Appendix I
Army NRS NARS Special Use Permit 2006

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

SPECIAL USE PERMIT
NATURAL AREA RESERVES SYSTEM

DEPARTMENT OF LAND AND NATURAL RESOURCES
1151 PUNCHBOWL STREET, HONOLULU, HI 96813

EFFECTIVE: April 5, 2006

EXPIRATION: April 5, 2007

RESERVES: Ka‘ena, Ka‘ala, Pahole

The Board of Land and Natural Resources or its authorized representative, with the approval of the Natural Area Reserves System Commission, hereby issues this Special Use Permit in accordance with: Section 195-5, Hawaii Revised Statutes, Section 13-209-5, Hawaii Administrative Rules pertaining to Natural Area Reserves; and Section 195D-4, Hawaii Revised Statutes and Section 13-107-4 Hawaii Administrative Rules pertaining to Threatened and Endangered Plant Species to:

Joel E. Godfrey,
Chief, Environmental Division
U.S. Army Garrison Hawaii
572 Santos Dumont Avenue, BLDG 105
Schofield Barracks, HI 96857-5013

Phone: 656-2878 Fax: 656-1039

to allow the Permittee, and his authorized designees within the Army Natural Resources staff, to conduct work in the above three Reserves as outlined in the permit application to help stabilize species of endangered plants. This work will be conducted by Permittee to enable the Permittee to fulfill its Section 7 Endangered Species Act species stabilization requirements for 27 target taxa of endangered plants in order to continue military training in Makua Valley. The U. S. Fish and Wildlife Service determined that routine military training would jeopardize the continued existence of these taxa and that the Army was to prepare an Implementation Plan (IP) to provide stabilization actions. These three Reserves contain some of the most intact areas of dry, mesic, and wet ecosystems remaining in the Wai‘anae Range of O`ahu.

GENERAL CONDITIONS

1. Besides conditions stipulated here, the Permittee will adhere to project specifications given in the permit application.

2. Disturbance of native vegetation and wildlife will be avoided as much as possible.

3. Reports:
   a. A field report will be submitted within five (5) weeks of project completion.
   b. Results of the project, as published or unpublished reports, also will be submitted. Reports will be submitted by Reserve and should cover all the activities requested under this permit. These individual reports shall be separate from the standard annual report produced by Army Natural Resources Staff (NRS) that encompasses all their activities.
   c. The reports will identify the Reserves as project sites and acknowledge the Special Use Permit as approved by the Board of Land and Natural Resources or its authorized representative, with the approval of the Natural Area Reserves System Commission.

4. Precautions will be taken to prevent introduction of plants or animals not naturally present in the area. Should an infestation develop, Permittee is responsible for eradication by methods to be specified by O`ahu Natural Area Reserves System (NARS) Staff - whether it occurs during or after the permit period, and even though it may be only indirectly attributable to the project activities.

5. This permit is not transferable.

6. This permit does not exempt the permit holder from complying with any other applicable rule or statute, and should be consistent with the Statutes, Rules and Management Policies of the Natural Area Reserves System.

7. The State of Hawaii shall be released and held harmless from any and all liability for injuries or death, or damage or loss of property however occurring during any activity related to this permit.

8. The Department of Land and Natural Resources will maintain control and supervision of State lands while this Permit is in effect.

9. Permittee shall not bring any heavy equipment onto the Premises except as necessary to access the Premises through the nearest road (i.e. a four-wheel drive vehicle) and provide necessary maintenance and improvements for access and fire suppression.

10. The Permittee shall observe and comply with all laws, ordinances, rules and regulations of the federal, state, municipal, or county government affecting the Premises or improvements.

11. In case the State of Hawai`i shall, without any fault on its part, be made party to any litigation commenced by or against the Permittee (other than condemnation proceedings), the

Permittee shall pay all costs, including reasonable attorney's fees, and expenses which may be incurred by or imposed on the State of Hawai`i; furthermore, the Permittee shall pay all costs, including paid by the State in enforcing the covenants and agreements of this permit, in recovering possession of the Premises, or collection of delinquent charges.

12. In the event any unanticipated cultural or historical sites, materials or remains (such as bone or charcoal deposits, human burials, rock or coral alignments, pavings or walls) are encountered by the Permittee and/or its contractors, all work shall stop immediately and Permittee will contact the State Historic Preservation Division in Honolulu at (808) 692-8015 immediately for further direction, as well as DOFAW staff (808) 973-9683.

13. The Division of Forestry and Wildlife reserves the right to add further conditions to this permit during the period of permit validity. The permittee will be informed of these changes in writing at least one week prior to the additional conditions taking effect.

14. Special Use Permits are granted for a maximum of one year at a time. If renewal or extension is necessary, at least one month prior to expiration of present permit, Permittee is required to submit a progress report detailing work completed within the present permit and plans for the new permit period. Failure to submit a written progress report and request a renewal of this permit prior to expiration may result in all work being ceased in the Reserves and a denial of access to all areas covered by this permit until this matter is resolved.

15. Hazardous materials:
    a. For the purpose of this, "hazardous material" shall mean any pollutant, toxic substance, hazardous waste, hazardous material, hazardous substance, o roil as defined in or pursuant to the Resource Conservation and Recovery Act, as amended, the Comprehensive Environmental Response, Compensation, and Liability Act, as amended, the Federal Clean Water Act, or any other federal, state, or local environmental law, regulation, ordinance, rule, or by-law, whether existing as of the date hereof, previously enforced, or subsequently enacted.
    b. Permittee shall not cause or permit the escape, disposal or release of any hazardous materials except as permitted by law. Permittee shall not allow storage or use of such materials in any manner not sanctioned by law or by the highest standards prevailing in the industry for storage and use of such materials, nor allow to be brought on the Premises any such materials except to use in the ordinary course of Permittee's business, and then only after written notice is given to the State of the identity of such materials and upon the State's consent, which consent may be withheld at the State's sole and absolute direction. If any lender or government agency shall ever require testing to ascertain whether or not there has been any release of hazardous materials by Permittee, then the Permittee shall be responsible for the reasonable costs thereof. In addition, Permittee shall execute affidavits, representations and the like from time to time at the State's request concerning Permittee's best knowledge and belief regarding the presence of hazardous materials on the Premises placed or released by Permittee.
    c. Permittee agrees to indemnify, defend, and hold the State harmless from any damages and claims resulting from the release of hazardous materials on the Premises

occurring while Permittee is in possession, or elsewhere if caused by Permittee or persons acting under Permittee. These covenants shall survive the expiration or earlier termination of this permit.

SPECIAL CONDITIONS

16. In a letter to the NARS Commission Executive Secretary, Betsy Gagné, from Army NRS Manager, Michelle Mansker, dated January 10, 2006 the Army NRS sent 12 pages of tables of actions, including 88 separate actions, that the Army NRS Staff plan to accomplish between March 2006 and March 2007. The Army NRS to authorized conduct all these actions with the exception of the collection of cuttings from *Flueggea neowawrea* trees in O`ahu Natural Area Reserves (NARs). The Army is to only collect seed from this species; no cuttings are to be taken from *Flueggea neowawrea* within the Natural Area Reserves..

17. The Army NRS will only use paid staff to carry out actions on the O`ahu NARS. The O`ahu NARS will not be available to the Army Environmental Program for the use of volunteers or service groups.

18. The number of days available to the Army NRS to work in Pahole NAR may be limited by the ability of the O`ahu NARS Staff to provide oversight and escort. The O`ahu NARS Manager may require that Army NRS be escorted by the O`ahu NARS Specialist IV or other designee when working in Pahole NAR.

19. The Army Environmental Program are encouraged to assist with DOFAW O`ahu NARS priority projects. These projects include but are not limited to the improvement, maintenance, and repair of: roads trails, fences, helicopter landing zones, irrigation systems, water catchment systems, shelters, and any other facilities or infrastructure that directly support either the O`ahu NARS Program or the Army Environmental Program. The Army NRS will also be encouraged to assist with weeding projects that are a priority of the O`ahu NARS Staff. The assistance the Army provides will be through Army NRS work and direct monetary support to purchase or lease equipment and hire personnel to complete the work; for example purchase or rental of a bulldozer, or provide funding for an equipment operator position. The exact level of monetary support will be established in the MOU between the State of Hawai`i and the Army, to address carrying out the Makua Implementation Plan.

20. Outplanting projects must be approved as stand alone projects. The O`ahu NARS Staff considers the attempt to stabilize rare plant species by outplanting plants propagated in a nursery into a wild population to be an experimental design. The O`ahu NARS Staff will have the ultimate discretion in deciding where outplanting sites will be located. Written request to do the outplanting project request to do the outplanting project must:
    a. Identify the species to be planted
    b. Provide a description of after planting care.
    c. Provide a detailed location for the outplanting including a detailed map.
    d. Identify the personnel doing the planting.
    e. Written outplanting plan shall be submitted by Army NRS to O`ahu NARS staff for approval at least 8 months prior to the outplanting project taking place.

All outplanting projects should have a research component that provides a baseline survey of habitat conditions at the proposed outplanting site prior to planting, and then monitoring those habitat conditions throughout the years the Makua Implementation Plan is in place. The research component will monitor parameters such as temperature, humidity, light intensity, etc. as identified by O`ahu NARS; such data can be collected by installing remote data loggers (i.e. Hobo Data Loggers) at each outplanting site. The Army NRS must receive written permission from the O`ahu NARS Manager or his designee prior to proceeding with the outplanting project. The O`ahu NARS Manager or his designee may stipulate that the Army NRS will assist with other DOFAW priority weeding projects as a condition to proceed with the outplanting project. Some of this assistance may be help in managing outplanting sites (i.e. Kapuna Stream site) that have already been developed and that have outplanted species included in the Makua Implementation Plan. The State of Hawai‘i does not accept any responsibility to maintain, enhance or protect any outplanting sites that are created by the Army NRS when permission to proceed with the outplanting project is granted to the Army by O`ahu NARS Staff.

21. Cooperation at Pahole Rare Plant Nursery. The Army NRS and the Army Horticulturist will agree to develop a MOU with the O`ahu Branch of the Division of Forestry and Wildlife to formalize the relationship between the State of Hawai‘i and the Army NRS and to establish an agreement to guide the day-to-day cooperation of the two agencies at the Pahole Rare Plant Nursery.

22. The Army will inform the O`ahu NARS Manager or his designee in writing at least two weeks prior to any trip to Ka`ala Natural Area Reserve and adjacent Army lands when allowing groups to transit through Ka`ala NAR for educational or service project related visits. The O`ahu NARS Program may direct what routes the Army NRS takes through the NAR and reserves the right to decline the request to transit through the Ka`ala NAR. The Army NRS will assist O`ahu NARS staff with rebuilding the Ka`ala boardwalk by providing materials and labor.

23. The Army NRS and any Botanist contracted by the Army NRS will limit their collection of Threatened and Endangered plants in Natural Area Reserves to the collection of seed. The Army NRS must request permission to collect from Threatened and Endangered Plant species in writing and must obtain the appropriate Threatened and Endangered plant collection permit from the Division prior to initiating seed collection activities. No collection of cuttings, collection of plant materials for vouchers, or air layers will be allowed; however, if voucher specimens are considered to be essential, specimens will be deposited in the Herbarium of Bishop Museum (Official State Repository); digital photographs are also considered to be suitable as herbarium specimens eliminating the need to make more collections than necessary of rare taxa. When the Army Environmental Program collects seeds of Threatened and Endangered plants on Reserves the State will be identified as the owner of these seeds and will be offered a portion of these seeds to be used for State of Hawaii propagation and outplanting programs. The Army NRS will also seek permission to draw any seed collected on State land that is currently in the seed bank at the Seed Conservation Lab at Lyon Arboretum. The Army NRS will also provide O`ahu NARS staff with information on the disposition of seed and propagules collected in the past from State

land by allowing access to this information from their database and assistance with retrieving this information from their database. The Army NRS will provide an annual report of all Threatened and Endangered plant collections on State land, including

a. Species.
b. Population.
c. Amount of propagules collected.
d. Disposition of propagules collected.

This report shall be separate from the standard annual report produced by Army NRS that encompasses all their activities. The Army Environmental Program will review the records of all past Threatened and Endangered plant species collection on State of Hawai‘i land and will change the ownership of those collections from the Army to the State of Hawai‘i.

24. The Army NRS will notify the O`ahu NARS Staff in writing at least one week in advance of any ungulate control activities within O`ahu NARs. Notification will identify the Army NRS staff doing the ungulate control activities, the methods to be used, and a map of the area where the ungulate control work will take place.

25. Permittee is responsible for explaining permit terms to the Army NRS, other Army Environmental Program Staff, individuals contracted by the Army Environmental Program, volunteers, and guests to ensure compliance at all times, including having a copy of the permit in the field at all times. Permittee will also identify the Point of Contact staff person for the day-to-day execution of this permit.

26. Permittee assumes responsibility for damages caused by stabilization actions if such damages are cognizable and payable under appropriate federal statutes and regulations.

