

Cost/workload. $30,000 per year
CPSU contract

HAVO-59 MANAGE ENDANGERED, THREATENED, AND RARE PLANT SPECIES

Statement of the Problem. Many rare plant species in Hawaii Volcanoes require intensive corrective management. A significant percentage of the native flora of the Park is threatened with loss or extinction by the activities of man or his introductions. These anthropogenic causes of reproductive failure or habitat loss need to be redressed, preferably by habitat manipulation rather than a planting program.

Forty-three of the approximately 240 native vascular plant species found in Hawaii Volcanoes are listed as candidates under review for endangered or threatened status. Thirty-nine additional species are considered by staff botanists to be rare, at least within the Park. The presence, abundance, or reproductive status of fourteen other species in the Park is not known. The high percentage of endemism (85%) of vascular plant species found in the Park confers special biological significance to the flora of Hawaii Volcanoes. NPS policy requires management for perpetuation or protection of all rare or unique plant species.

Native plants have suffered from the direct or indirect effects of man. Many are threatened by the direct loss of habitat resulting from historical land use practices, the depredations of feral pigs, goats, rats, and arthropods, or suffer from competition from exotic plants, loss of pollinators, or the spread of introduced diseases. Most of these problems can be addressed by localized habitat manipulation such as the control of feral pigs, rats, or non-native plants. Active propagation of threatened species will be used as a last resort or a temporary measure. Park-wide control of localized exotic plants and feral goats and control of pigs in small management units benefit many populations of rare plants. Control of all exotic threats in intensive management units (HAVO-60) will benefit other populations. Additional corrective management actions will be needed for many other populations of target rare plant species to address their site specific needs.

The information base needed to formulate rehabilitative management strategies for rare plants is being developed. A systematic assessment of the status of rare plants has been initiated (HAVO-16). A computerized data base on the location of rare plant species has been established. Standardized inventory summaries, listing important ecological and distributional information, are being prepared for target rare species (c.f. Vegetation

Management Overview). The status and rehabilitative management actions for some target rare plant can be inferred from these summaries. Other species require further field studies to determine distribution, abundance, reproductive status, or causes of reproductive failure.

Alternative Actions and their Probable Impacts.

1. Take no action. Rare plant species will not be managed on a site specific basis. Some rare plant populations will not suffer because they benefit from Park-wide management of exotic threats or control of all significant threats in intensive management units. These kinds of management efforts will not address problems of other rare plant populations. Consequently, many rare plants will suffer further losses or extinction.

2. Manage rare plant species according to recommendations developed in rare plant assessments, field studies, and research on causes of reproductive failure. In this way, population levels and reproductive success of native rare plant species can be restored and native biota and natural diversity maintained. Because corrective management actions involve some form of habitat manipulations, environmental impacts are similar to those outlined in project statements that describe exotic plant control, feral pig control, management of remnant ecosystem, and rare plant assessments. Native organisms are not expected to be adversely impacted in a significant way by native plant management actions.

Recommended Course of Action. Manage rare plants to maintain populations at levels high enough to sustain natural reproduction and the genetic diversity these species need to continue to survive, adapt, and evolve. Implement recommendations developed from rare plant assessments and research. Redress anthropogenic sources of population decline through site specific habitat manipulations such as localized exotic animal or plant control. Propagate declining species when necessary on a temporary basis. Focus management efforts on populations not benefiting from management efforts carried out on a Park-wide basis or in intensive management units.

Cost/workload. $40,000 base increase
2 Biological Technicians and support

HAVO-20 STUDY ECOLOGICAL ROLE OF FIRE

Statement of the Problem. The existence of natural sources of ignition, fuels dry enough to support fire, and species adapted to recover from fire suggest that natural fire undoubtedly played some ecological and evolutionary role in native Hawaiian ecosystems. Aboriginal Hawaiians used fire extensively in the dry lowland areas for clearing forest and maintaining a savannah-like environment. Studies of the role of fire have been hampered by our inability to access many historical records (many are in Hawaiian or buried in archives). Also, tropical vegetation is not suitable for standard fire history studies and the arrival of several fire-adapted non-native plants has confounded natural fire effects. Introduced plants, particularly fire-stimulated grasses such as broomsedge and fountain grass, dramatically increase in cover following fire at the expense of native species. Introduced grasses undoubtedly raise fire intensities, in many cases probably above levels to which native species are adapted. The presence of human sources of ignition and heavy loadings of fine fuels have increased the frequency and areal extent of wildfires. With successive fires Park forests and woodlands are incrementally degraded to fire-climax exotic grasslands.

Fire, whether of natural or human origin, does not help achieve Park mangement goals since it degrades native ecosystems by favoring exotic species. For this reason, the current fire management plan stipulates suppression of natural fire in most areas and conditional suppression in limited, mostly exotic-dominated portions of the Park. The failure to suppress fires in severely disturbed environments exacerbates the exotic character of such areas. Fire suppression capabilities in the Park's fire-prone environment are especially critical with a fire management plan based on fire exclusion. Fire suppression capabilities requisite to implementing the fire management program in the Park are limited in Hawaii in comparison with parklands on the Mainland because of the lack of aerial surveillance, air tankers, and trained personnel. Suppression problems are compounded by a year-round fire season, heavy fuel loadings of fine fuels, and the apparent lack of appropriate local fuel models for predicting fire behavior. Fire behavior observations have not been tested against possibly appropriate Mainland fuel models, but the capability to develop local fuel models exists if needed. The presence in the Park of 43 candidate endangered plant species and 39 other rare native plants, essential habitats of the endangered nene (Hawaiian goose) and endangered forest birds and unique or special biotic communities, and cultural sites warrant absolute fire protection. The

protection of special biological or cultural resources from the effects of fire or fire suppression activities is hindered by the lack of an atlas of high value resource areas.

The literature on the ecological role of fire and fire effects is extremely limited in Hawaii. The Park's fire management policy is based therefore more on intuitive impressions of short-term fire effects than on long-term quantitative studies. Several fire effects studies have been initiated and require follow-up. Additional long-term monitoring is needed and recent man-caused, natural, and prescribed fires provide a rich variety of study sites in a diversity of vegetation types. The impact of a complete suppression policy on native ecosystems also needs to be assessed.

Alternative Actions and their Probable Impacts.

1. No action. This alternative is characterized by the current situation. Fire suppression capabilities are hampered by the lack of appropriate fuel models. Areas of special ecological significance will continue to be degraded by fire or fire suppression activities, and fire management policy will be based on an inadequate information base.

2. Improve information base for fire management. Under this alternative, fire effects and successional patterns following fire will be quantitatively assessed and translated into sound fire management policy. Significant ecological areas will be mapped and thereby protected from the untoward effects of fire or fire suppression. Local fuel models will be developed and will aid in fire suppression, thus protecting resources. It is expected that fire ecology will be directed at monitoring of plant succession following fire. This is a non-manipulaitve form of research with no significant impact on habitat features.

Recommended Course of Action. Enhance knowledge of fire effects and plant succession following wildfire by revitalizing ongoing studies and initiating new investigations. Develop an atlas of significant resource areas, fuel loads in each vegetation type, flammability indices of the dominant species, and other relevant information. Use existing fuel models or develop local fuel models if necessary. Increase the fire suppression capabilities of the Park.

Cost/workload. $50,000 per year for three years for studies

HAVO-17 STUDY STATUS OF PATHOGENS ON NATIVE PLANTS

Statement of the Problem. Native, co-evolved pathogens generally do not pose a threat to native plant life. Introduced pathogens may reduce the vigor, competitiveness, or reproductive capacity or effectively eliminate native host plants. Moreover, the effects of a native pathogen may be intensified with enhanced dispersal brought about by an introduced vector. Hawaiian woodlands and forests may be rather vulnerable to destabilization in that the woody plant or tree fern strata of these plant communities consists of very few species. Loss of one of these species, such as koa, ohia, a'ali'i (Dodonaea spp.), pukiawe (Styphehia tameiameiae), or hapuu would radically alter community composition and structure. It might also be the case that insular species which evolved in isolation and are now exposed to many introduced pathogens, may also be more vulnerable to invasion by exotic pathogens.

Studies are in progress for several potentially serious pathogens on several dominant native species: A'ali'i, affected by a witch's broom of unknown cause; and koa, suffering from native rusts whose spread may be enhanced by an introduced psyllid vector and possibly from a lethal vascular wilt fungus. Pathogens were also suspect initially in ohia dieback but a primary pathogen could not be found. Recently, a fungus found growing through the bark of dying trees has been suggested as a pathogen important in ohia dieback.

Studies of pathogens on native plants in a national park usually do not result in the kinds of management implications that can be made in an agricultural, silvicultural, or horticultural setting; in a park environment, management options rarely include containment of a pathogen by chemical or mechancial means, silivcultural techniques, or the breeding and culturing of resistent strains of the host plant. However, pathogen studies may determine the identity of the causal organism, if the pathogen is introduced or native, and thereby interpret perturbations observed and expected in native vegetation. In so doing, they provide valuable information for interpreting and predicting vegetation dynamics essential for management strategies and prioritizing management actions on diseased species.

Alternative Actions and their Probable Impacts.

1. No action. If pathogens on native plants are not studied, pathogens will not be identified, their native or exotic status will not be clarified, and the effects of

disease on vegetation dynamics will be unknown. As a result, wasteful management strategies may be developed or actions taken that are futile or counterproductive.

2. Continue current pathogen studies and expand studies to additional biologically significant host species or pathogens as potentially important diseases are expressed. In this way, appropriate management strategies can be developed based on changes occurring or expected in vegetation structure and function resulting from the effects of disease on important native plants. Management efficiency will be enhanced and native ecosystems optimally managed. No environmental impacts are expected from this essentially non-manipulative research.

Recommended Course of Action. Alternative 2 is recommended. Current pathogen studies will be completed and new research undertaken on important host species as conditions warrant. This approach will provide important information leading to understanding vegetation dynamics affected by plant disease and appropriate management strategies and actions.