27. Permittee will prepare all applicable legal and environmental documents required to conduct the stabilization actions.

28. Permittee will continue to be on, and follow terms of, the U. S. Fish and Wildlife Service Permit Number TE - 826600, and State of Hawai`i Threatened and Endangered Species Permit Number FHM06T&E-06, issued to Dr. Michael Hadfield, who holds the master permits for work on endangered *Achatinella mustelina* tree snails. Army NRS will continue to operate as Sub-Permittees.

_____ _____

JOEL E. GODFREY date
Permittee

_____ _____

PETER T. YOUNG, Chair date
Board of Land and Natural Resources

Appendix III: MMR July 3, 2006 Fire

APVG-GWV (200-3) 5 July 2006

MEMORANDUM FOR RECORD

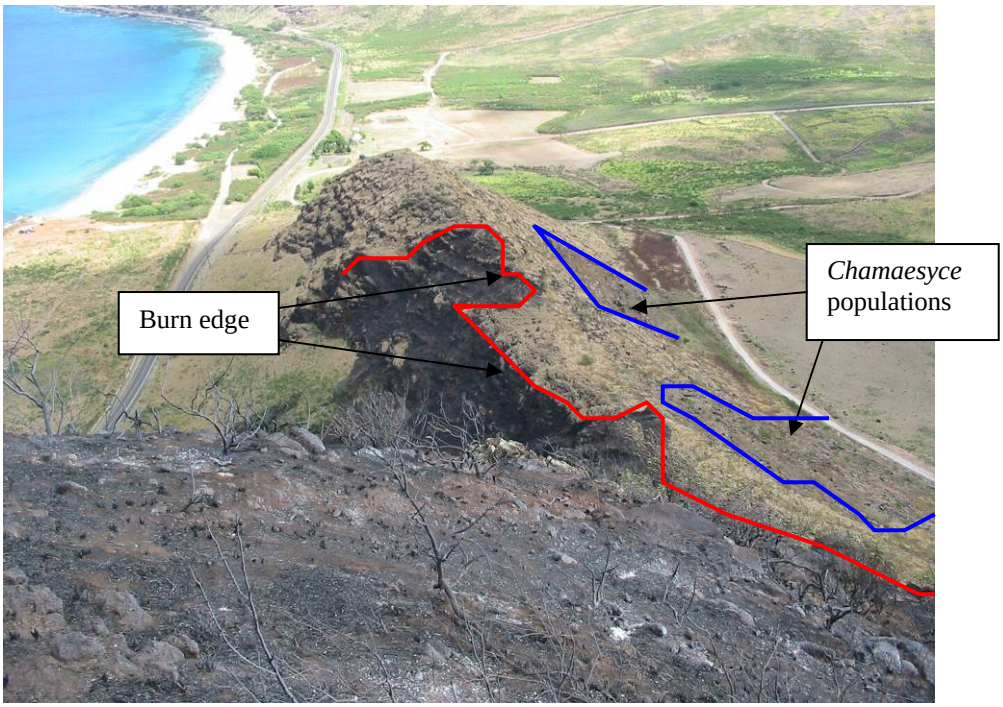
SUBJECT: Reconnaissance for Makua Military Reservation Fire started 7/3/06

On 3 July 2006, a fire started along Farrington Highway near the Kaneana Cave. The suspected cause of the fire is arson (possibly fireworks prior to Independence Day celebrations). See enclosed serious incident report submitted by Chief Enriques, IFSO (Encl. 1)

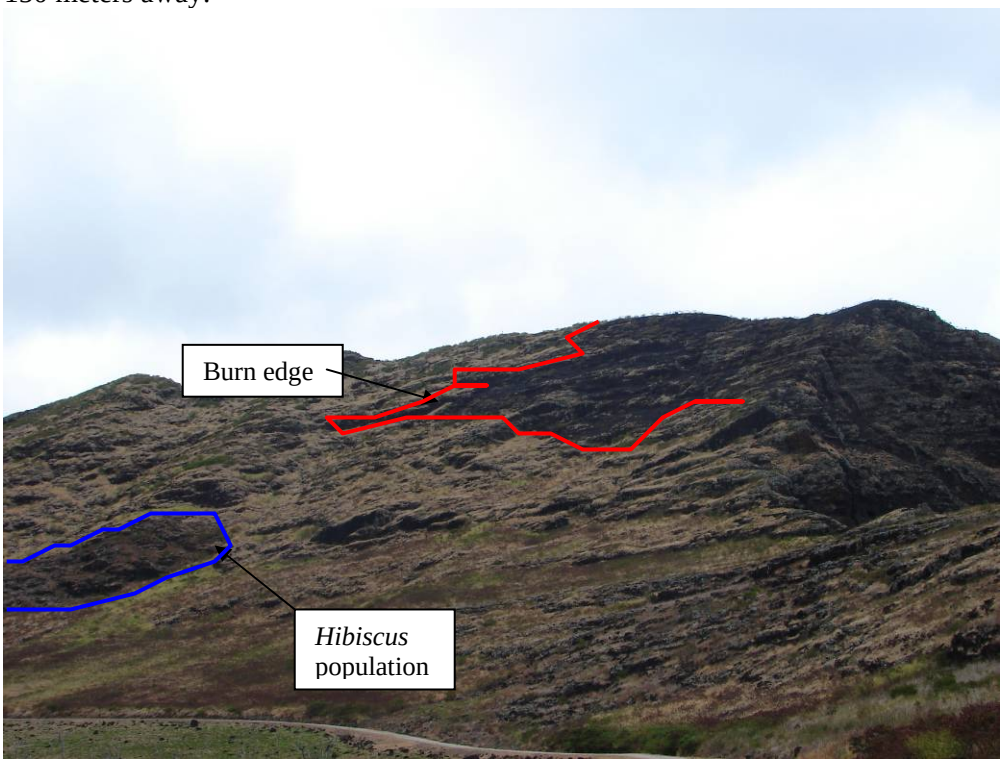
1. Natural Resource Involvement. Natural Resource field crews in Kahanahaiki Management Unit reported the fire at approximately 3:30 pm to the Natural Resource Baseyard. IFSO notified DPW Environmental (Bldg. 105) at approximately 3:45 pm. Peter Yuh called to notify the Natural Resource Office just after he heard the news. Chief Enriques requested Natural Resource Staff to head out to the fire to give guidance regarding where to direct firefighting resources. Ms. Susan Ching Harbin from the Natural Resource Office left the Natural Resource Baseyard for MMR at 3:45 pm. Natural Resource Staff at the baseyard contacted contract helicopter pilots to assist with firefighting activities. Richard Potts with Tropical Helicopters few out to MMR and assisted with water bucket drops. The fire burned approximately 20.2 acres.

2. Extent of Fire. Please see enclosed map showing the fire's extent (Encl 2). In addition photos are also included to illustrate the fires extent where natural resources are a concern.

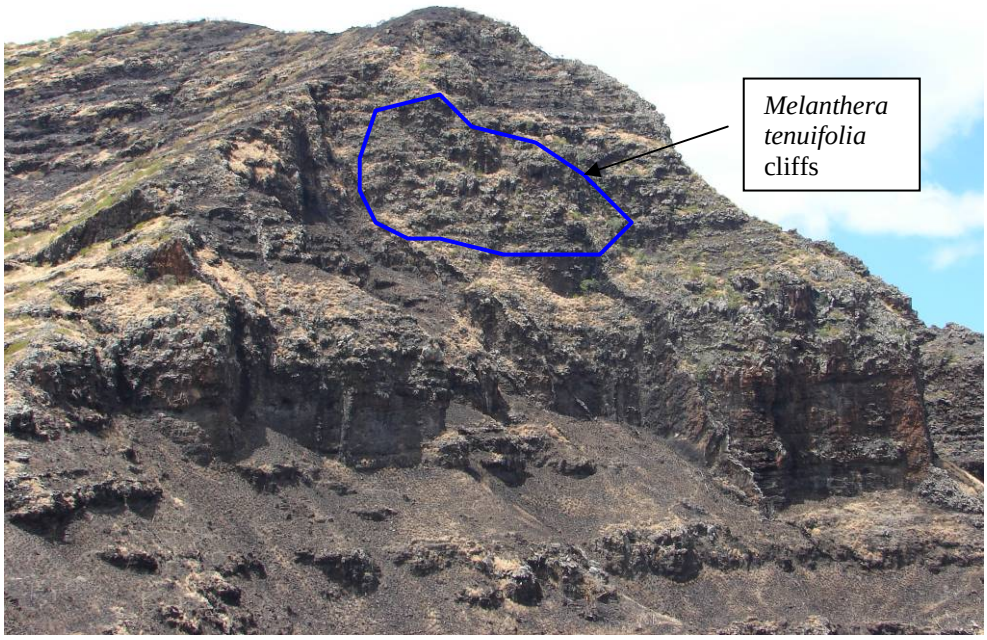
3. Natural Resource Impact. The photograph below is taken from Ohikilolo fence looking north toward Makua Range Control. The blue lines outline the edge of the grass control areas maintained by the Natural Resources Crew to protect two sites with *Chamaesyce celastroides* var. *kaenana*. The closest *Chamaesyce* plant to the edge of the burn was approximately 50 meters away.



The photo below shows the proximity of the fire's edge to the westernmost perimeter of the grass control area maintained by Army Natural Resource Staff to protect *Hibiscus brackenridgei* ssp. *mokuleianus*. Again the edge of the *Hibiscus* grass control area is shown in blue and the fire perimeter is outlined in red. The closest *Hibiscus* plant to the edge of the burn was approximately 150 meters away.



The photo below shows the Makai cliffs of Ohikilolo Ridge. The blue outlined area is the portion of the cliff where NRS have found the endangered daisy plant, *Melanthera tenuifolia*. This part of Ohikilolo ridge has burned numerous times in the past ten years as a result of fire started within MMR and also fires started similar to this one, from arson along Farrington Highway. It is no accident that plants remain on this small cliff. It appears that the cliff is in part naturally protected from fires because of the steep barren cliffs just below. The last monitoring on rappel that NRS conducted at this site was in September 2004. At the time there were 1 juvenile and 10 mature plants. Since NRS have been monitoring the site, the numbers of plants here have fluctuated below 22 total individuals. Although it is difficult to discern from the photo, the area all around the *Melanthera* cliff was blackened and parts of the cliff were singed. Since NRS had not monitored this population more recently, it is impossible to say the number of plants impacted by the heat of the fire. At most 22 plants could have been destroyed. NRS have collected extensively from this population of *Melanthera* as it is so vulnerable to wildfire. In addition, this population is unique in that, elevation-wise, it is the lowest known population.



The common native plants and alien plants which burned are listed in the tables below.

Native Plant Species

Argemone glauca (Puakala)
Dodonaea viscosa (A`ali`i)
Myoporium sandwichensis (Naio)
Psydrax odoratum (Alahe`e)
*Heterpogon contortus (*Pili*)*
Schiedea ligustrina
*Waltheria indica (*Uhaloa*)*
Coccinea trilobus (Huehue)
*Sida fallax (*Ilima*)*
Doryopteris decora

Alien Plant Species
Acacia mearnsii (Klu)
Andropogon virginicus
Chloris barbata
Leonotis nepetifolia
Leucaena leucocephala (Koa Haole)
Opuntia ficus-indica (Panini)
Panicum maximum (Guinnea grass)
Pluchea symphitifolia
Prosopis pallida (Kiawe)
Rhyncheletrum repens (Natal Red Top)
Stapelia gigantea

An additional impact is that the ungulate fence along Ohikilolo ridge burned. A total of approximately 600 meters were burned over, of this, approximately 175 meters had not been burned previously according to our records.

4. POC is the undersigned, 656-7741/7641.

Encl

KAPUA KAWELO
Biologist, Environmental Division

INSTALLATION OPERATION CENTER
Schofield Barracks, Hawaii 96857-5000

SERIOUS INCIDENT REPORT

RECORD DATA

REPORT NUMBER:	**060703A**	**REPORT CATEGORY:**	3.19

CATEGORY DESCRIPTION:	Makua Valley Fire

DATE TIME GROUP OF REPORT:	031600JUL06
LOCATION OF INCIDENT:	Vicinity of Kamehameha Hwy (Grid: EJ798050)
DATE TIME GROUP OF INCIDENT:	031600JUL06

SUBJECT:	N/A
LAST NAME, FIRST, MI:	N/A
RANK:	N/A
SSN:	N/A
UNIT ASSIGNED TO:	N/A
RACE:	N/A
GENDER:	N/A
AGE:	N/A
MOS:	N/A
SECURITY CLEARANCE:	N/A
DRUG/ALCOHOL INVOLVED [IF YES-TYPE]:	N/A
INJURIES/ILLNESS:	N/A

MARTIAL STATUS:	**Single>**	N/A	**Married>**	N/A	**Number of Children>**		N/A
RESIDENCE:	**Government Quarters>**	N/A	**Unit Billets>**	N/A	**Off Post>**		N/A
OIF:	N/A	**OEF:**	N/A	**REDEPLOYMENT DATE:**	N/A		

REPORTING DATA

Reported By:	Chief Enriquez	**Received By:**	SSG Royce
Duty Position:	IFSO fire Chief	**Duty Position:**	Emergency Actions Controller
Duty Telephone:	438-3533/3531	**Duty Telephone:**	655-8763/4

Enclosure 1

NOTIFICATION DATA

Commanding General	E-mail	ADC(O)	E-mail	ADC(S)	E-mail
Chief of Staff	E-mail	DIV CSM	E-mail	Division Surgeon	E-mail
Chief, IOC	2050	Chaplain	E-mail	PMO	E-mail
Senior EA Controller	E-mail	OBSB	N/A	USAG-HI	E-mail
ACofS, G3	E-mail	ACofS, G1	N/A	SJA	E-mail
PAO	E-mail	ACofS, G2	N/A	USARPAC	Informed
SGS	E-mail	ACofS, G4	N/A	Ops Duty Officer	E-mail
Installation Safety	Rpt By	EOD	N/A	DOC NCOIC	E-mail
Subject's Unit	N/A				


IOC....SIR TEMPLATE 060315.doc

REPORT NUMBER:	**060703A**

CHRONOLOGICAL SUMMARY OF INCIDENT

Identify names, duty positions, and duty telephone numbers of persons other then Subjects whenever possible to increase clarity.

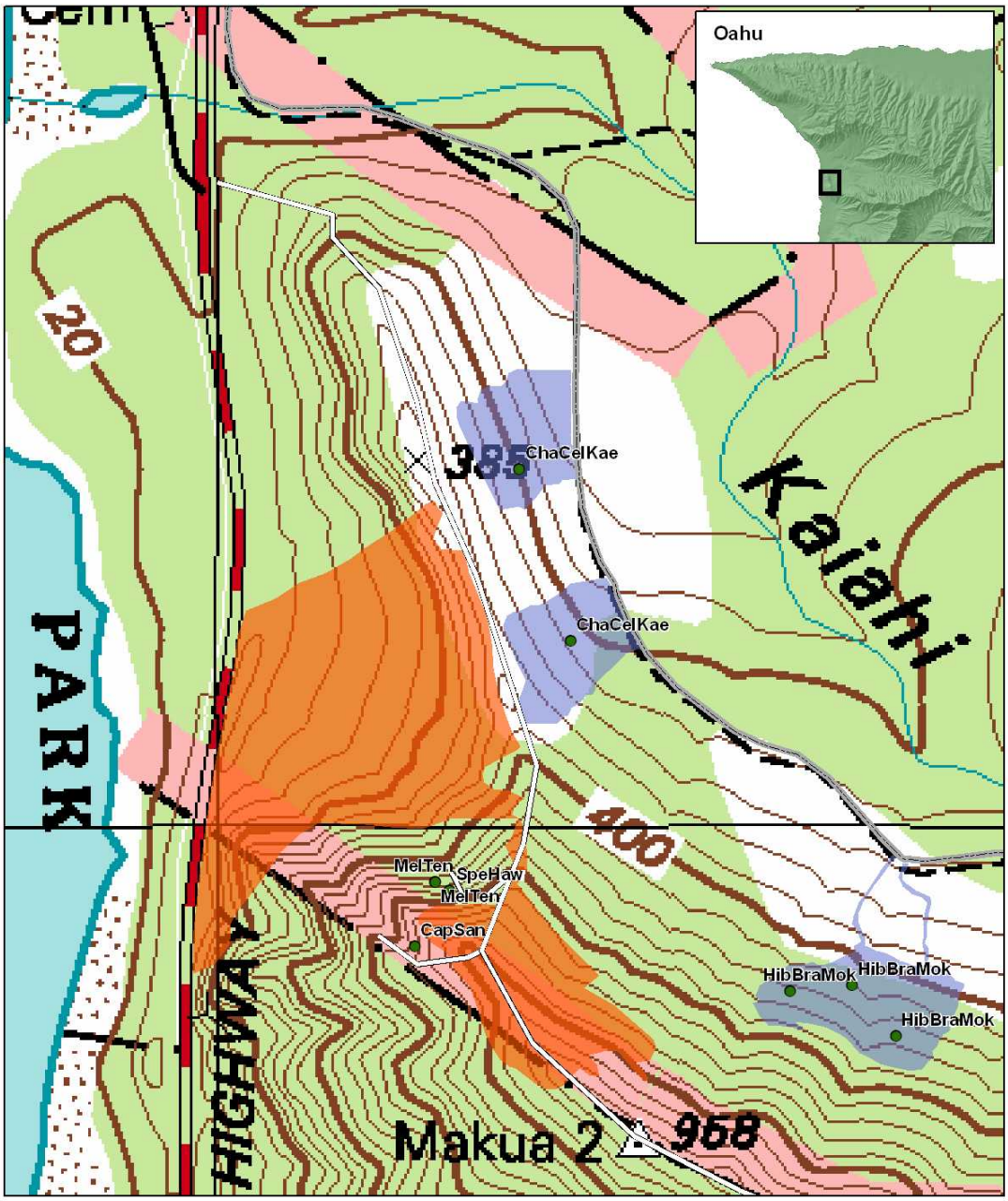
Final: At 032050JUL06, received the following information from Chief Enriquez: the fire is 100% contained with a few hot spots. The Honolulu Fire Department's Air 1 helicopter assisted with 70 drops in four hours of flight time and the contracted helicopter assisted with 43 drops in two hours of flight. An environmental team made an unofficial assessment and will be back on 5 JUL 06 to do an official assessment of environmental damage. At 040600JUL06, the Army Wildland Fire will return to check on hot spots. Until then, Makua Range Control will maintain hourly observation. The cause of the fire has been determined to start roadside from an unknown source.

The point of contact for this report is Chief Enriquez, IFSO at 438-3533. This is a final report.

At 031600JUL06, the Installation Operation Center, USAG-HI received the following information from Chief Enriquez IFSO, Fire Chief: At 031507JUL06, received call from Fed Fire Dispatch (Ms. Colleen) that there is a 10 acre brush fire in Makua Valley (vicinity: EJ798050) and are coordinating with USARPAC for fire bucket support. The cause of fire is currently unknown Currently FFD has Engine 111, Brush Tanker 105, and two HFD engines, and one Air One along with Chief Enriquez (USAG-HI –IFSO) is on-scene. Two contracted aircrafts have been requested and are enroute. The winds are currently blowing at 9 mph from the north to the south, causing the fire to spread towards Kamehameha Hwy. It is too early to report percentage of fire contained. At 031530JUL06, Makua Valley Range control has informed DPW and requested for an Environmental Survey Team.

The point of contact for this report is Chief Enriquez, IFSO at 438-3533/31. This is an initial report.

Enclosure 1



July 3 2006 MMR Fire

Legend

Army Rare Plants
Roads
July 3 2006 Fire
MMR Fences
Grass Control Areas

0 50 100 Meters

N

Enclosure 2

Appendix II: SBW June 26, 2006 Fire

APVG-GWV 26 June 2006

MEMORANDUM FOR RECORD

SUBJECT: Reconnaissance for Fires at Schofield Barracks, West Range started on 6/15/06

1. On 26 June 2006 Kapua Kawelo (Biologist, USAG-HI), Krista Winger (Army Natural Resources), Eric Vanderwerf and Dawn Greenlee (U.S. Fish and Wildlife Service) and Charles Donaldson (Donaldson Enterprises Inc.) conducted a survey of the damage done by fires at Schofield West Range on 6/15/06. The purpose of the survey was to compile an exact map of the fire's extent and to assess impacts upon federally listed species and critical habitat for Oahu `Elepaio.

2. Maps displaying the extent of the fires is attached (encl. 1 & 2). A total of 3.89 acres burned in this fire. The Army is still determining the cause of the fire. It may have been caused by tracer ammunition. The fire extended from the firebreak road at 1,600 feet in elevation to approximately 1900 feet on the ridge top. The vegetation burned in this fire was dominated by *Eucalyptus robusta* (See the photo below). Very few native trees were present in and adjacent to the burned area. For a list of plants which burned and birds detected in the vicinity of the burn see enclosure 2. No known federally listed species are known from the burn location. Although this fire affected primarily *Eucalyptus robusta*, the northern and western edges of the burn destroyed thick alien forest dominated by *Psidium cattleianum*. This forest type is considered suitable habitat for Oahu Elepaio (*Chasiempis sandwichensis* ssp. *ibidis*) while the *Eucalyptus robusta* dominated forest is considered marginal habitat for Oahu Elepaio.

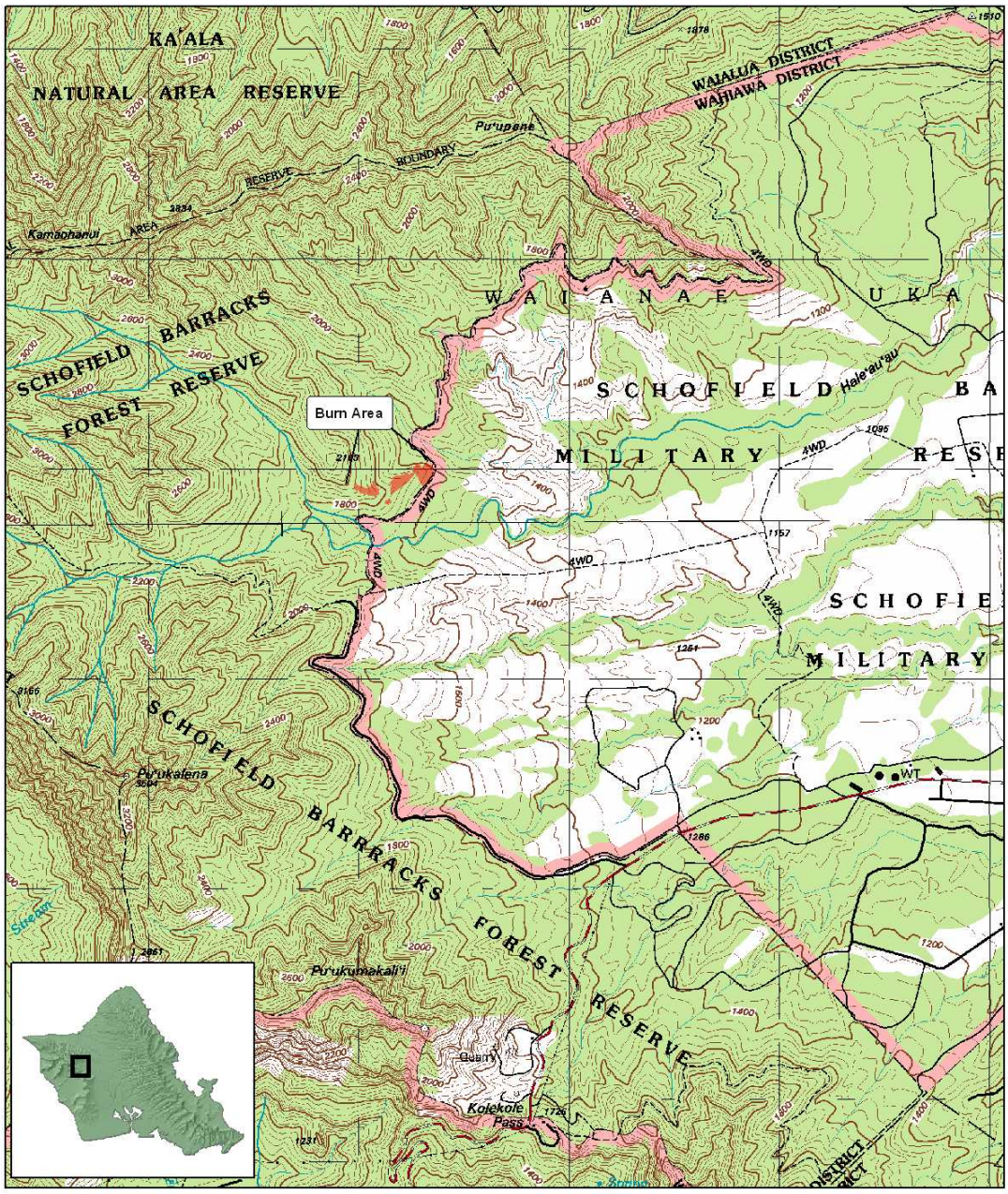
3. No rare plants or animals were impacted in this fire. The closest known Oahu Elepaio territory is 280 meters southwest from the western edge of the fire perimeter. This point is represented on the enclosed map. During the most recent observation in 2005, this territory was occupied by a lone male bird. A total of 2.44 acres of critical habitat designated for Oahu Elepaio was burned. The critical habitat that burned is a very small portion of that designated statewide and it was unoccupied habitat. The negative effect of this fire on the approximately 2.44 acres of Oahu Elepaio critical habitat is small considering that the total acreage of the designation is 66,354 acres.