Cost/workload. $15,000 per year
Research Scientist and Research Technician

HAVO-65 UPDATE PLANT CHECKLIST

Statement of the Problem. The Park's plant checklist needs to be updated, the herbarium and botancial data storage and retrieval system require upgrading, and plant inventory surveys need to be expanded to support Research and Resource Management programs.

Many plant species, including the ferns which constitute about 25% of the vascular flora of the Park, were omitted from the most recent Park checklist, Fosberg's Revised Checklist of Vascular Plants of Hawaii Volcanoes National Park (1970). In addition, many species have been discovered in the Park since the publication of this checklist. Frequent updating of checklists is necessary in a park whose flora includes many rare species and frequent introductions of new species. Past Park collections have not focused on systematic collections in different ecosystems or geographical areas and new additions to the Park, such as Olaa Tract or Ainahou Ranch, are poorly collected. Exotic species and systematically difficult taxa of native species are poorly represented in the herbarium. The lack of duplicate collection material diminishes the value of the herbarium as an identification resource and a repository of distributional information. Collections of non-vascular plants (mosses, liverworts, lichens, algae, and fungi) are incomplete to nonexistent. Non-vascular plants are constituent elements of the biota meriting protection and management and often serve as sensitive indicators of disturbance, ecological change, or the impacts of management programs. Label information such as collection site, population status, and other ecological data is not readily retrievable because this data base is not computerized. A computerized data base for new sightings and collections has been recently established.

Distributional and abundance data derived through systematic collecting and an updated herbarium and data storage and retrieval system are essential to research and resource management programs: they supplement quantitative vegetation studies; they serve as a baseline to assess current research and resource management needs and evaluate the effects of management programs; they aid in planning such as in delineating biologically significant areas and priortizing these areas for intensive management; and they are needed in assessing the status of endangered, threatened, or rare plant species. The identification of exotic plants is essential in literature searches on the biology or treatment methods of target species and supplements early detection of new introductions while localized enough for control efforts.

Alternative Actions and their Probable Impacts.

1. Follow the present course of action. Under this alternative, plants are collected opportunistically rather than systematically, large areas of the Park are poorly inventoried, non-vascular plants are ignored, weaknesses in the herbarium are not rectified, many exotic plants are not identified or detected, and collection data are difficult to access. As a result, a valuable data base essential in resource management planning will not be utilized, management and research needs and biological resources will not be identified, and the impacts of management programs will be inadequately evalauated.

2. Update plant checklist and upgrade collections. These actions will provide the information base about plant distributions and abundance necessary for making ecologically sound decisions and will improve the value of the herbarium as an identification tool and a repository of readily accessible data on distributions and abundance. Collections made by knowledgeable botanists collecting minimal material necessary of rare taxa will not have a significant impact on native plant species or Park ecosystems.

Recommended Course of Action. Revise plant checklist to include current collection information, upgrade herbarium by incorporating collections of poorly represented groups or species and clarifying taxonomically difficult taxa, computerize collection data for improved access, expand and systematize plant collections particularily in poorly investigated sites, and initiate the collection of non-vascular plants. The current level and quality of curatorial and collection work, conducted incidental to other resource management and research activities, are inadequate for utilizing this potentially valuable information base in making ecologically sound resource management decisions and evaluating their impact.

Cost/workload. $50,000 per year for 3 years
CPSU contract

HAVO-68 IMPLEMENT PHOTO-POINT MONITORING SYSTEM

Statement of the Problem. A photo-point monitoring system is needed to augment quantitative resource monitoring efforts. Dramatic changes are occuring in plant communities in Hawaii Volcanoes resulting from non-native plant invasions, succession following wildfire, recovery of vegetation after removal of feral animals, and lava flows. Quantitative studies are time consuming and labor intensive and therefore inadequate to record these kinds of vegetational changes in the Park. Photographs illustrating plant succession in the Park are available in private collections and in the Resource Management files. These have not been systematically organized and the scenes have not been rephotographed in most cases. In a few instances, comparative photos have dramatically illustrated significant vegetation improvement following removal of feral goats and pigs in exclosures. These kinds of photo-documentation studies have not been carried out to document the effects of other management programs.

Alternative Actions and their Probable Impacts.

1. Do not systematically photo-document vegetation changes occuring in the Park. Valuable and graphically cogent data needed to supplement quantitative monitoring programs information will not be gathered. As a result, management needs will not be adequately determined and the impact of management programs will not be adequately assessed or documented.

2. Establish a systematic photo-monitoring program. Photo-monitoring will enhance and, in many cases, substitute for quantitative monitoring to evaluate and document vegetation changes resulting from management programs. Systematic photo-monitoring can serve as a memory for managers whose short-term tenure precludes observing long term changes. Photo-monitoring enhances the information base for making mangement decisions.

Recommended Course of Action. Establish a systematic photo-monitoring program, retake worthwhile historical photographs, take documentary photographs of management programs and quantative studies, and establish photo-monitoring of vegetation changes or plant communities not assessed by quantitative monitoring. In all cases, establish permanent photo-monitoring points.

Cost/workload. $10,000 per year, .5 FTE

## WILDLIFE MANAGEMENT OVERVIEW

Limits to funds, personnel, and expertise confine wildlife management and research activities to feral goat control, fera pig study and control, small mammal studies, and nene (Hawaiia goose) study and restoration. These activities in combination receive the majority of funding and work energy in the Resourc Management and Research programs.

Hawaii's mammalian fauna is characterized by a paucity of nati families and genera. The colonization of Hawaii by Europeans, beginning in the late eighteenth century, opened an era during which hundreds of animal species were introduced. Some of the now occupy vast areas and a broad range of habitats, causing considerable disruption of native ecosystems. Park managers a researchers have focused attention on the most visible introductions, namely goats, pigs, cattle, sheep (Ovis spp.), and mongooses, but programs to control cats (Felis catus), dogs (Canis familiaris), rats, mice (Mus musculus), exotic birds, wasps, mosquitoes (Culex quinquefasciatus), and the many other known and unknown introduced species, await identification, study, prioritization, and funds.

Feral goat populations within the Park have been significantly reduced during the past decade through boundary and internal fencing, driving, hunting, and tracking. Within fenced areas, numbers have been reduced from approximately 15,000 to less tha 10 animals, and perhaps to zero. Organized control efforts began in the early 1970's with the advent of wire-mesh boundary and interior fences. Fences were put up along the western boundary from the coast to about 6,000 feet elevation, and alon the eastern boundary from about 3,900 feet to 6,000 feet. Interior fences were installed in the lowlands to divide the population into workable units. In all, 60 miles of fences wer constructed over a period of eight years, at a cost of about $960,000. The fences both prevented ingress and provided barriers against which to drive animals for massive capture. The first phase of goat control emphasized drives and capture, and in fact, succeded in eliminating about 90% of the populatio that were inside the fences within about five years. By about 1978 the goat population consisted of small and scattered groups which could not be driven. Instead they were hunted, usually with helicopters, and were shot by hunters who were on foot. By 1981 there were only a few groups of goats remaining. These were so wary and elusive that helicopter searches became prohibitively expensive and impractical. Radio transmitters were attached to captured goats, which were then released to the wild in areas where remnant bands of goats were suspected to be residing. Transmittered goats were subsequently tracked on foot by hunters with receiver units, and if a transmittered goat had joined a wild band, the wild goats were shot. The transmittered

goat was left to join other bands. This method has succeded in reducing goat numbers to zero in some, if not all, areas which are enclosed by fences. The transmittered goat method is now used in long-term monitoring to determine trends and to check the efficacy of control. Currently there are seven transmittered goats in the Park backcountry: four are in the Mauna Loa Strip area, and three are in the lowland-pali areas from Ke Ala Komo to the Great Crack. These goats have provided valuable information and have saved thousands of dollars that would have been spent in costly searches. The emphasis in the goat control program has shifted to long-term fence maintenance and population monitoring.

Goats in the Mauna Loa area above 6,000 feet elevation are not contained by fences. They roam freely in the Park subalpine zone, and are causing heavy damage to vegetation. There are an estimated 250 animals in this area, which evidently range beyond the Park in both easterly (Keauhou) and westerly (Kapapala) directions. A funding request, which will enable the Park to construct boundary fences, is expected to be granted within FY-86.

Feral pigs have been eliminated in three control units, which comprise 6,132 acres (Kilauea, Kipuka Ki, and Olaa West). They have been reduced to remnant levels in two control units, which comprise 3,493 acres (Puhimau mauka and Powerline). Control work is underway in the Kipuka Kulalio unit (Mauna Loa) which is 2,813 acres, and is scheduled for a 720-acre section of Olaa East. Feral pigs occupy rainforest, mesic forest, seasonal montane forest, shrubland, and perhaps even open grassland habitats - about 65,000 acres (28%) of the Park. Populations are most dense in the rainforests, which comprise about 40,000 acres, primarily in Olaa and East Rift forest areas. Here their population densities are believed to be about 80-130 pigs per square mile. Total Park population of pigs may be 4,000 animals.

Following programs in place to maintain feral goat control, feral pig control and research programs are the highest priority activities of this Resources Management Plan. Pigs are relentlessly destroying understory plants in the forests and shrublands, enhancing the spread of exotic plant species, and through their rooting and wallowing habits, are creating pockets of standing water which are favorable breeding places for mosquitoes and other water borne vectors of disease. Avian malaria among native forest birds is one result of this condition. The dispersal of seeds of banana poka, firetree, and guava can be directly attributed to pigs, and the spread of most other non-native species are enhanced by the disturbance of surface litter, cover vegetation, and opening of the tree fern subcanopy. Research activities intend to provide managers with

the most efficient methods for controlling feral pigs and to propose models for long-term monitoring of control effects. Control methods examined so far include live trapping with bai live and kill snaring, and expert hunting with trained dogs. Driving animals was also tried once. Experimental work is carried out in each habitat type since it is now obvious that the different pig densities and different cover and feeding types directly affect animal behavior and, thus, management approach to control. Thus far expert hunting with trained dog has been the most effective both in terms of cost and efficiency. The labor intensity, risk, and physical limitatio of this method compel further investigation, however. Investigation of toxins and attractants, further research into animal behavior, better definition of optimal size of control units, more knowledge about population dynamics, and testing o methods for eliminating remnant animals in nearly liberated areas need study.