4. POC is the undersigned, 656-7641/7741.

2 Encls

KAPUA KAWELO
Biologist, Environmental Division

Map removed,
available upon request



Schofield Barracks West Range

Legend

Burn Area

Enclosure 2

N

0 315 630 Meters

Plants and Animals Affected by the June 2006 SBW Fire

Native Plants

Scientific Name	Common Name
Acacia koa	Koa
Microlepia strigosa	Palapalai

Non-Native Plants

Scientific Name	Common Name
Acacia confusa	Formosan koa
Blechnum appendiculatum	None
Buddelia asiatica	Dog Tail
Casurina equisetifolia	Ironwood
Christella parasitica	None
Clidemia hirta	Koster's curse
Cordline fruticosa	Ti
Eucalyptus robusta	Swamp Mahogany
Ficus sp.	None
Grevillea robusta	Silk Oak
Lophostemon confertus	Brush box
Melaleuca quiquinervia	Paperbark
Melia azedarach	Chinaberry
Nephrolepis multiflora	Sword fern
Oplismenus hirtellus	Basket Grass
Panicum maximum	Guinnea grass
Passiflora suberosa	Corky Passion Vine
Psidium cattleianum	Strawberry guava
Schinus terebinthifolius	Christmas berry
Spathodea campanulata	African Tulip
Syzygium jambos	Rose Apple
Toona ciliata	Australian Red Cedar

Native Birds

Scientific Name	Common Name
Hemignathus virens	Amakihi

Non-Native Birds

Scientific Name	Common Name
Leiothrix lutea	Red-Billed Leiothrix
Paroaria coronata	Red Crested Cardinal
Pynonotus jocosus	Red-Whiskered Bulbul
Zosterops japonicus	Japanese White-Eye

Appendix IV: MMR Keawaula July 12, 2006 Fire

MMR Keawa`ula Post Fire Survey
July 25, 2006

APVG-GWV (200-3) 25 July 2006

MEMORANDUM FOR RECORD

SUBJECT: Reconnaissance for Fire burning into Makua Military Reservation, started on 7/12/06 in the Keawa`ula area, north of Makua Valley.

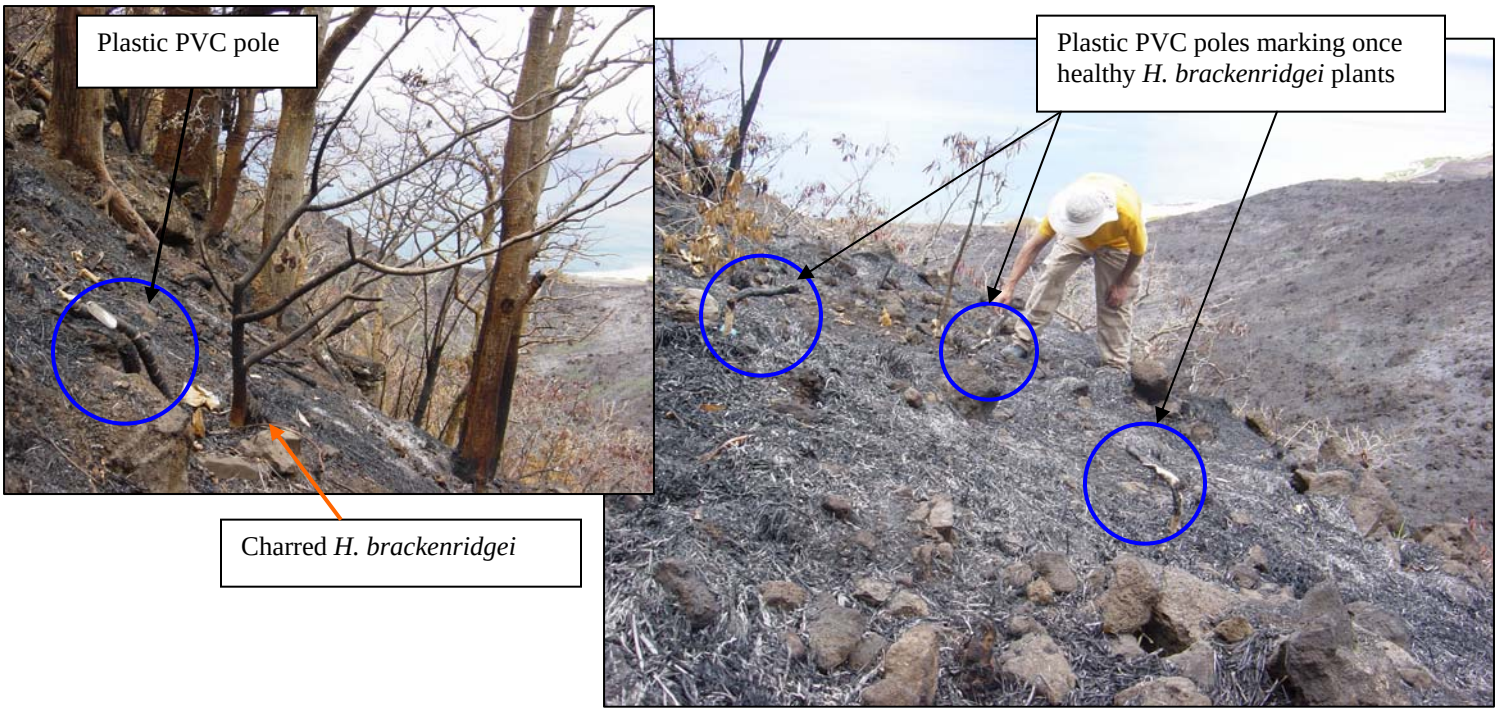
At 10:30pm on 12 July 2006, a fire was ignited in the Keawa'ula Beach Park area, north of Makua Military Reservation. According to the Honolulu Fire Department, the cause of the fire is arson; however the exact location where the fire began is unknown. On 25 July 2006, Natural Resource Staff members, Larry Abbott and Lasha-Lynn Salbosa, conducted a fire assessment survey to generate an exact map of the fires' encroachment in to Makua Military Reservation and to assess impacts to a reintroduction site and an existing wild site of federally listed plant species. A total of approximately 754 acres burned both on State and Military lands.

1. Natural Resource Involvement. Natural Resource Staff, Kaleo Wong and Julia Gustine were headed to Makua Valley to conduct rare plant monitoring. They diverted their trip when they saw the smoke from Keawaula, out of concern for the resources in the Kaluakauila Management Unit. They drove up the Yokohama road to the incident command center and remained there for approximately three hours in order keep our office informed of the status of the fire and to provide advice on the need for additional helicopter resources. Army Natural Resources called in and paid for additional helicopter support to battle the blaze. A total of 7K was spent and based on comments from the Division of Forestry and Wildlife staff, the contract helicopter support was critical in extinguishing the blaze in one day and protecting critical resources.

   Ms. Gustine and Mr. Wong left the Incident Command Center to return to their originally planned work. As they drove down the paved road to the Yokohama guard shack to return to MMR, they observed a back burn which was started to protect the cellular phone building near the bottom of the road. The need for this to protect the structure was logical. While waiting for the road to re-open, they observed that a back burn was conducted not only from near the building but also from that building down along the road to the Yokohama guard shack. It appeared that the back burn conducted was larger than necessary and that it increased the size of the fire's front. The front of the fire was being held on the north side of Kaluakauila gulch until this back burn was initiated. The ultimate result was that the fire crossed the gulch to the south side and subsequently burned into the Kaluakauila Management Unit. It is our observation that this may have been avoided had the back burning only focused around the building it was intended to protect. What this incident shows is that Army interests need to be better represented at these types of fires. It also shows that resource maps must be distributed to the fire crews on site at these fires. Natural Resource Staff will be making field maps to give to Army Wildland fire crews and will have some on hand to take to fires in the future.

2. Extent of Fire. Please see enclosed map showing the extent of the fire near Makua Military Reservation (Encl 1). In addition photos are also included to illustrate the fires' extent where natural resources are a concern.

3. Natural Resource Impact. The following photographs below are taken near the Kaluakauila Fenceline looking down slope and out into Keawa'ula Bay. At this location there is a reintroduction site of endangered *Hibiscus brackenridgei* subsp. *mokuleianus*, planted 10 December 2002. Highlighted in the photographs are charred remains of *H. brackenridgei* and plastic PVC poles used to mark each plant location. A number of other native plant species were also burned. See below for a partial list of native and alien species surveyed. It is estimated that 90 percent of the reintroduction site has been severely burned.

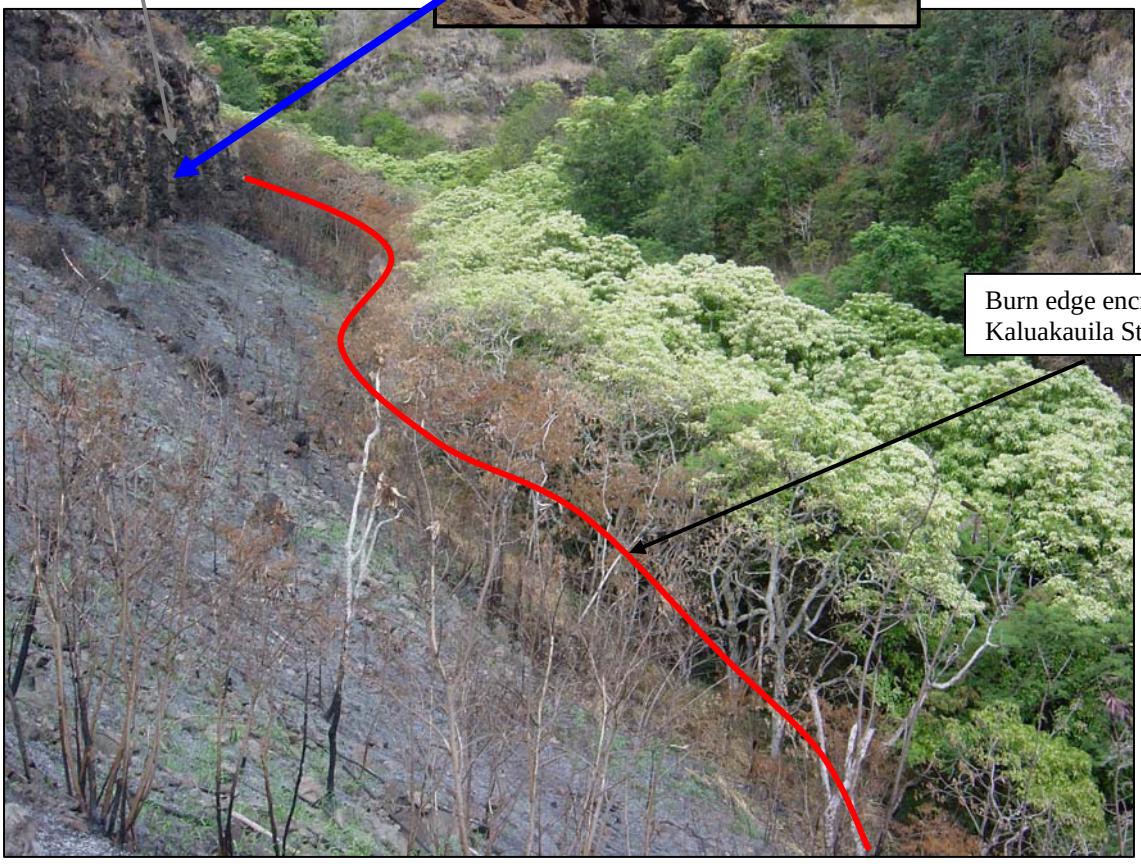


The following photographs are taken on the southeastern facing slope of Kaluakauila Stream at the wild site of the endangered *Chamaesyce celastroides* var. *kaenana* plant species. The area along the slope and cliff side appear to be severely burned.

Further monitoring will be done to determine whether or not *C. celastroides* var. *kaenana* will survive at this site.

Rare plant monitoring tag for *C. celastroides* var. *kaenana*

Wild site of rare plant *C. celastroides* var. *kaenana*

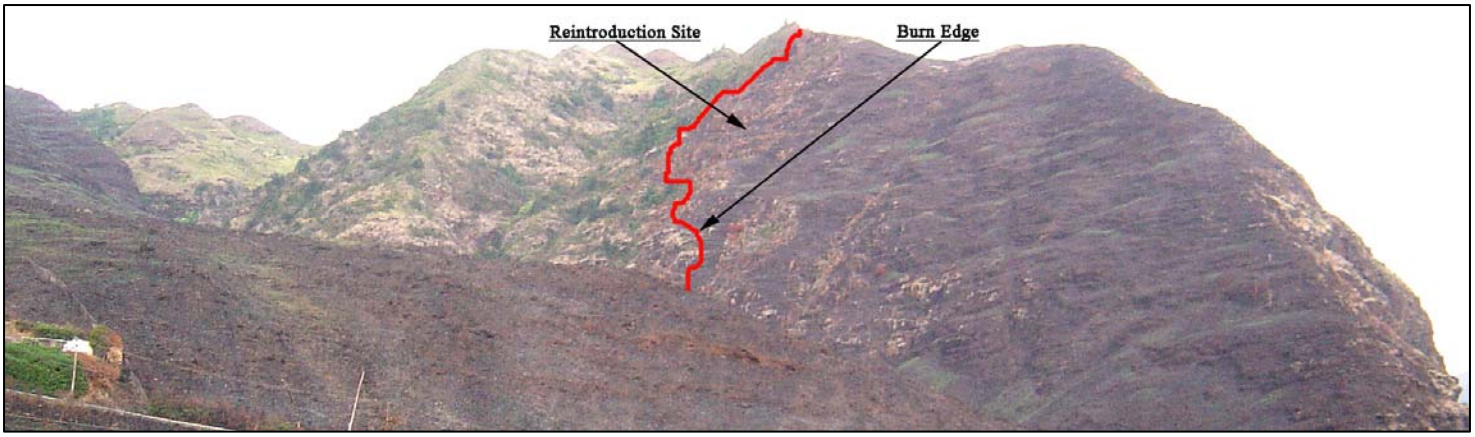


Burn edge encroaching in to Kaluakauila Stream

The following is a list of Native and Alien plant species surveyed in the burn area.