Mongooses occupy Park land from sea level to 8,200 feet elevation and all habitats except the most hostile portions of the Kau Desert and Mauna Loa alpine areas. An aggressive and opportunistic predator, the mongoose may be an important contributor in the failure of the native nene to become re-established in the wild. Management programs have done no more than attempt to trap mongooses around the perimeter of backcountry rearing and release pens. A control method for a broader area is needed if nene are to be provided with suitable and natural nesting territory. Consequently, research activities by the USFWS and by the NPS are underway to discover effective control methods for mongooses in localized areas.

Rats have not been subject to control attempts except in dwellings or offices. They are known to be serious threats to forest birds and nests, to invertebrates, and to some species o native plants. A study is underway to discover more about thei population dynamics, habitat utilization, and true nature of their impact on the native ecosystem. This study is an inter-disciplinary effort, which has utilized the forest in Kipahulu Valley, Haleakala National Park, as the primary field area.

Other non-native mammals are known to inhabit Park lands and to be disruptive to at least some degree. These animals include cats, dogs, mice, and occasional trespass cattle. Mouflon sheep (Ovis musimon), expanding their territory in Kahuku Ranch, several kilometer towards the west, are a potential problem. Axis deer (Axis axis), if they are ever introduced to this island, are another potential problem. Cats have been subject to control only opportunistically in campgrounds and residences.

Introduced birds are numerous, outnumbering natives in some areas. Certain of these exotics usurp territory or compete with natives for food. Others are carriers of diseases and parasites which natives are susceptible to. The island-wide deterioration of bird habitat and the introduction of diseases, predators, and competitors presents a combination of factors which native bird populations may not ultimately withstand. The USFWS State-wide forest bird inventory project will provide an important basis for identifying and pursuing studies and management programs in the Park. There are presently no research or management programs which deal with this problem in the Park.

Five endangered forest birds (i'o [Buteo solitarius]; 'akepa [Loxops coccineus]; 'akiapola'au [Hemignathes munroi]; and Hawaii creeper [Loxops maculatus]; and o'u [Psittirostra psittacea]) occur or have occurred in the Park. The primary habitat for the 'akepa, 'akiapla'au, and Hawaii creeper is on adjacent private of State lands, which are undergoing deforestation because of logging, cattle grazing, and sustained yield management of feral goats and pigs. National Park lands, threrefore, are becoming a very important refuge and essential habitat for remnants of forest bird populations. The primary habitat for the o'u is the Olaa Forest, an area in the National Park which is designated as critical habitat by the USFWS. This very rare bird was last recorded in Olaa Tract in January, 1984. Noting the deterioration of native forest bird habitat island-wide, the USFWS has proposed a translocation study of the akiapola'au into the koa-ohia forest of the Mauna Loa section of the National Park. Forests in this area have recovered dramatically since the removal of goats and cattle, and may once again support viable populations of forest birds which are currently listed as endangered. Funds for management and long-term monitoring will be needed.

Invertebrate studies and management actions await identification, funding, and prioritization. The only programs underway include a Hawaii State Department of Health inventory of yellow-jacket wasps and a continuing long-term study and collection of insects by a part-time retired entomologist. The latter work provides an extremely valuable foundation for future work on invertebrates. The yellow-jacket wasp work had originally intended to produce a method of long-term localized control of wasps, but has unfortunately produced only numbers which indicate that these animals are well established and nearly ubiquitous. This RMP identifies a need for research to provide a localized control method.

Nene (Hawaiian goose) research and management are directed toward the long-term restoration of this once nearly extinct bird to its former range in and around the Park. Previous research served to summarize prior studies about the bird and to

suggest that problems of wild population survival include cat and mongoose predation, disturbance by people, habitat degradation, and restricted movements. Further research is needed which identifies nutritional needs, specific habitat requirements, and possible genetic deficiencies. There are presently no NPS funds to carry out this research. Management activities include rearing and releasing birds from backcountry pens and monitoring of the wild population. This program is undertaken in cooperation with the DLNR, and depends on their generous donation of goslings for release in the Park. The Park staff has been increased and backcountry release pens have been improved to accommodate this extra workload. Communication with State of Hawaii workers has been improved, demonstrating both agencies' ability to take a regional approach in solving land management problems which are of mutual concern.

HAVO-72 BUILD GOAT AND PIG FENCES

Statement of the Problem. Feral pigs inhabit 50,000 acres of the Park rainforest, seasonal submontane forest, and shrublands, and feral goats inhabit 10,000 acres of the Park above the 6,000 feet elevation. These animals are severely degrading the habitat for six endangered bird species, one endangered mammal, and 43 nominated plant species. Boundary and internal fences are immediately needed to prevent pig and goat ingress from adjacent State and private lands and to delineate control units.

The Significant Resources Problem (SRP) funds provided during 1983-1985 were used to test pig control methods and barrier fences, determine size of management units, and demonstrate the feasibility and cost-effectiveness of controlling pigs in different habitat types. The success and recommendations of this program now enables the Park to embark on a major Park-wide control program by constructing 80 miles of boundary and interior pig-proof fences.

The comprehensive goat fencing program during 1970-1979 did not include the subalpine habitat above the 6,000 feet elevation. Funding for 13 miles of wire mesh or electric fencing to control feral goats is needed.

Alternative Actions and their Probable Impacts.

1. Take no action. Under this alternative, no more fence construction to enclose feral goats or pigs would take place. Feral goats and pigs would be impossible to eliminate from unfenced areas, and any control attempts would be only temporary, since animals from outside would be able to re-populate the control area. Long-term costs would be prohibitive, and long term control would not be realized. This alternative would avoid the environmental impact caused by cutting vegetation cover along fence corridors and the permanent installation of fences along Park boundaries and in Park wildlands. This alternative would not solve the very serious problem of continued degradation of Park ecosystems caused by feral goats and pigs.

2. Build only the high elevation goat-proof fence. Under this alternative, the feral goat control program would be completed within a year of completion of the fence. Feral pig control work would not progress. Vegetation in the high elevation life zone of Mauna Loa is sparse and low in stature, thus fences would be visible for long distances, and some impairment of aesthetic qualities of this section of the Park would be inevitable. The same has been noted for lowland areas, where fences are installed. Fence construction workers would be the cause of some damage to plants along the fence corridor because

of their travel and working patterns. Workers would occasionally use a tracked motor vehicle about 3 feet wide to transport heavy materials along the fence corridor, and they would use gasoline drills, hammers, winches, etc. A helicopte would be used to haul in posts and rolls of wire. Workers wou operate out of a backcountry camp near their work site, and in this area a certain amount of trampling and discarding of rubbish would be inevitable. Some materials would also be inadvertently discarded along the fence, such as short lengths of wire, lost tools, etc. The fence would not hinder movement of any native animal or people, if they should happen to enter the area. It is remotely possible that the nene, the native Hawaiian goose, would accidently fly into wires and sustain injuries or death.

3. Build a high elevation goat-proof fence along the Mauna Loa boundary and build pig-proof fences to enclose approximately 50,000 acres of the unfenced habitat of feral pigs in the Park. Under this alternative the final phase of the feral goat contro program would be realized and fences would be installed to prepare the way for a Park-wide feral pig control program. Environmental impact as noted above would be anticipated in the Mauna Loa area, and in addition, vegetation cover (except matur native trees and tree ferns) would be removed along an approximately 3-feet wide corridor wherever pig proof fences ar built. Removal of the vegetation cover results in localized disturbance which enhances the colonization of certain non-native plant species, at least temporarily until native subcanopy plants can recover. Some temporary impact from worke camps walkways, discards, etc., as noted, would be anticipated.

Recommended Course of Action. Alternative 3 is recommended. A high elevation goat-proof fence, approximately 13 miles long in two sections, in the Mauna Loa area would be either traditional 47-inch high wire mesh with steel posts, or five-strand electri fence with combined steel and fiberglass posts. The Mauna Loa environment, with its arid climate and sparse vegetation, is especially suited for a solar-powered electric energy fence, if such a fence can effectively prevent escape and ingress of goats. An experiment which will test the efficacy of electric fencing under the remote and low density conditions peculiar to the Mauna Loa section of the Park will be conducted prior to selection and purchase of materials. Electric fencing will be the fence type of choice, if it proves to be feasible, because of lower installation and maintenance costs and because it will be less visible, and thus will reduce aesthetic impact. Wire mesh fencing, 47-inches high, will be used if the electric fence experiment demonstrates that electric fencing will not be effective. Wire mesh fences, 32-inches high, will be built in Park rainforest, seasonal montane, and shrubland areas to isolate feral pigs into control units. Approximately 50,000

acres will be enclosed with 50 to 80 miles of new fences strategically located to include all remaining feral pig habitat in the park. Requests for funding will be made to the Natural Resources Preservation Program (NRPP) for three-year funding.

Costs/workload. $390,900 first year, to fence Mauna Loa goat control fence and selected sections of Olaa $800,00 per year second and third years, to complete 80 miles of fences in Olaa, Kalapana Extension, and Ainahou sections of the Park.

HAVO-4 MAINTAIN CONTROL OF FERAL GOATS

Statement of the Problem. Feral goat control was recently the single most serious resources management problem in the Park. A well organized and persistent program succeded in reducing the goat population from approximately 15,000 in the early 1970's to nearly zero today. Boundary fences, goat drives, helicopter searches, radio tracking, and long-term monitoring have been applied at different stages of the program. Drives were very effective in the early stages of the control program when goats were found in large herds and could be moved enmasse. Recently, goat numbers have been so low, that they cannot be driven and they have become so wary that they cannot be spotted from helicopters. Remnant groups have been tracked with radio telemetry instruments, and nearly all non-transmittered animals have been destroyed. Except for animals in higher elevations where exclusionary fences have not yet been built, goats are so few that the program is essentially in a long-term monitoring mode. Goats have high fecundity, so it is very important to keep close surveillance of fences and carry out regular monitoring in order to prevent any increase in population.

Alternative Actions and their Probable Impacts.

1. Maintain and repair boundary fences regularly. Carry out regular inspections of radio transmittered released goats in several backcountry locations to confirm presence or absence of non-transmittered animals. Destroy all non-transmittered animals. Replace radio transmitters as needed.

Cost/workload. $20,000, .3 FTE per year
Biological Technician

HAVO-26 ELIMINATE FERAL GOATS IN HIGH ELEVATION AREAS

Statement of the Problem. Feral goats have been nearly eliminated from all sections of the Park except for unfenced areas of Mauna Loa above the 6,000 feet elevation. This section of the Park was not included in the comprehensive fence construction program of the 1970's. Consequently, feral goats roam freely into and out of the Park from neighboring ranch and Forest Reserve lands. It is clear from an ongoing study that goats have severely impacted subalpine vegetation. Browsing has greatly reduced vigor of trees and shrubs and has virtually eliminated reproduction of koa, mamane, and a'ali'i. Furthermore, this area is known to be inhabited during part of the year by the nene, an endangered species, and by three endangered forest bird species. Goat browsing degrades the habitat for these species, thus imperiling their survival. No formal goat population estimate is available for this area, but it is thought that about 250 animals may at times be within the Park. Damage to native plant communities is substantial and enduring because of the slow rate of plant growth and recovery which is inherent in the subalpine area.

Alternative Actions and their Probable Impacts.

1. Take no action. Under this alternative, feral goats would continue to wander into the Park from neighboring lands, causing continuing damage to native plant and animal communities. The feral goat control program, for which Hawaii Volcanoes and NPS have gained such eminence, would be compromised. The Park would be in violation of the Federal and State Endangered Species Acts, the legislative mandates of the Park Master Plan and Statement for Management. A no-action posture would compromise the Park's status as an International Biosphere Reserve.

2. Carry out periodic control without constructing boundary fences. Under this alternative, feral goat numbers would be temporarily reduced, depending upon the frequency and efficiency of hunts. This alternative characterizes the method used prior to comprehensive fencing in other parts of the Park, which proved to be ineffective over the long term.

3. Eliminate goats within upon completion of wire mesh or electric fence in the Mauna Loa area. Under this alternative goats could be eliminated within a year following the completion of the fencing project. Native vegetation would slowly recover to some extent in a very long process of ecosystem restoration. This area would

constitute the only native subalpine area in Hawaii which would be free of depredations by feral goats. It would provide improved habitat for the endangered nene and forest birds, and it would be a valuable demonstration area for scientists and land managers.

Environmental impact would arise primarily from helicopter flights into the area. These are necessary to search for or track goats. Since they are infrequent and temporary, causing no permanent alterations of natural features, this project poses no significant environmental impact to the area.

Recommended Course of Action. Alternative 3 is recommended. The method of helicopter search and radio telemetry tracking of feral goats within fences is documented and known to be effective. Following the completion of fence installation in FY-86 or 87, all goats within fences would be driven out or destroyed.

Cost/workload. $20,000, .5 FTE for one year
Radio telemetry tracker and hunter
Purchase radio transmitter, a receiver, and rent a helicopter with pilot. These costs would be borne by base funds.

HAVO-35 EXTEND FERAL PIG CONTROL TO ADDITIONAL AREAS

Statement of the Problem. Feral pigs are the most destructive vertebrate pests in the Park. Following three years of intensive control work, they presently are uncontrolled in approximately 50,000 acres of Park wildlands, most notably rainforest and montane seasonal woodlands. They cause immense damage to the natural habitat through rooting and wallowing, consuming native plants, creating pockets of stagnant water, and causing conditions favorable for, and distributing seeds of, non-native plant species. Damage caused by pigs is degrading the quality and integrity of native plant communities; in some cases beyond the point of natural recovery. Eradication of feral pigs is a necessary first step in the restoration and recovery of native plant communities. Pig control is possible through planned and educated management involving exclusionary fencing of selected areas, intensive hunting and trapping, and other methods under study. SRP project funds in 1983-85 enabled the Park to construct or enhance 30.5 miles of pig-proof fences, which enclosed eight control units, totalling approximately 16,000 acres. Pigs were eliminated from three units (6,132 acres) and reduced to remnant levels in two units (3,493 acres). Reduction to remnant levels is anticipated in two more units (3,533 acres) by late 1985. A distinction must be made between reducing and eradicating a feral pig population. Reduction is the necessary and achievable first phase of a complete eradication effort. For this, long-term funding for hunting, fence construction, and fence maintenance is needed as new control areas are added. Pigs in these areas would be reduced to remnant levels, which experience has indicated, requires a different control approach, and is therefore described in a separate project statement, HAVO-13.

Alternative Actions and their Probable Impacts.

1. Ignore the feral pig problem. Allow natural ecosystems to deteriorate. Anticipate that pig populations will ultimately reach a stable relationship to their habitat, which will necessarily be substantially unlike natural communities and permanently degraded and beyond recovery. Under this alternative managers would be abrogating their Service and Congressional mandates to protect the natural environment.

2. Attempt to maintain pig populations at low levels, but make no organized attempts to eradicate them from any or all areas. Use citizen hunters and occasionally NPS personnel to conduct periodic control in unfenced areas.

Under this alternative, management action would retreat to the casual and unproductive method of control which had traditionally been practiced in the Park prior to 1982. This alternative, like #1 above, does not meet Service and Congressional standards for protection of the natural environment.

3. Attempt to eradicate feral pigs from Park lands. Begin by reducing numbers to remnant levels in new control units. Embark on a deliberate long-term eradication program, based on scientific research, to systematically eliminate pigs from natural systems. In close cooperation with the Research Scientist, implement closely monitored and carefully planned control actions progressively throughout portions of the Park which are infested with pigs.

Recommended Course of Action. Implement Alternative 3 because of its committment to fulfilling the Park's mandate to protect and restore native plant and animal communities. Continue a long-term program, already begun, which will identify previously uncontrolled areas to work, delineate areas to be enclosed, plan a control strategy to reduce Park pig populations to remnant numbers, and carry out control work. Design the management program around recommendations and advice of the Research Scientist. Carry out monitoring throughout the course of the work, and beyond into the phase of final eradication of population remnants. Significant progress can be made if funds for fence construction are allocated, as requested from NRPP, ref. Package (Pkg.) 179. If fence money is not allocated, critical areas of the Park will have to be enclosed using funds from base operating program.

Cost/workload. $226,000, 6 FTE per year
Funded by anticipated base increase

HAVO-13 ELIMINATE REMNANT PIGS

Statement of the Problem. Initial control of feral pigs within control units normally succeeds in reducing populations to low levels. Remnant animals pose a distinctly different control problem, invariably requiring highly creative strategy, much persistence, and great skill. The amount of effort and funds required to eliminate remnant populations is commonly underrated, often requiring as much time and money (discounting costs of major capital items such as fences, surveys, etc.), to reduce few numbers to zero as it takes to reduce large numbers to few. It is important to completely eliminate all animals targeted for control within control units, hence the distinction of this statement in the context of HAVO-35.

Alternative Actions and their Probable Impacts.

1. Regard remnant animals as inevitable and attempt to maintain them at low levels. Use control methods which had previously been successful in reducing numbers. Under this alternative it would be possible to maintain pig populations at low levels with sustained pressure but at considerable long term cost. At low levels, feral pigs would continue to degrade natural plant communities, albeit at a lower rate than during times when population levels were higher. Reproductive activity would continue, and populations would have the potential for rapidly expanding. If funding were to decrease or administrations or priorities change, gains over the past decade could be negated.

2. Recognize the ecological importance and long-term cost-effectiveness of eradicating all the pigs which remain within control units following initial control programs. Develop specific control strategies and carry out planned and educated eradication work. Under this alternative it would be possible in most cases to reduce pig numbers within control units to zero, thus completely removing from natural plant and animal communities the primary source of degradation. Zero numbers of feral pigs, once attained, would reduce control activities to long-term monitoring and fence maintenance, thus substantially lowering costs which would otherwise be required under a program of low level control.

Recommended Course of Action. Select Alternative 2 because of its ecologically sound and cost-effective features. This would be consistent with an approach already established for feral goat eradication, which employs

radio-telemetry tracking of goats released in the wild for betrayal of non-transmittered animals and for long-term monitoring of liberated areas. Methods for detecting and eradicating remnant feral pigs would need to be developed and utilized. The importance of this project and the special attention in requires cannot be underrated.

Cost/workload. $80,000, 4 FTE per year
Hunters
$ 3,000 per year
Hunting dogs maintenance

HAVO-5 CONDUCT FERAL PIG CONTROL RESEARCH

Statement of the Problem. Feral pigs cause the destruction of native forests and plants and begin and accelerate the deterioration of entire ecosystems in Hawaii. Hawaiian ecosystems contain especially rich assemblages of unique plants, invertebrates and birds, many of which are present in small and local populations and areas sensitive to the disturbances initiated by feral pigs.

Pig control methods need to be developed and tested to allow managers to remove pigs from forests at a rate that will exceed reproductive increase. The effectiveness of methods needs to be evaluated in terms of effort involved, economics, and reduction of damage to the forest. Information about pig population structure and density, damage distribution, movements, food habits, and control methods needs to be accumulated for different habitats, seasons, and areas. Recovery of forest vegetation after feral pig removal should be monitored.

Alternative Actions and their Probable Impacts.