Native Plant Species	**Alien Plant Species**
Diospyros sandwicensis	*Leucaena leucocephala*
Santalum ellipticum	*Panicum maximum*
Hibscus brackenridgei subsp. *mokuleianus*	*Grevillia robusta*
Dodonaea viscosa	*Melinus minutiflora*
Erythrina sandwicensis	
Sida fallax	
Psydrax odoratum	
Chamaesyce celastroides var. *kaenana*	

The photograph below illustrates the extent of the fire along the northwest facing slope of Kaluakauila Stream. Outlined in the photograph is the surveyed burn edge of the fire and reintroduction site of *H. brackenridgei* subsp. *mokuleianus*.



The photograph to the right was taken near the *H. brackenridgei* subsp. *mokuleianus* reintroduction site. Highlighted in the photograph is the Kaluakauila Fenceline. Approximately 500 meters of fence line was subjected to fire.

Map removed,
available upon request

Appendix V: Taxa Abbreviations

Taxa Abbreviations	Taxa
Abugra	Abutilon grandifolium
Acacon	Acacia confusa
Acafar	Acacia farnesiana
Acaman	Acacia mangium
Acamea	Acacia mearnsii
Achasp	Achyranthes aspera var. aspera
Adihis	Adiatum hispidulum
Adirad	Adiantum radianum
Agasis	Agave sisalana
Ageade	Ageratina adenophora
Agerip	Ageratina riparia
Agecon	Ageratum conyzoides
Alemol	Aleurites moluccana
Alomac	Alocasia macrorrhiza
Altses	Alternanthera sessilis
Alyvag	Alysicarpus vaginalis
Amaspi	Amaranthus spinosus
Amavir	Amaranthus viridis
Ambart	Ambrosia artemisiifolia
Anaarv	Anagallis arvensis
Andvir	Andropogon virginicus
Angeve	Angiopteris evecta
Antodo	Anthoxanthum odoratum
Aracol	Araucaria columnaris
Arcale	Archontophoenix alexandrae
Ardcre	Ardesia cretica
Ardell	Ardesia elliptica
Artcil	Arthrostemma ciliatum
Arugra	Arundia gramminifolia
Ascphy	Asclepias physocarpa
Asygan	Asystasia gangetica
Atrsem	Atriplex semibaccata
Avefat	Avena fatua
Axocom	Axonopus compressus
Axofis	Axonopus fissifolius
Bidalb	Bidens alba
Bidpil	Bidens pilosa
Bleapp	Blechnum appendiculatum
Boecoc	Boerhavia coccinea
Botper	Bothriochloa pertusa
	Bouganvillea sp.
Bramut	Brachiaria mutica
Brasub	Brachiaria subquadripara
Brexmad	Brexia madagascariensis
Brugym	Bruguiera gymnorrhiza
Budasi	Buddleia asiatica

Taxa Abbreviations	Taxa
Budmad	Buddleia madagascariensis
Caedec	Caesalpinia decapetala
	Callitris sp.
Calvia	Calyptocarpus vialis
Cancat	Canavalia cathartica
Carpap	Carica papaya
Casarv	Castilleja arvensis
Casela	Castilloa elastica
Casequ	Casuarina equisetifolia
Casgla	Casuarina glauca
Cecobt	Cecropia obtusifolia
	Cedar sp.
Cencil	Cenchrus ciliaris
Cenech	Cenchrus echinatus
Cenery	Centaurium erythraea
Cenasi	Centella asiatica
Cerfon	Cerastium fontanum subsp. triviale
Cesnoc	Cestrum nocturnum
Chanic	Chamaecrista nictitans var. glabrata
Chahir	Chamaesyce hirta
Chahyp	Chamaesyce hypericifolia
Chapro	Chamaesyce prostrata
Chemur	Chenopodium murale
Chivir	Chielanthes viridis (green cliff break)
Chlbar	Chloris barbata
Chlrad	Chloris radiata
	Chloris sp.
Chlvir	Chloris virgata
Chrden	Christella dentata
Chrpar	Christella parasitica
Chroli	Chrysophyllum oliviforme
Chraci	Chrysopogon aciculatus
Ciclep	Ciclospermum leptophyllum
Cinbur	Cinnamomum burmannii
Cirvul	Cirsium vulgare
Citcau	Citharexylum caudatum
Citspi	Citharexylum spinosum
	Citrus sp.
Clihir	Clidemia hirta
Cluros	Clusea rosea
Cocgra	Coccinia grandis
Codvar	Codiaeum variegatum
Cofara	Coffee arabica
Coilac	Coix lachryma-jobi
Comdif	Commelina diffusa
Conbon	Conyza bonariensis

Appendix V: Taxa Abbreviations

Taxa Abbreviations	Taxa
Corgla	Cordia glabra
Corfru	Cordyline fruticosa
Cordid	Coronopus didymus
Corlae	Corynocarpus laevigatus
Cracre	Crassocephalum crepidioides
Criaug	Crinum augustum
Criasi	Crinum asiaticum
CroXcro	Crocosmia X crocosmiifolia
Cropal	Crotalaria pallida
Croret	Crotalaria retusa
Cupcar	Cuphea carthenagensis
Cyacin	Cyanthillium cinereum
Cyclep	Cyclospermum leptophyllum
Cyodac	Cynodon dactylon
Cypgra	Cyperus gracilis
Cyprot	Cyperus rotundus
	Cypress sp.
Datstr	Datura stramonium
Daupus	Daucus pusillus
Deppet	Deparia petersenii
Desvir	Desmanthus virgatus
Desinc	Desmodium incanum
Desint	Desmodium intortum
Dessan	Desmodium sandwicense
Destor	Desmodium tortuosum
Destri	Desmodium triflorum
Digcil	Digitaria ciliaris
Digins	Digitaria insularis
	Digitaria sp.
Digvio	Digitaria violascens
	Dracaena
	Echinochloa sp.
Ehrsti	Ehrharta stipoides
Elegen	Eleocharis geniculata
Eleobt	Eleocharis obtusa
Elerad	Eleocharis radicans
Eleind	Eleusine indica
Emifos	Emilia fosbergii
Emison	Emilia sonchifolia
EpiXobr	Epidendrum X obrienianum
Epipinaur	Epipremnum pinnatum var.aureum
Eraelo	Eragrostis elongata
Eraten	Eragrostis tenella
Erival	Erichtites valerianifolia
Erikar	Erigeron karvinskianus
Erijap	Eriobotrya japonica

Taxa Abbreviations	Taxa
Eucglo	Eucalyptus globulus
Eucrob	Eucalyptus robusta
	Eucalyptus sp.
Euphet	Euphorbia heterophylla
Euppep	Euphorbia peplus
	Euphorbia sp.
Falmol	Falcataria moluccana
Ficmic	Ficus microcarpa
	Ficus sp.
Frauhd	Fraxinus uhdei
Gampur	Gamochaeta purpurea
Neowig	Neonotonia wightii
Gomglo	Gomphrena globosa
Goshir	Gossypium hirsutum
Greban	Grevillea banksii
Grerob	Grevillea robusta
Haecam	Haematoxylum campechianum
Hedcor	Hedychium coronarium
Hedfla	Hedychium flavescens
Hedgar	Hedychium gardnerianum
Helpop	Heliocarpus popayanensis
Helprodep	Heliotropium procumbens var. depressum
	Hibiscus sp.
Hibtil	Hibiscus tiliaceus
Hollan	Holcus lanatus
Hypruf	Hyparrhenia ruffa
Hypgla	Hypochoeris glabra
Hyorad	Hypochoeris radicata
	Hypochoeris species
Hyppec	Hyptis pectinata
	Hyptis sp.
Indspi	Indigofera spicata
Indsuf	Indigofera suffruiticosa
Ipoalb	Ipomoea alba
Ipobat	Ipomoea batatas
Ipocai	Ipomoea cairica
Ipoobs	Ipomoea obscura
Ipooch	Ipomoea ochracea
	Ipomoea sp.
Ipotri	Ipomoea triloba
Ipovil	Ipomoea viloaceae
	Iris sp.
Jasflu	Jasminum fluminense
Junpla	Juncus planifolius
	Juniperus sp.

Appendix V: Taxa Abbreviations

Taxa Abbreviations	Taxa
Jusbet	Justicia betonica
Kalcre	Kalanchoe crenata
Kalpin	Kalanchoe pinnata
Kylbre	Kyllinga brevifolia
Kylnem	Kyllinga nemoralis
Labpur	Lablab purpureus
Lancam	Lantana camara
Leonep	Leonotis nepetifolia
Lepfla	Leptospermum flavescens
Lepsco	Leptospermum scoparium
Leuleu	Leucaena leucocephala
Lintri	Linum trigynum
Livchi	Livistona chinensis
Lopcon	Lophostemon confertus
Ludoct	Ludwigia octovalis
	Lychee sp.
Lycesc	Lycopersicon esculentum
Lycpim	Lycopersicon pimpinellifolium
Macint	Macadamia integrifolia
Macmap	Macaranga mappa
Macung	Macfadyena unguis-cati
Macatr	Macroptilium atropurpureum
Maclat	Macroptilium lathyroides
Macaxigla	Macrotyloma axillare var. glabrum
Malpar	Malva parviflora
Malcor	Malvastrum coromandelianum
Malpen	Malvaviscus penduliflorus
Manind	Mangifera indica
Medlup	Medicago lupulina
Medpol	Medicago polymorpha
Melqui	Melaleuca quinquenervia
Melcan	Melastoma candidum
Melaze	Melia azedarach
Melmin	Melinis minutiflora
Melumb	Melochia umbellata
Meraeg	Merremia aegyptia
Mertub	Merremia tuberosa
Mimpuduni	Mimosa pudica var. unijuga
Momcha	Momordica charantia
Mondel	Monstera deliciosa
Monhib	Montanoa hibiscifolia
Morcit	Morinda citrifolia
	Musa sp.
Myrfay	Myrica faya
Nepmul	Nephrolepis multiflora
Nerole	Nerium oleander

Taxa Abbreviations	Taxa
Nicphy	Nicandra physalodes
Ocigra	Ocimum gratissimum
Odocus	Odontonema cuspidatum
Oplhir	Oplismenus hirtellus
Opufic	Opuntia ficus-indica
Opucoc	Opuntia cochenillifera
Oxacorn	Oxalis corniculata
Oxacory	Oxalis corymbosa
Oxypan	Oxyspora paniculata
Panmax	Panicum maximum
Parfal	Paraserianthes falcataria
Pascon	Paspalum conjugatum
Pasdil	Paspalum dilatatum
Pasfim	Paspalum fimbriatum
	Paspalum sp.
Pasurv	Paspalum urvillei
Pasedu	Passiflora edulis
Pasfoe	Passiflora foetida
Paslau	Passiflora laurifolia
Paslig	Passiflora ligularis
Pasmol	Passiflora mollissima
Passub	Passiflora suberosa
Pencla	Pennisetum clandestinum
Penpol	Pennisetum polystachion
Penpur	Pennisetum purpureum
Penset	Pennisetum setaceum
Perame	Persea americana
Phatan	Phaius tankervilleae
	Philodendron
Phlaur	Phlebodium aureum
Phyded	Phyllanthus debilis
Phyten	Phyllanthus tenellus
Phynig	Phyllostachys nigra
Phygro	Phymatosorus grossus
Phyper	Physallis peruviana
Pilmic	Pilea microphylla
Pimdio	Pimenta dioica
	Pinus sp.
Pitdul	Pithecellobium dulce
Pitaus	Pityrogramma austroamericana
Pitcal	Pityrogramma calomelanos
Plalan	Plantago lanceolata
Plamaj	Plantago major
Plucar	Pluchea carolinensis
Pluind	Pluchea indica
	Plumeria sp.