1. Take no action. The research budget supports one research scientist administrator and one botanist with some operating money. This level of support allows completion of vegetation plots and transects to determine abundance and distribution of damage and reading of exclosures set up to measure forest recovery in the absence of pigs. It also allows limited testing of baits and control methods on a small scale in one or two areas.

2. Increase budget support in order to conduct research on feral pig control methods, including snaring, hunting, trapping and baiting, on population characteristics and movements, and on recovery of the ecosystems. This alternative allows the gathering of information on several methods in several areas, refining of methods at a reasonable rate, determining response of forests in the absence of pigs, determining efficiency and economics of methods, and gathering information in many areas on pig population structure and characteristics, movements, food habits, and other behavior. The consideration of a number of areas and the full complexity of the situation is necessary to fully understand management measures needed, to generalize and build adequate models, and to efficiently plan for the resources needed to do the job of controlling feral pigs in Hawaii's valuable ecosystems.

Recommended Course of Action. Conduct research on feral pig control methods, population characteristics, movements, behavior, and on ecosystem recovery. This alternative allows accumulation of the necessary information over a short period of time with more thorough consideration of the complexities involved and more realistic recommendations to management.

Cost/workload. $100,000 per year for 2 years
3-4 research technicians

HAVO-22 CONTROL TRESPASS CATTLE

Statement of the Problem. Cattle from neighboring ranches occasionally breech boundary fences and trespass in the Park. Kipuka Ki and Kipuka Puaulu are especially subject to such trespass, as the Kapapala (west) and Keauhou (east) properties adjoin the Park in those areas. Trespass animals usually are not detected until fence inspections are carried out, which sometimes provides enough time for animals to do considerable damage to native plants. Although ranch managers are cooperative and eager to retrieve their animals, they sometimes are not able to respond quickly, requiring some effort on the part of NPS personnel to remove the animals and repair the fences.

Alternative Actions and their Probable Impacts.

1. Request ranch manager neighbors to remove trespass animals as soon as they are detected. If this cannot be done in a timely way, NPS workers will remove animals and repair fences. Ensure continued good will and respect of neighboring ranch managers.

Cost/workload. $2,500, 1.5 FTE per year

HAVO-9 MAINTAIN GOAT AND PIG FENCES

Statement of the Problem. Woven-wire fences along parts of the Park boundary and internal animal control units are essential elements of feral goat and pig control programs. Approximately 50 miles of goat-proof boundary fence and 12 miles of internal fence have been constructed since 1972. Approximately 10 miles of pig-proof fence has been constructed since 1982, and 20 miles of goat-proof fence has been modified to prevent passage of pigs. An additional 3 miles of pig-proof fence is expected to be constructed during 1985. Fences are galvanized, woven-wire mesh supported by galvanized or painted iron T-type posts. Bottom strands are snugged to the ground by special T-post anchors. Some pig-proof fences have an additional strand of barbed wire along the bottom to discourage rooting, and all goat fences have two strands of barbed wire above the top strand to discourage leaping. Goat-proof fences are normally about 60-inches high, including the two barbed strands above the mesh section, and pig-proof fences are normally 32-inches high without barbed strands above the mesh.

Goat-proof fences must be inspected every two months, and pig-proof fences must be inspected every two weeks. Maintenance and minor repair are invariably required during inspections. Sections of fence which are older than three years occasionally require major repairs. The goat-proof fence along the western Park boundary between the coast and Highway 11 (approximately 12 miles in length) is subject to rapid deterioration because it is downwind of the Kilauea Volcano and hence receives acid rain fallout from the sulfur-dioxide plume which characterizes that section of the Park. The lower section of this fence, within reach of heavy sea aerosols, typically requires replacement every three or four years. Rapid deterioration has also been observed on fences in the vicinity of Mauna Ulu, which is in the fallout zone of the East Rift. Fence inspections and repairs are funded by Resources Management base account money, despite the cyclic character of the program.

Alternative Actions and their Probable Impacts.

1. Inspections and repair of goat-proof fences at two-month intervals and of pig-proof fences at two-week intervals cannot be discontinued. To do so would allow fences to fall into disrepair and thus negate progress made to date in two of the Park's most important Resources Management programs. Discussion of alternatives becomes, therefore, choices between: selecting day laborers hired by the NPS, or selecting private sector workers hired under

contract to carry out inspections and maintenance. No significant differences between the two alternatives is anticipated, providing contract specifications are properly written and standards adhered to.

2. No other alternatives are considered.

Recommended Course of Action. Continue using laborers hired by NPS to carry out fence inspection and maintenance only until private sector contract specifications can be written and a contract awarded. Establish a one-year trial for the first contract. At the end of the first year evaluate the quality of private sector work and analyze cost and benefit factors. Determine at that time whether NPS day laborers or private sector contractors provide the most economical and highest quality work. Proceed from then with the preferred method.

Cost/workload. $40,000, 1.2 FTE per year

HAVO-8 REMOVE DETERIORATING FENCES FROM THE BACKCOUNTRY

Statement of the Problem. In several locations along boundary (and in some interior) fence corridors, there are caches of deteriorating fence wires and posts. These are remnants of fence restoration and construction work which has been carried out in the past. These materials were not removed from the backcountry at the time the work was done. They constitute an unsightly and totally inappropriate spectacle and should be removed. Removal will require helicopter or pack animal support.

Alternative Actions and their Probable Impacts.

1. Remove the wire and posts. Use helicopter and/or livestock as time and funds allow. Select time and method opportunistically, e.g. combine this work with other projects being carried out in the same general area, in order to conserve funds and staff energy. Complete this project by May, 1985. Impact of this project will be to remove a source of aesthetic degradation in the Park backcountry. This removal will satisfy a subtle but important ethical anomaly which has persisted for several years and has heretofore gone unchallenged.

2. No other alternatives are considered.

Recommended Course of Action. Schedule helicopter or livestock to remove old wire caches along the Kau boundary and along interior fence lines in the Keauhou-Kaone areas during the course of the year and during times when horses or a helicopter will be working in the general area anyway. Haul materials to the nearest road-head for final removal by truck to disposal sites. Deliberately keep costs and disruptions of important staff work to a minimum.

Cost/workload. $5,000 for one year
No additional staff is required.

HAVO-43 SURVEY AND FENCE EASTERN PARK BOUNDARY

Statement of the Problem. Comprehensive fence construction for feral goat control programs did not include boundary fencing along the eastern (Puna) Park boundary from the area near State Highway 11 (approximately 4,000 foot elevation) to sea level. Division operating funds have supported fencing work on or near the boundary from 4,000 feet to the Mauna Ulu lava flows (about 7 miles) as part of the Park's feral pig control program. Western Region (WRO) Protection Division is funding survey work to be undertaken in Calendar Year-85 along the eastern boundary from the Thurston Lava Tube area to the Chain of Craters Road near Wahaula Visitor Center, about 14 miles. The survey will be sufficient for marking the boundary and for fencing, when funds are available. Parts of the boundary are unstable due to volcanic activity along the East Rift, Puu O'o vent, so survey markers and fences would most likely be overrun by lava flows if they were established before the current series of eruptions are over. Over the long-term they would be overrun, anyway.

Alternatives and their Probable Impacts.

1. Construct as much fencing along the Puna boundary as is possible with funds from Pkg. 179, after the Mauna Loa boundary fences are constructed. Avoid the areas likely to be impacted by volcanic activity in the near future, such as the area near Puu O'o. The entire East Rift is unstable, so the inevitability of damage or loss of fences and boundary markers is acknowledged, but at least the area from Mauna Ulu to the area north of Makaopuhi Crater, and from the coast to about midway up the slope west of Royal Gardens have escaped the most recent lava flows.

2. Construct no fence near the East Rift due to the inevitability of lava flows damaging or destroying it. Instead use Pkg. 179 money to construct more fences in Olaa Tract.

Recommended Course of Action. Alternative 2 is recommended. Feral pig control work has begun in the Olaa Tract forest, primarily because it is now regarded as being of higher biological value than the East Rift forests, despite the infestation of banana poka in Olaa. East Rift forests near the Park boundary are relatively minor because they are buffered by recent lava flows, which separate them from the continuous forests south of the Rift. Furthermore, seismic instability and volcanic activity in the vicinity of the Rift are likely to damage or destroy fences.

Cost/workload. Survey to be undertaken by WRO.
Construct fences for $15,000 per mile

HAVO-63 STUDY NATIVE ANIMAL MANAGEMENT NEEDS

Statement of the Problem. Almost nothing is known about the management needs of most native vertebrate species that occur in or near Hawaii Volcanoes. An endangered bat, several species of honeycreepers and other species of birds now use or did recently use Park forests. Of special concern are endangered species and their habitats or potential habitats. These include the Hawaiian bat (Lasiurus cinereus), Hawaiian hawk or i'o, akiapola`au, Hawaiian creeper, and crow or alala (Corvus tropicus). The nene is discussed in HAVO-18. The USFWS intends to study captive propagation and translocation of rare species. Some general information on habitat requirements of the species of concern is available. However, identification of suitable habitat for reintroduction of native vertebrates, literature review and translocation experiments, and more intensive studies of some of the rare and common species are necessary if managers are to make informed decisions about native vertebrates in the Park. Of special concern is habitat degraded by feral ungulates and non-native plants and the effect of lack of management on native vertebrates. Current emphasis on managing nearly intact or ecologically important areas for natives and against non-natives also requires a better information base.

Alternative Actions and their Probable Impacts.

1. No action. Under this alternative, general information about native vertebrates should eventually be made available from studies conducted by USFWS and independent researchers. Whether these results would provide enough detail for specific Park areas, priorities, and species is doubtful. Intensive studies in conjunction with intensively managed areas in the Park would not be done unless USFWS or others were supported for such. The information base on rare and common native vertebrates for which we are responsible in the Park would remain sketchy. Monitoring of native vertebrates would remain sporadic and incomplete.

2. Conduct research on native vertebrates and their occupied and potential habitat in the Park. Under this alternative an information base would be built and monitoring set up for native vertebrates in the Park or for those which could be reintroduced into the Park. Feasibility studies of suitable habitat could be made. Coordination of efforts with USFWS would be possible. Tests of translocations in intact or intensively managed areas could be made at the discretion of NPS.

Recommended Course of Action. Conduct research on native vertebrates and their occupied or potential habitat in the Park. A research associate could be hired to set up a monitoring system for native vertebrates, identify important native bird and mammal habitat in conjunction with other rare plant and ecosystem identification projects, assist with translocation experiments, conduct studies of rare and common native vertebrates where needed, and participate in intensive management of key areas by providing input on native vertebrate requirements.

Costs/Workload. $30,000 per year for 3 years
Research Associate

HAVO-34 MAINTAIN CAPTIVE BREEDING NENE FLOCK

Statement of the Problem. It is known that a wild, free flying nene (Hawaiian goose) population cannot presently sustain itself without human manipulation. Low reproduction rate, depleted natural habitat, and predation are thought to be the most important factors which contribute to this problem. Low breeding and nesting rates and very low gosling survival among wild birds must be offset by releases of captive-reared birds in order to prevent population decline. Annual releases of an average of seven captive-reared birds into Park wildland prior to 1984 were not able to counteract natural mortality. Mature birds characteristically survive for several years in the wild, but low recruitment rates forestall any possibilities for population increase or maintenance without stocking.

During the 1984 season Park releases were augmented by 28 goslings donated by DLNR, as part of a cooperative endeavor to increase the regional nene population. This provided Park and State officials with an unusually good opportunity to study a larger wild population and to evaluate problems of nutrition, predation, and habitat utilization. Interagency cooperation is expected to continue if the Park can continue to receive goslings and properly rear, protect, and release them. The Park strives to rear goslings under near-natural conditions by fostering them with captive pairs and releasing birds into backcountry pens, from which they fly when they are ready to fledge. Released birds are normally recruited into the wild population, which inhabits the Park and neighboring State and private lands.

Alternative Actions and their Probable Impacts.

1. Abandon the captive breeding-wild release program. Withdraw management support for the birds and allow them to survive or perish without human manipulation. This alternative would reduce program costs to monitoring levels and would most certainly lead to the decline and ultimate failure of populations and/or would place the entire management burden on the DLNR. Some would argue this pathway is inevitable and the public interest is best served by recognition of the nene's disharmony with modern Hawaii's depleted wildlands.

2. Maintain a captive breeding and wild release program sufficient only for equalizing mortality and recruitment. Ignore the regional dimensions of the problem and do not pursue cooperative nene management activities with DLNR managers. This alternative would characterize the Park program of 1978-1983, during which the wild population

remained at low numbers and provided little hope for natural recovery or for proper analysis of survival potential.

3. Expand the captive breeding-wild release program. Cooperate with DLNR managers and Park and other researchers in a regional approach to nene survival. Support DLNR breeding and release efforts by rearing donated goslings to fledgling stages, releasing birds to the wild, and monitoring wild birds. This alternative maximizes both agencies' efforts and affords optimum opportunity for increasing population size and studying nene ecology.

Recommended Course of Action. Alternative 3 is recommended. Support the DLNR breeding program and accept donations of 20 to 50 goslings per year for rearing and release in the Park and vicinity. Share information with State managers and researchers.

Costs/workload. $45,000, 1.8 FTE per year

HAVO-33 MONITOR WILD NENE POPULATION

Statement of the Problem. Management and research on captive and wild nene (Hawaiian goose) are undertaken by the DLNR, USFWS, and the NPS. These agencies, recognizing the regional nature of the problem of nene survival, implemented in 1983-1984 a cooperative action plan that combines agency expertise and resources toward a common objective of increasing the chances for nene survival in a significantly altered natural environment. Basic strategy involves DLNR producing goslings at the Pohakuloa brooding facility, Hawaii Volcanoes releasing goslings in back-country pens after rearing them with pairs of captive nene, and monitoring wild birds in and around the National Park. NPS and USFWS scientists will undertake studies of predation, nutrition, habitat utilization, population trends, social behavior, habitat and population manipulation, and breeding success - all now greatly enhanced by the addition of more birds into the population.

Park managers and researchers intend to integrate efforts by taking such actions as placing feeding stations in selected areas, manipulating selected wild family groups, carrying out localized habitat improvements, and implementing localized predator control.

Alternative Actions and their Probable Impacts.

1. Ignore the opportunities made available by an inter-agency approach to nene management and research, and especially the contributions which can be made by the NPS in wild bird monitoring. Nene survival problems will remain unanswered, breeding success will remain vague, and a comprehensive assessment of necessary management actions cannot be made.

2. Embrace an interagency approach to nene management and research by contributing expertise in monitoring wild nene populations in and around the National Park. This contribution will encourage other agencies to continue their efforts and the Park nene population, which also uses neighboring State and private lands, will probably increase.

Recommended Course of Action. Alternative 2 is recommended as the only responsible and legally proper course to follow. Effective management is based on the utilization of all available resources, especially the information which can be gained from short and long-term monitoring. The interagency strategy which shares responsibility and expertise places an important

responsibility on the Park. Park workers will utilize direct observation and radio-telemetry tracking. Data will be entered in a computerized information base system and will be made available to other participants in the cooperative program.

Costs/workload. $25,000, .8 FTE per year
Seasonal Technician

HAVO-18 STUDY NENE HABITAT

Statement of the Problem. Nene (Hawaiian geese) can be readily raised in captivity and they show high survival in the wild. However, they do not sustain wild populations for long, because most reproductive attempts in the wild end in egg or gosling mortality. The major egg predator is the mongoose, but effective controls for this species, even on a seasonal basis, are not available. Breeding effort by breeding-aged pairs may be low over their lifespans and survival of young is definitely low. Major information needs exist in predator control, nutritional adequacy, genetics, and behavior related to management manipulations.

The USFWS has funded a 3-year study to register a toxicant to control mongooses seasonally in endangered bird habitat. Some of the effort will focus on nene. A study of nene nutritional needs and food habits in much modified nene habitat is critical. Adequate study of the responses of nene to management manipulations such as artificial feeding, movement of nene families to adequate feeding areas, and use of wild foster parents for captive-reared birds is needed. Information on year-round habitat use of nene introduced to lowland habitat is also necessary.

Alternative Actions and their Probable Impacts.

1. Take no action. Under this alternative, USFWS will presumably develop a toxicant for registration in 3 years. The effect on nene will not be systematically studied. Knowledge about nene introduced into lowland mongoose habitat will be marginal. Nutrition as a limiting factor in much modified lowland habitat and in the uplands will be unstudied. Currently preferred foods of nene in all areas will be unknown. Responses of nene to management manipulations will be investigated as time allows, and money will be taken from other projects to do so. Answers will not be definitive.

2. Conduct research on nutrition and management manipulations. Under this alternative, a graduate student would be funded to determine nene food preferences in wild and pen studies. Adults and goslings would be studied and fecal materials analyzed. Nutritional quality of alien and native foods would be determined. Management manipulations to enhance nene survival and reproduction would be systematically tested and adequate follow-up on the cooperative DLNR/NPS captive release program could be made through radio telemetry. Assistance could be given to USFWS on the mongoose toxicant project, thus assuring more effort in nene habitat in the National Parks.

Recommended Course of Action. Conduct research on nutrition and management manipulations. Fund a doctoral student for a 3-year nutrition study and hire a research technician to study management manipulations. Research support would complement the USFWS programs and the increased efforts and budget by Resources Management. The effect would be synergistic, since all groups would be working in the same areas on different aspects of nene research and management. Determination of the importance of nene nutrition subsequent to mongoose removal would be possible; similarly, better studies of and knowledge about released birds would ensure populations of lowland birds to manage in selected areas. Cooperative efforts with other agencies would enhance their effectiveness. Information applicable to nene habitat in Haleakala National Park and on State and private lands would be obtained.

Cost/workload. $40,000 per year for 3 years
Research Technician and a doctoral student candidate

HAVO-12 STUDY SMALL MAMMAL CONTROL

Statement of the Problem. Small introduced mammals (black and Pacific rats and small Indian mongoose) have tremendous impact on Hawaiian ecosystems via consumption of native plants, invertebrates, and birds, distribution of introduced plant propagules, and competition with native fauna. The preservation and restoration of native systems and processes cannot realistically be accomplished until the roles and impacts of these numerous and widespread introduced animals are understood.

Control of rats in agricultural situations is a continual but sometimes effective process. Registered chemicals to reduce rat numbers and damage are available but have been little used in non-agricultural situations. Non-target and secondary hazards of chemical use are few in Hawaii, and effective reduction of these species in certain intensively managed areas may be possible and should be tried. Much can be learned about the role of rats in ecosystems through food habits studies and accumulation of information on seasonal population fluctuations and densities.

Mongooses are important predators on several rare species, and they also affect plant distribution and other biota. A project to develop a "drop bait" toxicant for mongoose control has been funded by the USFWS, and NPS has agreed to work with them on field testing of baiting and chemicals and on pen testing of secondary toxicity. No NPS funds are currently available for this important project.

Alternative Actions and their Probable Impacts.

1. Take no action. Under this alternative, nothing will be learned about the importance of rats as invertebrate, bird and plant consumers or distributors of plants. We will have no indication of the feasibility of reducing rats in intensively managed areas to enhance restoration of native systems and reduce introduced plant spread. Registration of a mongoose toxicant will emphasize mongoose biology and reduction in several rare bird areas but resources will not be adequate to thoroughly understand mongoose biology and control strategy in nene habitat through several years.

2. Conduct research on rat and mongoose biology and control in important rainforest and nene habitat. Under this alternative, the USFWS effort on mongoose control can be supported with a NPS technician who will work in nene habitat only. Another technician or student can specialize in rat ecology and control in areas under intensive

management for ungulates and exotic plants and in other less intensively managed areas. Effects on ecosystem protection and restoration and on interrelationships among native and exotic biota can be thoroughly studied.