Appendix V: Taxa Abbreviations

Taxa Abbreviations	Taxa
Polpan	Polygala paniculata
Porole	Portulaca oleracea
Porpil	Portulaca pilosa
Propal	Prosopis pallida
Psicat	Psidium cattleianum
Psigua	Psidium guajava
Pteglo	Pterolepis glomerata
Rhiman	Rhizophora mangle
Rhotom	Rhodomyrtus tomentosa
Rhyrep	Rhynchelytrum repens
	Rhyncospora sp. (Beak-rush)
Riccom	Ricinus communis
Rivhum	Rivina humilis
	Roystonea sp.
Rubarg	Rubus argutus
Rubros	Rubus rosifolius
Ruebre	Ruellia brevifolia
Ryncad	Rynchospora caduca
Sacspo	Saccharum spontaneum
Sacind	Sacciolepis indica
Salcoc	Salvia coccinea
Salocc	Salvia occidentalis
Samsam	Samanea saman
Sanalab	Santalum album
Schact	Schefflera actinophylla
Schter	Schinus terebinthifolius
Schgla	Schizostachyum glaucifolium
Senmad	Senecio madagascarensis
Sensur	Senna surattensis
Setgra	Setaria gracilis
Setpal	Setaria palmifolia
Sidrho	Sida rhombifolia
Sidspi	Sida spinosa
Sidmic	Sidastrum micranthrum
Solame	Solanum americanum
	Solanum sp.
Sonole	Sonchus oleraceus
Spacam	Spathodea campanulata
Spapli	Spathoglottis plicata
Speass	Spermacoce assurgens
Sphcoo	Sphaeropteris cooperi
Sphtri	Sphagneticola triloba
Spoind	Sporobolus indicus
Staarv	Stachys arvensis
Stadic	Stachytarpheta dichotoma
Stajam	Stachytarpheta jamaicensis
	Stachytarpheta sp.
Staurt	Stachytarpheta urticifolia
Stagig	Stapelia gigantea
Styfru	Stylosanthes fruticosa
Swimah	Swietenia mahagoni
Synnod	Synedrella nodiflora
Syzcum	Syzygium cumini
Syzjam	Syzygium jambos
Syzmal	Syzygium malaccense
Taroff	Taraxacum officinale
Tercat	Terminalia catappa
Termyr	Terminalia myriocarpa
Thepop	Thespesia populnea
Thugra	Thunbergia grandiflora
Tiburv	Tibouchina urvilleana
Toocil	Toona ciliata
Treori	Trema orientalis
Tripro	Tridax procumbens
Triarvarv	Trifolium arvense var. arvense
Tridub	Trifolium dubium
Trisem	Triumfetta semitriloba
Verlit	Verbena litoralis
Verenc	Verbesina encelioides
Vulbro	Vulpia bromoides
Wedtri	Wedelia trilobata
Xanstrcan	Xanthium strumarium var. canadense
Youjap	Youngia japonica
Zinzer	Zinziber zerumbet

Appendix VI: RESULTS SUMMARY: *Dodonaea viscosa* seeding experiment at Lower Ohikilolo

A study was undertaken in December 2005 to assess the validity of broadcast seeding as a method to increase the establishment and cover of a native shrub, *Dodonaea viscosa*, both inside and outside a current invasive species grass control area. Within the grass control area, invasive grass has been sprayed with herbicide in an effort to reduce its cover and as a result the vegetation in this area is dominated by *D. viscosa* and native herbaceous plants. The adjacent area is dominated by the invasive guinea grass, *Panicum maximum*, which reaches near 100% cover in most untreated areas.
The hypothesis was that a greater percentage of *D. viscosa* seeds would germinate and establish in the grass control area where the soil is exposed and there is less competition for space and light than in the adjacent *Panicum maximum* dominated areas.

Five 1 x 1 m quadrats were established and marked inside the grass control area and five were located outside but adjacent to the grass control area on December 13, 2005. The soil within each quadrat was left undisturbed and 500 heat scarified seeds were broadcast in each. The seeds were broadcast evenly throughout each quadrat by hand. The presence of any *D. viscosa* seedlings in the quadrats was noted.

The number of seedlings was counted 2 days after the first significant rain fell on January 3, 2006 and again on January 12, 2006. No seedlings were found in the quadrats outside the grass control area. Inside the grass control area ungerminated seeds as well as seedlings were observed on both dates. The quadrats may be reexamined at any time in order to determine the long term success of this method for increasing cover of *D. viscosa* at this site.

In conclusion, it appears as if broadcast seeding in areas without any control of invasive grass will not produce the desired increase in *D. viscosa* cover. In order to evaluate the success of the method within an area of grass control the quadrats will need to be revisited and the fate of the seedlings determined.

Table 1. Number seedlings observed within each quadrat either inside grass control area or outside

Date	Inside	Outside
Initially	0	0
1/3/06	1	0
1/12/06	16	0

Appendix VIII: Snail ground shell plot methodology

Purpose: Ground shell plots are set up in order to help assess current threats to snails at a given site and the effectiveness of our predator control actions. Recently deceased shells that are collected can be examined for rat damage and the age distribution of these shells provides clues to the health of the overall population. For example, if several recently deceased immature shells are collected, the population is suffering a dramatic decline. However, if only larger mature shells are collected the population is probably growing, mortality is due to normal causes, and the population does not require intervention.

Method: Locate an area that is densely populated with the species of interest.

Determine the center of density. This can be a tree, several small trees, or an area of vegetation that appears to contain a large number of snails.

The plot can be as large as ~5 x 5 m or as small as ~1 x 1 m. In certain cases the plot will need to be smaller, which is acceptable so long as it is demarcated. Pound PVC posts or other permanent marking in each of the 4 corners of the plot. Plots can be any shape that can be delineated with 4 corners marked. Fasten a metal tag with the plot number to one corner post and GPS the plot location.

Once the four corners have been demarcated, use flagging to outline the boundaries of the plot. Fill out the ground shell search data sheet with plot information, date and initials of searchers.

Assign sections to be searched by all searchers and work to the boundaries of the plot and to your assigned area being mindful not to extend you search beyond the bounds of the plot.

Searching: remove and 'sift' through all leaf litter for shells. Collect all shells in a zip lock bag labeled with the plot number and date of the search as well as your initials. The top of the soil should be slightly disturbed and raked with finger tips and bases of plants such as sedges and grasses must be separated and searched.

Note the presence of shell caches which are defined as groups of shells occurring at the same location that appear to be rat predated, live or dead *Euglandina rosea*, the number of each and collect or kill any that are found, and the number and species of slugs found. If live slugs or *E. rosea* are collected place each *E. rosea* in their own container properly labeled with location, date and your initials and all slugs in a separate container (not the shell bags or the *E. rosea* containers) and label with the location, date and your initials.

Continue searching until all areas within the plot have been searched and all searchers are satisfied that the area has been cleared of all shells.

BE MINDFULL OF THE SHINY SHELLS. Newly deceased specimens of *Achatinella* spp. will be shiny and should be investigated to determine if the specimen is in fact dead. Live snails sometimes fall from trees and appear to be dead. Live shells will usually not have any mud or debris clinging to the inside of the lip of the shell and can be persuaded to come out by leaving

them on a moist leaf undisturbed for several minutes. Efforts should be made to return the live snail to the tree from where it likely fell, and the snail should not be collected.

After the search is completed the shell bags should be filled with air to protect fragile shells and returned to the office to the Monitoring Program Manager for measurements and cataloging. All collected slugs should be turned in to the Research Specialist for identification. Any live specimens of *E. rosea* should be turned over to the current predatory snail researcher or the Research Specialist.

Post search analysis: Each shell will be measured from (L) the apex to the lip and (W) the girth of the widest point and numbered with a unique number that represents where the shell was found and the date it was collected. Shells that appear to have been rat predated will be noted, as will shells that were mature.

The proportion of shells in each size class (small ≤ 8 mm, medium 8 ≤ 18 mm, and large > 18 mm) as well as the proportion of shells with evidence of rat predation will be plotted immediately. Data from subsequent searches (not the initial clearing) will be plotted and measured in the same way paying special attention to the age/size distribution looking for a distribution skewed to larger/older shells indicating a growing population. The number and distribution of each subsequent collection will be compared to previous collections from the same plot to compare the number of shells found and to detect any marked increase in mortality or predation. Such analysis must be done within one week of collection in order to address threats in a time frame that is meaningful and allows for action to be taken to reduce mortality. If such an increase is detected, resource managers must be notified.

Frequency: Ground shell plots in areas where active rat control is ongoing (ie. baiting every 6 weeks) shall be read at least annually, unless a need for information arises in which case they can be read more often. Plots in areas without active rat control OR areas where *Euglandina rosea* are seen often should be read at least quarterly to detect population decline.

Appendix VIII:

Impacts of alien rodents on Hawaiian plant communities

Scientific Research Proposal to the U.S. Army Environmental, Hawaii

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Proposed project period: 08/01/06 – 06/28/08

Project Summary

Seed predation and seed dispersal are two critical components for vegetation regeneration in ecosystems world-wide. Tropical forests exhibit a wide range of seed dispersers and seed predators that influence vegetation structure and community dynamics. In Hawaii, there is little quantitative evidence of the effects of rodents on native and non-native plant communities. In this study, I will determine the impact of alien rodents (rats and mice) on plant communities in the Wai'anae and Ko'olau Mountains, Oahu. Common fruits, seeds, and seedlings of both native and non-native plant species will be arranged in three types of treatments (total animal exclusion, access for rodents only, and open sites) in mesic montane forest. Rats (*Rattus exulans* and *Rattus rattus)* are anticipated to be the most pervasive rodent (rather than mice) at the study site, and preliminary studies at Lyon Arboretum suggest that rats are removing fruits and seeds (secondary dispersal) rapidly and possibly damaging seedlings of both native and alien species. At three study locations in Makaha Valley, I will first determine rodent densities using the mark-and-recapture technique. The densities of rodents will

enable comparisons across the three sites, as well as with sites both within and outside of Hawaii. In order to determine the home-ranges of rats, individuals at each site will be captured and tracked after attaching collars containing radio transmitters. Radio-tracking will also help uncover the locations of both nesting sites and husking stations. Obtaining the locations of husking stations, which are sites that rats take seeds and fruits for consumption and disposal, is particularly important for determining the fate of seeds removed from the forest floor. These sites will be observed using night vision to associate the rat behavior with the fate of rat-manipulated seeds. Feeding trials, followed by germination studies, will also be conducted on captured rats in order to determine seed fate of important seeds. The findings from this study will reveal how rodents are affecting forest structure in Hawaii by removing, destroying, and potentially dispersing fruits and seeds. Additionally, this novel research has direct and important implications for the conservation of Hawaiian plants, native tropical forests, and islands worldwide.

Projected Time Line

Year 1: August 1, 2006 – July 31, 2007. The three sites in the Wai'anae Mountains will be established**,** measured for various forest attributes, and microclimate data loggers will be installed. Rodent densities at the three sites will be determined using mark-and-recapture techniques. Determination of rat homeranges will begin by use of radio telemetry. Exclosures will be constructed and set up to begin testing fruit/seed and seedling removal of dominant plant species by rodents. Seeds found in rat feces (recovered from live-traps) will be identified, and germination/viability of the seeds will be determined. Summary reports for these results will be completed, and will contain information on the densities of rodents at each of the three sites and the rat home-ranges of the marked individuals. Indices of plant species 'vulnerability' to rodents will be established based on the seed and seedling trials. This information will be used to focus rat baiting and conservation efforts in Makaha Valley. I will give an oral presentation based on the results of this work at the international conference ("Rats, humans, and their impacts on islands: Integrating historical and contemporary ecology"; UH campus) in Spring 2007.

Year 2: August 1, 2007 – June 28, 2008. Determining rodent impacts on specific plant species will be expanded using exclosures. Rat home ranges will be finalized and husking sites will be located, both of which will be mapped using arcview GIS. Sites in the Ko'olau Mountains will be established and measurements similar to those in year 1 will begin. Feeding trials of captive rats will begin in effort to determine the direct effects rats have on particular seeds. Viability of seeds passed through the gut will be determined. Rodent densities will be measured again to determine seasonal effects. Summary reports for these results will be completed and will include the rodent densities and home-ranges in the Ko'olau Mountains sites, and a revised plant species 'vulnerability' list for both mountain ranges. Scientific publication 1 will be submitted.

Appendix IX: Proposed *Euglandina rosea* research

Project title: Feeding ecology, microhabitat utilization, population size estimates, and possible control of the introduced predatory snail *Euglandina rosea* on O‘ahu, Hawai‘i (Year 2)

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Proposed project period: 08/01/06 – 07/31/07

Project Description/Objectives:
The introduction of the predatory land snail *Euglandina rosea* has been implicated as a major factor influencing the decline of native Hawaiian and Pacific island land snail faunas. Despite its reputation of having a major effect on the land-snail fauna of the Pacific, relatively little attention has been focused on the biology of *E. rosea*. Instead, a large effort has been focused on studying the biology of the threatened/endangered land snail species of the Pacific, especially Partulidae and Achatinellidae species. There remains a need to understand the basic biology of *E. rosea* in order that managers can better design conservation strategies incorporating it.

With Year 2 funding, tracking technology will be used to elucidate the microhabitat preferences of *E. rosea*. Understanding how *E. rosea* utilizes microhabitats within its range will help managers determine which snail species are likely to be the most threatened. In addition, this information will help determine where traps or searches that aim to trap/catch *E. rosea* as part of a control effort should be focused.