Recommended Course of Action. Conduct research on rat and mongoose biology and control. Two technicians, or a PhD student and a technician, would be funded for three years on this effort. Emphasis would be on food habits, ecosystem impacts, and control technique development and evaluation. Emphasis would be on important ecological areas and sites already under intensive management, or on areas nearly pristine, with degraded areas as comparison sites. Thorough understandings of ecosystem structures and processes necessary for effective management would be sought.

Cost/workload. $45,000 per year for three years
Two technicians or one technician and a doctoral student

HAVO-50 STUDY NATIVE BIRD REINTRODUCTION

Statement of the Problem. A number of native bird species were formerly found in Hawaii Volcanoes and vicinity but are currently much more limited in range or numbers than in the past or have been extirpated in the Park. Prominent among these species are the `akiapola`au, the `o`u, the `i`iwi (Vestaria coccinea), the Hawaii `akepa, the Hawaii creeper, and the `alala. Because Park habitat is protected from development and managed with increasing effectiveness for removal of feral ungulates and non-native plants, it is possible that some areas may now be adequate for re-introduction of native species. Deterioration of surrounding habitat makes that in the Park increasingly valuable for native species. Further, some avian species are endangered and, in the case of the `alala at least, very near extinction. Knowledge of suitability of Park habitat for rare birds, and in some cases, experiments with translocated individuals (or sometimes closely related species) are necessary to avoid further reductions in populations through lack of action where situations are desperate.

Alternative Actions and their Probable Impacts.

1. Take no action. Under this alternative, NPS will not know potential habitat suitability for native birds other than in a very general way. Community restoration will be less complete than it possibly could be. The potential for endangerment and extinction of some taxa will be increased through incomplete use of well protected and managed lands within their natural range.

2. Conduct research on habitat requirements and behavior of rare avian species and translocated birds. This work will complement any efforts by the State or USFWS, but will emphasize Park lands and species found there. It will encourage other programs to develop in the Park, make better use of protected and managed native habitat, and enhance survival of rare species and populations. It will increase understandings of limiting factors in the Park.

Recommended Course of Action. Conduct research on habitat requirements and behavior of rare avian species formerly more abundant in Hawaii Volcanoes and on translocated birds. Synergistic efforts that benefit the Park and the species and its habitat and result in better restoration of native Hawaiian ecosystems will result. Literature review and reconnaissance will identify the most likely species and areas for study.

Cost/workload. $40,000 per year for 3 years Research Technician or doctoral candidate.

HAVO-49 STUDY INVERTEBRATES

Statement of the Problem. Very little is known about the habitat requirements and limiting factors for Park invertebrates. Hawaii Volcanoes employs one part-time retired entomologist to maintain a modest insect collection and to consult on certain management actions. The importance of birds, rats, pigs and non-native invertebrates in affecting the distribution and abundance of native invertebrates is largely unknown. There is a limited information base for managing invertebrates. Current management strategy is to conserve and manage for the most intact and diverse native plant and animal communities. The overall health of the ecosystem and optimum maintenance of bird and plant species depends upon a healthy and intact invertebrate population. However, more information is needed for intelligent stewardship and conservation of invertebrates, and to better understand their roles in maintaining health and diversity of natural systems. There is an urgent need to monitor the impacts of, and develop management procedures for, invasive keystone non-native invertebrates such as ants and yellow-jacket wasps.

Alternative Actions and their Probable Impacts.

1. Take no action. The status of invertebrates for which we are responsible will be largely unknown. As habitats continue to decline, there will be less information about invertebrates for managers to consider in their management actions. Additional species will undoubtedly become extinct as ecosystems deteriorate and more non-native invertebrates invade. Invasions of non-natives will be similarly unmonitored. Effects of invertebrates on rats and exotic and native birds and vice versa will be unknown. Some key interrelationships in pollination biology, forest ecology, soil science, energy and nutrient cycling, etc. will be unexplored. Understandings necessary to manage ecosystems intelligently and intensively (or not to manage them) will remain incomplete.

2. Conduct research on invertebrate status, interrelationships, habitat requirements, and limiting factors. Under this alternative, initial understandings of important taxa could be made, a monitoring program set up for managers to establish an information base, and important limiting factors could be identified. Entomologists could work with botanists, ornithologists, mammalogists, etc., on managing important areas intensively, identifying important invertebrate habitats, and even restoring some species or suppressing non-native invertebrates.

Recommended Course of Action. Conduct research on invertebrates. The benefits identified above would accrue. Hire a Park entomologist for 5 years with suitable budget to contract out important studies to specialists and students. Alternatively, contract entomological studies, including problem identification, to specialists initially. A Park entomologist would coordinate with scientists who are conducting entomological research in the Park or on problems relating to conditions within the Park. Recommended research topics are: cave invertebrate inventory, monitoring program for important taxa (which are to be further defined), status of insects eaten by endangered birds, mosquito abundance and distribution in conjunction with avian malaria and pox incidence, and compiling a list of threatened and endangered species.

Cost/Workload. $50,000, 1 FTE per year for 5 years
Staff Entomologist

HAVO-25 STUDY CONTROL OF NON-NATIVE BIRDS

Statement of the Problem. A few non-native bird species are able to survive in numbers within nearly intact native forests. The Japanese white-eye (Zosterops japonicus) and the red-billed leiothrix (Leiothrix lutea) are the most prominent of these. Impacts of these species upon native insects and plants and the importance of their role in distributing propagules of non-native plants are largely unknown. Competition of these species with rare native species has been hypothesized, based on comparisons of abundance of species pairs in several areas and on overlapping food habits. Other introduced species such as the Kalij pheasant (Lophura leucomelana), common mynah (Acridotheres tristis), and melodious laughing thrush (Garrulax conorus) influence the distribution of exotic plants and perhaps compete with natives for scarce resources. House sparrows (Passer domesticus) and house finches (Carpodacus Mexicanus), among many others, transmit avian diseases. Requirements of, and limiting factors for, the introduced species, especially in or near important Hawaiian ecosystems, need to be better understood.

Alternative Actions and their Probable Impacts.

1. Take no action. Under this alternative, we will have little direct knowledge of the effects of non-native birds on native and introduced flora and fauna. We will be less able to define restorable ecosystems and determine priorities for protection and management of important ecological areas. The impacts of irruptions and declines of introduced species in key areas will remain unstudied. Important limiting factors potentially useful in minimizing impacts of introduced birds will remain undetected.

2. Study important introduced birds in important ecological areas. The roles and importance of these species will be determined. Limiting factors will be better understood and management decisions more knowledgeable. Management programs for other components of ecosystems will be better structured through understandings of these mobile and widespread animals.

Recommended Course of Action. Conduct research on selected introduced species of birds in or near important ecological areas in Hawaii Volcanoes. If done concurrently with research on native birds in these areas, cost savings and more complete understandings of total ecology can be obtained. Management knowledge and decision making will be enhanced. Literature review and reconnaissance will identify the most likely areas and species for study.

Cost/workload. $40,000 per year for 3 years
A Research Technician or doctoral candidate

HAVO-71 CONTROL YELLOW-JACKET WASPS IN LOCALIZED AREAS

Statement of the Problem. Yellow-jacket wasps have been in the Park only since 1978 and have become ubiquitous nuisances. They are also dangerous to people who are subject to allergic reaction from wasp stings, and they are undoubtedly devastating to native invertebrate populations. Control methods currently in practice consist of locating nests and applying Ficam dust (a pyrethrin) with a hand-held boom to the nest portal. Nests are located only infrequently, usually through complaints from people who get stung by the wasps, or by alert employees who understand the hazards and recognize nest features.

Although the Ficam dust is very effective in eliminating the nests which are treated, a method for eliminating all wasps in a localized area, such as a picnic ground, campground, residential area, etc. is needed. A study by the Hawaii Department of Health, Vector Control Division, has not produced desired results so far. A study by the Hawaii Sugar Planters Association has only just begun.

Alternative Actions and their Probable Impacts.

1. Do nothing. Ignore the wasp problem. Under this alternative complaints would go unanswered. Visitors and employees would receive wasp stings from nests which are in close proximity to work or gathering places. Total wasp populations would probably remain high, but nests in the vicinity of people would not get treated.

2. Continue treating nests as they are located, particularly where wasps are a nuisance or health hazard. Realize that most nests go undetected, but that the ones causing immediate problems to people are destroyed opportunistically.

Recommended Course of Action. Alternative 2 is recommended, pending development of more efficient methods under HAVO-70. The environmental impact of applying Ficam dust to nest portals is negligible, providing label instructions are followed and common sense is used. The insecticide is approved for use by the NPS pesticide coordinator's office. It is not considered to be an issue, particularly in comparison to the threat to human health and safety and to the the natural environment which is posed by the wasps.

Cost/workload. $5,000, .1 FTE per year

HAVO-7Ø STUDY CONTROL METHODS FOR YELLOW-JACKET WASPS

Statement of the Problem. Yellow-jacket wasps are recent arrivals in the Park. The first specimen was collected in 1978. They have since become ubiquitous. They pose serious human health problems and are believed to causing heavy impact on native insect and arachnid populations. This is probably adversely affecting native birds by dimnishing their food supplies. V. pensylvanica are difficult to control except in localized areas, such as picnic areas, residential areas, scenic overlooks, etc.

Method of control at present requires locating nests, which are invariably undergound. Insecticide is deposited with a hand-held applicator around the nest portal. Insecticide is a pyrethrin, Ficam powder. Normally a light coating of the material around the nest entry will kill the entire colony within a day or so. This method is labor intensive and it is inefficient since only a small number of the total nests are ever discovered.

Hawaii Department of Health, Vector Control Division, began an experiment with the cooperation of the NPS in the Park and vicinity to discover a poison bait method for localized wasp control. Difficulties finding a suitable bait have delayed success, and it appears the study will not progress. In the meantime, the Hawaii Sugar Planters Association have begun a study in cane lands.