Methods:
There are two phases to the Year 2 research: 1) testing the utility of three tracking methods, and 2) tracking *E. rosea* in the Wai‘anae Mountains.

Testing the Utility of Tracking Methods

The three tracking methods to be tested, the spool and line method, RFID technology, and harmonic radar technology, are described below. Each method will be tested on six individual *E. rosea* at the same time at Lyon Arboretum in the first two weeks of September 2006. The utility of each method will be addressed by comparing the distances moved and paths taken by individual snails tracked by each method, the ease of tracking and recapture, and the quality of data collected.

Spool and Line Method: The spool and line method uses the least complex technology of the three methods and has many advantages. A lightweight line is attached to the snail. The other end of the line is wound around a spool which will easily release line as the snail moves. This technique has advantages over the other methods because it leaves a trace of where the snail moves. Thus, total distance moved can be compared with a linear distance moved away from the initial starting point, and the habitat utilized between monitoring events can be determined. The only potential difficulty associated with this method is that the line could become caught and limit the movement of the snails. Although this method has been used elsewhere to track a range of species of snails, a pilot study suggests that it is likely that movement of *E. rosea* will be restricted by this method, as on many occasions the line was found wrapped multiple times around a plant or branch preventing the snail from moving further.

RFID Method: Radio Frequency Identification (RFID) technology has been used for many years to identify and monitor pets. RFID uses a small tag that can be attached to or incorporated into a product, animal, or person. RFID tags contain silicon chips and antennas to enable them to receive and respond to radio-frequency queries from an RFID transmitter. Recently the technology has been used by biologists to track wild animals, including small animals such as bees, and by golfers to find lost golf balls. The technology, appropriately modified for tracking snails, should allow a snail to be found within a 25 m radius. This method is considerably less expensive than the harmonic radar technique. However, it has never been used to track snails.

Harmonic Radar Method: Harmonic radar uses a diode attached to the animal that allows a receiver to locate it. Although this method has been used to track snails, the snails were either large or arboreal. Pilot studies in Hawai‘i suggest that this technique has difficulty locating snails close to the ground. This may be because the ground reflects the signal, and the receiver is thereby unable to distinguish the direct signal from the diode from the reflected signal from the ground.

Tracking *Euglandina rosea* in the Wai‘anae Mountains

Tracking will be undertaken at two field sites, one in the northern and one in the southern Wai‘anae Mountains. The locations of these sites have not yet been decided. The criteria for suitable sites include presence of *E. rosea*, presence of native snails, and the ability to get to and from the sites and monitor the snails in one day.

Six *E. rosea* will be tracked for two weeks at each site during two different times of the year (October 2006, March 2007) (total 24 snails, 56 days of observation) using the most suitable tracking method as determined in the experiments to be undertaken in September 2006. The northern site will be monitored for the first two weeks of the month and the southern site will be monitored for the second two weeks. The snails’ movements and habitat utilization will be recorded daily during the two week tracking period. Relative humidity and temperature will be recorded using Hobo data loggers during the experiment. Rainfall totals will be measured using a rain gauge. The precise daily location of each snail will be marked with wire and orange flagging and GPS coordinates will be determined. Each day the distance moved by each individual will be measured. Each site will be characterized according to the different microhabitat types present

(these microhabitat types are still to be determined), and on each day the microhabitat where the snail is found will be recorded. At the end of the experiment the number of times the snails were found in each microhabitat type will be compared to the proportion of that habitat available in order to determine microhabitat preferences. If a snail climbs a tree, the tree will be surveyed for native snails. It may then be possible to determine if *E. rosea* can detect whether there are native tree snails in a tree before it climbs a tree or if it is indiscriminately searching trees for prey.

Projected Time Line:
August 2006: Obtain and become familiar with all the equipment needed. The harmonic radar for the trials will be provided by another University of Hawai‘i graduate student (Kevin Hall).

September 2006: Perform experiments aimed at determining the utility of each method for tracking *E. rosea*.

October 2006: Undertake tracking experiments.

November 2006 – February 2007: Analyze data using spatial mapping programs and appropriate statistical packages. I will work directly with the Army Environmental GIS specialist to produce all the appropriate maps.

March 2007: Undertake the second set of tracking experiments.

April – June 2007: Analyze data using spatial mapping programs and appropriate statistical packages.

July 2007: Present results at Hawai‘i Conservation Conference.

August 2007: Write up the results in the form of two papers to be submitted to scientific journals. The first will describe the utility of the different tracking techniques. The second will examine the microhabitat utilization of *E. rosea*.

Appendix X: Year 1 results: feeding ecology of the introduced predatory snail *Euglandina rosea*

Feeding ecology of the introduced predatory snail *Euglandina rosea* (Férussac) in Hawai‘i: implications for the preservation of native land snail species

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Project period: 08/01/05 – 07/31/06

Introduction

The introduction of the land snail *Euglandina rosea*, which feeds exclusively on snails, has been implicated as a major factor influencing the decline of the native Hawaiian land snail fauna (Hadfield 1986). It was introduced to Hawaii in 1955 to control populations of another introduced snail, *Achatina fulica*, the giant African snail (Davis & Butler 1964, Simberloff 1995, Civeyrel & Simberloff 1996, Cowie 2001). However, *E. rosea* has not reduced *A. fulica* populations (Civeyrel & Simberloff 1996, Cowie 2001) but it has been associated with the decline of many of the tree snail species, not only in Hawaii but also elsewhere in the Pacific (Hadfield & Mountain 1980, Clarke *et al*. 1984, Hadfield 1986, Murray et al. 1988, Hadfield *et al.* 1993, Murray 1993, Coote & Loève 2003), and may be the cause of the extinction of many other native land snails (Griffiths *et al*. 1993, Cowie 1998, 2001).

Despite its reputation for having a major effect on the land snail fauna of Hawaii, relatively little attention has been focused on the biology of *E. rosea*. Instead, a large effort has been focused on studying the biology of the endangered land snail species of Hawaii, especially the Hawaiian tree snails in the sub-family Achatinellinae (USFWS 1981). Therefore, there remains a need to understand the basic biology of *E. rosea* in Hawaii in order that natural resources managers may better design conservation strategies for the few extant native snails left in the islands.
Certain aspects of the feeding ecology *E. rosea* have been well studied. Feeding behavior and aspects of prey trail following have been well documented (Cook 1985 a, b). Prey size preferences have also been addressed (Cook 1989 a, b). Results from these and other studies suggest that *E. rosea* prefers smaller sized snails when given the choice (Davis & Butler 1964, Chiu & Chou 1962, Nishida & Napompeth 1975, Griffiths et al. 1993). In addition, the range of prey species in the field has been investigated on Mauritius (Griffiths et al. 1993).

Unfortunately, extrapolating these results to determine the effect *E. rosea* is having on the land snail faunas in other places such as Hawaii remains difficult. This is especially true since reasons for prey species preferences of *E. rosea* have not been adequately addressed, and consumption rates for *E. rosea* have never been reported. The literature suggests that *E. rosea* feeds non-selectively on numerous gastropod species (Cook 1989 a, b). However, the design of the experiments that aimed to address species preferences did not adequately control for the size of prey among prey species offered (Cook 1989 a, b). Instead, they standardized the total weight of each species offered in each replicate choice experiment. However, if prey size is as important as is suggested by all these experiments, the fact that the smaller species were preferred tells us little about species preferences other than that small snails are preferred. Although, this may be a more realistic approach for determining the impact of *E. rosea* at one place and time, it does not explain the reasons for preference among species other than for size. Since *E. rosea* does prefer smaller individuals as prey, it comes as no surprise that in trials in which species of different sizes were offered, the larger species were less preferred. In addition, the microcosms used in these experiments (clear glass dishes) did not provide conditions permitting possible predator avoidance behaviors.

The objective of the work reported here was to examine the feeding ecology of *E. rosea* in Hawaii. Particular attention was paid to determining the factors that influence prey choice, especially among prey species. Size preferences were also examined to confirm the findings of studies elsewhere. In addition, consumption rates were measured in an effort to begin to quantify, using community and population models, the impact of *E. rosea* on the land snail community of Hawaii and on certain target species that are considered particularly vulnerable to extinction. The goal was to gather accurate data on aspects of the feeding behavior of *E. rosea* that may help to quantify its impact and permit development of effective control measures.

Methods

Three microcosm experiments were performed at the University of Hawaii at Manoa between September 2005 and May 2006 to determine prey size and species preferences, as well as consumption rates. All experiments were done in 30 x 20 x 20 cm rectangular aquaria. Each aquarium was filled with top soil to a depth of 2.5 cm and kept damp to promote movement of both the prey and the predator. Five small pieces of lettuce were also added to provide food for the prey species and to entice certain species that had tendencies to bury themselves to come to the surface to feed and thereby become available to the predator. All prey were allowed to acclimate in the tank for 24 hr prior to the addition of the predator.

Euglandina rosea were collected at various sites throughout the island of Oahu between August 2005 and May 2006. Prior to their use in the experiments they were maintained individually in 15 cm diameter circular plastic aquaria and fed a diet of snail species other than those being used to test for differences in prey preferences. The species most commonly used was *Bradybaena similaris*.

<u>Prey Size Preference</u>

Seventeen adult *E. rosea* (35 to 55 mm in shell length) were used in size selection experiments. The predators were starved for two days prior to each experiment in an effort to standardize hunger levels. *Achatina fulica* were used as the prey and were divided into four size classes (0-1, 1-2, 2-3, and 3-4 cm in shell length). Ten snails from each of two of the four size classes were offered to one *E. rosea* after the prey had been allowed to acclimate for one day. Each day consumed prey were replaced with new individuals from the same size class. Experiments ran from four to ten days depending upon consumption rates and prey availability. Differences among size classes offered were evalulated using a Fisher's Exact test (Sokal & Rohlf 1995).

Prey Species Preference

Prey preference of *E. rosea* was assessed in microcosms that offered a choice of two prey species out of four. All prey were non-native species: *Achatina fulica*, *Paropeas achatinaceum*, *Veronicella cubensis*, and a *Succinea* sp. (there are native species of *Succinea* in Hawaii but these were not used). Each trial consisted of at least ten replicates, each with a choice of two prey species (ten snails of each). Prey were 5.0-12.5 mm in shell length. The size distribution, that is, the numbers of snails of various sizes, as measured by the length of their extended foot, was matched between the two prey species in order to minimize any effect size may play in determining a species preference. Using the length of the extended foot, rather than a shell size measure, was necessary since one of the prey choices was the slug *V. cubensis*. All six pair-wise combinations were represented in each trial but the number of each combination depended on prey availability. However, in total over the five trials there were ten replicates of each pair-wise combination. The number of prey items consumed was calculated by counting the number left at the end of the experiment and subtracting it from the total number of prey provided throughout the course of the experiment. A paired t-test was used for each pair-wise combination to determine whether prey preference was significant (Dowdy & Wearden 1991).

Additional experiments were performed using the same protocols specifically to examine the preference of *E. rosea* for slugs. Two slug species, *Deroceras leave* and *V. cubensis*, were used in combination with the snail *P. achatinaceum*. Five replicates of the pair-wise combinations *D. leave* vs. *V. cubensis* and *D. leave* vs. *P. achatinaceum* were performed in each of two trials. A paired t-test was used for each pair-wise experiment to determine whether prey preference was significant (Dowdy & Wearden 1991).

Consumption Rate

Twelve *E. rosea* were used in consumption rate experiments (seven adults 40-55 mm in shell length, five juveniles 10-25 mm in shell length). For a week prior to the experiments they were provided with prey snails (*Achatina fulica*, *Paropeas achatinaceum*, *Bradybaena similaris*) of various sizes *ad libitum*. Thirty prey snails (non-native *Succinea* sp., 15 in the size range 1.0-5.0 mm and 15 in the range 5.0-12.0 mm shell length) were then offered to an individual *E. rosea* for a period of 24 hr. Each prey snail was weighed to the nearest 0.0001 g and individually marked. At the end of the experiment, the number of snails remaining alive was counted and any shells remaining from consumed snails were weighed to the nearest 0.0001 g, these weights being subtracted from the weights of those snails at the beginning of the experiment to give a value of the weight consumed. Adding this amount to the know weight of snails consumed whole

provided a value for the total weight consumed. Growth of prey snails over the 24 hr of the experiment was assumed to be negligible. Wet weight consumed was regressed on *E. rosea* size. A two-factor ANOVA was used to test prey size preferences of adult and juvenile *E. rosea*. There were two fixed effects, an *E. rosea* size effect (adult vs. juvenile) and a prey-size effect (small prey 1.0-5.0 mm vs. large prey 5.0 -12.5 mm).