Alternative Actions and their Probable Impacts.

1. Ignore the wasp problem. Accept the inevitable occupation of vast territory by the wasps and the ultimate accommodations they will have to make with their new Hawaiian environment. Destroy nests which are located, and to that extent temporarily alleviate nuisance and health problems.

2. Conduct research in methods of control which utilizes a poisoned bait. Overcome difficulties which Hawaii Department of Health study encountered. Monitor population trends and effectiveness of treatments. A poisoned bait method is presumed to be safe if the bait is taken only by wasps and not by non-target animals. It requires less time and money to carry out than the current method of applying insecticide to nests.

3. Conduct biological control studies.

Recommended Course of Action. Alternative 2 is recommended. It should be pursued with respect to information available from the study underway by the Hawaii Sugar Planters Association. NPS mandates require deliberate action to protect visitor health and safety and protection of native ecosystems which are threatened by introduced wasps, therefore rendering Alternative 1 inappropriate. Alternative 3 could be included within Project Statement HAVO-49, Study Invertebrates. The listing of other research priorities and the probability of at least localized success of a poison bait approach reduce the urgency of Alternative 3. The objectives of a poison bait study would satisy an immediate need for localized control in picnic areas, campgrounds, residential areas, and other areas where people gather. Results under Alternative 2 are achievable with modest effort and funding, especially if the Hawaii Sugar Planters Association provides information relevant to the Park's need for localized control. Other wasp studies could be undertaken later.

Cost/workload. $40,000 per year for two years
CPSU contract

HAVO-11 MONITOR AIR QUALITY TO ESTABLISH BASELINE

Statement of the Problem. The Park is faced with an imminent external threat in the form of a proposal for a 250-megawatt geothermal electricity development. This proposal is for an area immediately upwind of the eastern Park boundary. Manganese nodule smelting 18 miles away is a potential threat. The Park has good preliminary air quality data, drawn principally from information gathered during 1983 and 1984 from reports to the State of Hawaii by Nuclear Environmental Analysis, Inc. (NEA, Inc.), consultants for the State and the developer, and from data gathered from four solar-powered remote portable units along the East Rift during 1984, and analyzed by NEA, Inc. These data are not of sufficient quality nor do they cover a long enough period to satisfy our needs for information which will help the Park understand the exact nature of air quality changes which may take place if and when geothermal wells and power plants begin to operate.

Park managers need to correlate changes in air quality with the development of geothermal resources in adjacent lands. Managers of Class I areas, such as Hawaii Volcanoes, are obliged by mandate of the Clean Air Act to prevent significant deterioration of air quality. Sulfur dioxide ($SO_2$), Total Suspended Particulates (TSP), and Hydrogen sulfide ($H_2S$) are the primary emissions of concern, although there are many others which need to be specified. The two former emissions are criteria pollutants regulated by the Clean Air Act. Standards for hydrogen sulfide are in preparation.

Alternatives and their Probable Impacts.

1. Do no air quality monitoring. Rely instead on data from the State and its consultants or on the developer to analyze baseline air quality. Under this alternative, Park managers would reasonably expect to provide supplementary funds and to cooperate with non-Service workers and analysts for data, and Park managers would have a reasonable expectation that modelling would be based on a regional perspective, for example southeastern Hawaii island rather than the Park's East Rift. Under this alternative, costs would most likely be less than if the Park were to undertake its own monitoring, but data would be less Park specific.

2. Carry out monitoring of areas downwind from the proposed geothermal development area, along the eastern Park boundary. Purchase instruments, hire a field person to collect data, and contract with an air quality analysis

laboratory to analyze the data. Under this alternative, the Park would reasonably expect to configure its model with regard for other monitoring activities underway by developers and State officials, but the intent would be to gather air quality data, first-hand, in order to build as complete a baseline for the Park as possible. Secondarily, the Park would assimilate data from stations belonging to others, and share Park data with others. Under this alternative, costs would be higher than in Alternative 1, but data would be highly Park specific.

Recommended Course of Action. Utilizing the expertise of the NPS Air Quality Office in Denver, Colorado, design an instrumentation and model configuration which would combine the alternatives described above. Working with State and developer consultants, make a committment to a regional air quality baseline, agree to provide modest funding in order to supplement data-collecting from stations outside the Park which would benefit from information gathering within the Park, and be willing to do modelling within the Park which would be of benefit to both the Park and to the region. Agree to exchange data and to have the data published in a regional format.

Costs/workload. $50,000 for the first year
$26,300 per year for the second and third years
Hire part-time Park Technician to collect and manage field data.

HAVO-41 MAP AND INVENTORY LAVA TUBE CAVES

Statement of the Problem. Hawaii Volcanoes contains many miles of unique, unstudied, unprotected, and increasingly impacted cave resources. These caves, resulting from lava tube formation during pahoehoe flows, contain specialized, endemic cave invertebrates, ancient Hawaiian artifacts and burial grounds, and unique geologic formations. Geologic formations found in lava tubes such as ice, drip stalagtites, and sand castles are vulnerable to visitor impacts and cultural artifacts are subject to removal. The primary energy source for the unique invertebrate life is the delicate network of ohia roots that penetrate lava tubes, hanging from the ceiling and forming a mass on the cave floor.

One cave in the Park is presently developed for intensive visitor use. No other caves are managed. Some other caves, whose locations were previously known to only a few individuals, have now been publicized and explored by speleological groups. Speleological and recreational visits appear to be increasing, thereby raising the potential for adverse impact on what is now a relatively pristine resource.

Park caves have been investigated only to the extent that their uniqueness and fragility is confirmed. An inventory of cave resources and locations has not been undertaken. A cave management plan is in preparation.

Alternative Actions and their Probable Impacts.

1. No Action. Continue current course of action in which cave locations are not mapped, cave resources are not inventoried, visitation and human impact in caves is not monitored, and caves are not managed. Without this information, an effective cave management program cannot be implemented. The current level of knowledge of cave resources is probably adequate for current levels of use. However, as cave locations become better known and recreational and speleological use increases, cultural, biological, and geological resources will be degraded through human impact.

2. Map and inventory Park's cave resources. By determining their fragility, resource value, and hazards, this study will provide the information base necessary for managing caves, classifying caves into management catetories based on their resource and hazard characteristics and developing regulations, guidelines, and a permit system. Without this information management will be not be based on cave resources and unique cave resources will be lost.

Recommended Course of Action. Map and inventory the Park's cave resources. Organize an interdisciplinary study of biological, geological, and cultural resources of caves and prepare a map of cave locations. From this study, caves can be classified into management categories based on hazards, resource values, and vulnerability to human impact and appropriate management strategies.

Cost/workload. $30,000 per year for three years
Study contract administered by CPSU

HAVO-46 PREPARE WATER RESOURCES MANAGEMENT PLAN

Statememt of the Problem. Hawaii Volcanoes contains water resources and a Water Resources Management Plan will be prepared as mandated to develop an information base about water resources and establish a park program to protect, manage, and use Park water resources in accordance with law and Park Service policy.

Park waters are limited to intermittent ground water, water catchment and public water systems, ephemeral tidepools in the splash zone, tidally fluctuating brackish water in cracks along the coastline, steam and fumeroles in hydrothermal areas, and ice in high elevation lava tubes. There are no lakes or streams although a few drainages may flow temporarily in heavy and prolonged rain and water may move over poorly drained rocky surfaces. There are no conventional surface water resources such as lakes and streams. Proposed geothermal drilling may pose a threat to the Park's hydrothermal waters and ground water along the East Rift of Kilauea.

Alternative Actions and their Probable Impacts.

1. Take no action. If a Water Resources Management Plan is not written, Hawaii Volcanoes will violate a legislative mandate and water resources may not be protected and managed in accordance with law and Park Service policy.

2. Prepare a Water Resources Management Plan. In so doing, water resources will be documented and appropriately managed.

Recommended Course of Action. Prepare a Water Resources Management Plan. Once a plan is written and problems are identified a management program can be undertaken if problems or threats are identified.

Cost/workload. $5,000 for one year
CPSU contract

HAVO-69 STUDY ADP INFORMATION MANAGEMENT

Statement of the Problem. Managers and researchers are collecting and compiling large amounts of data and attempting to store, retrieve, and analyze data using micro-computers. Some persons are applying word processing uses to their preparation of documents. Although some individuals are developing good skill with micro-computers, others are not advancing rapidly. No user has comprehensive skills and knowledge to fully apply potential Automatic Data Processing (ADP), including data sharing with colleagues, configuring data banks, accessing information within other systems, manipulation of data and data sets, and formatting data output for analysis or for presentation. Acquiring data management skills requires free and easy access to a micro-computer, time to become familiar with machines and with programs, and/or formal training. The necessary combination of the above elements is not generally available to most managers and researchers, consequently development of ADP skill and application to work within the work unit is advancing unevenly and slowly.

Alternatives and their Probable Impacts.

1. Allow persons within the research and resources management work units to acquire ADP skills on their own and at their own pace. Some workers will become very competent and others will progress slowly or will avoid using micro-computers. The full potential of ADP application to the work unit will not be realized, hence the full value which could be derived from data sets will be lost.

2. Institute formalized training in use and application of ADP technology to research and management programs. Provide workers with individualized, hands-on instruction in specific data management needs so that all who input, retrieve, and/or analyze data can do so with skill and purpose. Attempt to enhance the data management capabilities of workers and of the work unit. Furthermore provide additional ADP capacity to include graphics, geographical information system (GIS), telecommunications, and other enhancements.

Recommended Course of Action. Alternative 2 is recommended, since it recognizes the inevitability of ADP technology to the work unit and provides a framework for developing competence in managing data. Data management at local levels and data sharing through information banks, data libraries, and other massive data processing methods

are destined to be critical sources of reference for managers and researchers. Provide formal, specific training for incumbents whose positions require data management skills. Tailor courses and workshops for on-site instruction in specific work unit applications.

Cost/workload. $2000 per year for two years

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