Prey Value

The energy content of the snail species used in the *E. rosea* feeding trials, *A. fulica*, *P. achatinaceum*, *V. cubensis*, *D. leave* and the non-native *Succinea* sp., will be evaluated in July 2006. Shell length (for snails only), foot length, wet weight, dry weight, and total caloric value will be recorded for ten individuals of each snail/slug species. Shell length and foot length will be measured to the nearest 0.1 mm. For snails, the wet weight will be measured with the shell still intact to the nearest 0.0001 g. The shells will then be dissolved in a 1 M HCl solution and the bodies of the snails will be weighed in order to determine the weight of the shell, by subtraction. Snails (and slugs) will then be dried to a constant mass at 80^{o}C. The dry bodies will then be used to determine energy content, measured in a microbomb calorimeter. A regression will examine the relationship between size/weight and caloric value for each species, and an ANCOVA will examine the differences among the caloric values of the various prey species (Dowdy & Wearden 1991).

Results

Prey Size Preference

Regardless of which snail combination *E. rosea* was offered, it always preferred the smaller snails (Table 1). Pooling the data, 77 snails in the smaller size class were consumed compared to only two from the larger size class. In addition, consumption rate (number of snails consumed), decreased as size of prey offered increased.

Prey Species Preference

Prey preference experiments with *E. rosea*, using abundant introduced snails (*Succinea* sp., *Achatina fulica*, *Paropeas achatinaceum*) and slugs (*Veronicella cubensis*, *Deroceras laeve*) showed that it preferred the snail to the slug species but showed no preference among the three snail species (Tables 2 and 3). *Veronicella cubensis* was the least preferred prey, and *D. laeve* seemed to be preferred over *V. cubensis* but was less attractive than *P. achatinaceum* and therefore probably also less attractive than the other snail species (*Succinea* sp. and *A. fulica*).

Consumption Rate

The relationship between wet weight (g) consumed and the weight of *E. rosea* (g) is described by the following linear regression (Figure 1):

Wet weight consumed = 0.1193 (weight of *E. rosea*) + 0.0962;
$r^2 = 0.87$, $P < 0.01$, $N = 12$

Wet weight consumed increases as *E. rosea* weight increases. Although the sample size is small, the high r^2 value suggests that this mathematical model describes the relationship between the variables well. The regression line was not forced to go through the origin but the y-intercept was nevertheless close to it.

The size of *E. rosea* is important in prey size preference (Table 4, Figure 2). Larger *E. rosea* had a stronger preference for smaller prey (Figure 2). The ANOVA suggests that *E. rosea* size, prey size and the interaction of these two factors are important (Table 4).

Prey Value

These experiments remain to be done (see Methods section).

Discussion

Prey Size Preference

The results indicate that *E. rosea* has a strong prey size preference. When given a choice of prey sizes, *E. rosea* will eat significantly more small snails than large snails (Table 1). These results are consistent with many other experiments that have examined the prey size preference of *E. rosea* in the lab (Davis & Butler 1964, Chiu & Chou 1962, Nishida & Napompeth 1975, Cook 1989 a, b) and in the field (Griffiths et al. 1993). In addition, it seems that large (40 to 55 mm shell length) *E. rosea* have an even stronger preference for small prey (Figure 2).

One reason usually proposed for *E. rosea*'s preference for smaller snails is calcium intake. Cook (1989 a) suggested that there may be a compromise between the input of important nutrients, primarily calcium, when the prey is consumed whole (shell included), and the caloric intake that comes from the consumption of body tissue. Shells of small prey (> 1.0 mm in shell length) are usually consumed whole. Thus, the fact that *E. rosea* prefers to feed on smaller snails may be a response to its need to procure enough calcium and perhaps other essential nutrients in order especially to maintain shell growth. The predators do this despite the cost of the increased handling time involved in consuming the prey whole (Cook 1989 a).

The need for calcium and other essential nutrients present in the prey shells may explain some of the preference, but is probably not the only factor responsible for *E. rosea*'s preference of smaller prey. In the prey size preference experiments, no *Achatina fulica* were consumed whole but the smaller snails were nevertheless preferred. Most of the snails in the 0-1 cm size class were closer to 1.0 cm in size and perhaps large enough to discourage *E. rosea* from trying to consume them whole. However, if they were only choosing smaller prey for essential nutrients we would expect a more even distribution of preference between the 0-1 and 1-2 cm size classes. No data were collected on handling times, which may explain the difference between the two size classes. In addition, Griffiths et al. (1993) reported that *E. rosea* will swallow snails up to 1.1 cm in shell length, although the species consumed did not have as rounded a shell as *A. fulica*. Still, it is surprising that in the present experiments no *A. fulica* were eaten whole, since new hatchlings were often used.

The data suggest that the size of the *E. rosea* is important in prey size preference. Although counter-intuitive, larger *E. rosea* had a stronger preference for smaller prey (Figure 2). This may be because large *E. rosea* have a greater ability to consume snails whole. Thus, the impact of *E. rosea* on small snails may be even greater when *E. rosea* is large. This is consistent with experiments that have studied predation of *E. rosea* in the field where a large majority of the species consumed were swallowed whole (Griffiths et al. 1993).

Prey Species Preference

Euglandina rosea exhibited a clear preference for the three snail species over the two slug species in all the feeding preference tests (Tables 2 and 3). In all six pair-wise experiments examining the preference between either of the three snail species, *Succinea* sp., *Achatina fulica*, or *Paropeas achatinaceum* and the slug species, *Veronicella cubensis*, *E. rosea* preferred the three snail species to the slug. It showed no preference among the three snail species. In the experiment that examined the prey preference of *E. rosea* between the slug *Deroceras laeve* and the snail *P. achatinaceum*, *E. rosea* again preferred the snail to the slug. The results do suggest that *E. rosea* prefers the slug *D. laeve* over the slug *V. cubensis*, suggesting preferences among slug species.

I can only speculate on reasons why snails were preferred to slugs. The slugs seemed to spend a large proportion of their time buried in the soil compared to the snails. *Achatina fulica* also spent a large proportion of the time buried but seemed to come up to feed at night, coinciding with the time *E. rosea* was usually active. The other two snail species, *Succinea* sp. and *P. achatinaceum*, were always found on the surface of the soil or on the sides and top of the aquaria. This microhabitat preference of the slugs may have precluded them being available as often as prey items. Slugs may have evolved other defense strategies that enabled them to lose their shells, including production of copious amounts of mucus when provoked, having a relatively thick integument, and avoidance behaviors such as tail flicking and mantle flaring (Cook 1985 a).

Consumption Rate

The linear regression approximates the consumption rate of *E. rosea* well. As size of *E. rosea* increases, so does consumption, at a predictable rate. Therefore, if *E. rosea* population density and population size distribution are known, a model could be constructed to determine the impact of this predator on the land snail community as a whole and on populations of species of particular interest.

Prey Value

These experiments remain to be done (see Methods section).

Impact of *Euglandina rosea* on Native Snail Populations

The native Hawaiian land snail fauna used to be extremely diverse (over 750 species) and exhibited high endemism (over 99 %), but most of these unique species (perhaps as many as 90 %) are now extinct (Cowie 2002, Lydeard et al. 2004). Most of those species that remain appear

to be reduced to sparse populations on every island they formerly inhabited (Lydeard et al. 2004). Therefore, even slight increases in mortality caused by predation may have serious detrimental impacts on the remaining land snail populations. Results from this work provide a grave reminder of the deleterious impact of *E. rosea*.

The most likely criticism of this work may be that no native snails were used in the feeding trials. Therefore, extrapolating these results to say anything about the impact of *E. rosea* on native land snails of Hawaii could be misleading. However, all the species used as prey in the experiments currently occur in Hawaii, all five species come from different families, and one of those families, the Succineidae, is represented by extant endemic Hawaiian species currently found on all of the main islands. All these facts suggests that *E. rosea* is a highly generalist predator of snails, that probably would prey on native Hawaiian snails in very much the same way as it did in the experiments described herein. Most of the extant native Hawaiian land snails are endangered or threatened with the possibility of extinction, so that use of large numbers of them in experiments of this kind is probably not justifiable. In addition, most of the prey species tested can be found living in areas where native species occur and the behavior of *E. rosea* in these areas in relation to both native and non-native prey may be similar.

The prey size preference results are consistent with many previous experiments (Davis & Butler 1964, Chiu & Chou 1962, Nashida & Napompeth 1975, Cook 1989 a, b, Griffiths et al. 1993). *Euglandina rosea* prefers the smallest snails available. This is of concern for conservation efforts since many of the native snails are small compared to many of the abundant introduced snails/slugs that have become established in the native forests of Hawaii (e.g., *Limax maximus* and *Meghimatium striatum*) where a majority of the native Hawaiian snails are found (Meyer 2006, Joe 2006). For instance, all species in the native families Endodontidae, Helicinidae, and Pupilidae are extremely small (< 1.0 cm in shell length for their entire life), still found in the Waianae Mountains, and appear reduced to sparse populations on every island they formerly inhabited (Lydeard et al. 2004, Meyer in press). The results suggest that *E. rosea* would readily consume these snails whole if it encountered them and may have had a large impact on their populations in the past. Many native succineid species are also relatively small, being less than 1.0 mm in shell length when hatched and rarely getting to be over 13.0 mm (personal observation). Snails in the family Achatinellidae come in all sizes. For instance the 'tornatellinids' (Achatinellidae belonging to subfamilies other than Achatinellinae) are widely distributed but patchy, and extremely small (< 1.0 cm in shell length). Snails in the sub-family Achatinellinae, the Hawaiian tree snails, are larger. One species, *Achatinella mustelina* is born at an average size of 4.6 mm and reach sizes greater than 21.0 mm in shell length (Hadfield et al. 1993). Despite being larger, their populations have declined with the introduction of *E. rosea* (Hadfield & Mountain 1980). Decline of Achatinellinae in particular is probably related to their slow growth, the long time they take to reach reproductive maturity (3-5 yr), and their slow reproductive rate, which make them highly vulnerable to unnaturally high levels of predation by not only the introduced predatory snail *E. rosea*, but rats and shell collectors (Hadfield & Mountain 1980, Hadfield 1986, Hadfield et al. 1993).

The results of the prey species preference experiments also have conservation ramifications. There are no native slugs in Hawaii. Although, *E. rosea* will consume slugs, the data suggest that given a choice it would probably consume a snail rather than a slug when both are present in

equal numbers. Currently, in terms of biomass, slugs constitute a large portion of the Hawaiian land snail fauna (Meyer 2006) and have been shown to negatively impact the survivorship of young native Hawaiian plants (Joe 2006). Thus, predation of *E. rosea* on slugs could be seen as one positive conservation outcome. Unfortunately, the results suggest that *E. rosea* prefers snails to the slug species offered, and many of these slugs reach sizes that are well above *E. rosea*'s preferred size range for consumption.

Data from the consumption rate experiment suggest that if *E. rosea* did locate a patch of native snails it could quickly have a large effect. In two of the consumption rate trials, twenty snails were consumed in one day. Survey work conducted during 2005 led to the records of two small extant native ground-dwelling land snail species in the families Endodontidae and Helicinidae on the island of Oahu (Meyer 2006 b). These two species belong to two families that have been considered either extinct or extremely rare in the Hawaiian Islands (Lydeard et al. 2004, R.H. Cowie pers. comm., 2005). The endodontid population seems to be around a few hundred individuals, according to The Nature Conservancy (TNC), which have begun monitoring (D. Sailer, pers. comm. 2005). Thus one *E. rosea* may be able to consume all individuals in just a few days. Although these experiments suggest that small species of native Hawaiian snails may be especially susceptible to predation by *E. rosea*, in conjunction with previous studies of the larger Achatinellinae, they suggest that all extant native species are probably susceptible to *E. rosea*.

Direction of Future Research

It is not a surprise that *E. rosea* has proved to be an ineffective biocontrol agent and a serious threat to native species. In 1988 the World Conservation Union (IUCN) passed a resolution urging government agencies to stop further introductions of *E. rosea* for biocontrol purposes (Griffiths et al. 1993). Although this was a good initial step to control the impacts of *E. rosea* throughout the Pacific and other tropical areas, more drastic measures of control are needed to protect the native snails that are susceptible to predation in areas where *E. rosea* is established. To create effective control measures, a comprehensive understanding of the biology of *E. rosea* is needed. This report addresses aspects of the feeding ecology of *E. rosea*. With Year 2 funding, tracking technology will be used to elucidate the microhabitat preferences of *E. rosea*. Understanding how *E. rosea* utilizes microhabitats within its range will help natural resource managers determine which snail species are likely to be most threatened. In addition, this information will help determine where traps or searches for *E. rosea* as part of a control effort should be focused. In Year 3, attempts will be made to construct traps to determine *E. rosea* density and begin control measures.

Appendix XII: Use of cardboard, plastic, and wooden sampling sheets to estimate relative size of slug populations

Justification: In order to further our development of efficient and effective methods of controlling slugs (whether using beer traps or conventional molluscacides), knowledge of slug population response to these proposed strategies is needed to evaluate their efficacy. In the event that a molluscacide proves safe to use in a forest setting, whether one applies 10 or 100 lbs. of bait per acre will depend largely on whether slug mortality differs between the two application rates. Thus, control strategies can be compared using indices drawn from measurements of slug numbers.

Estimation of slug population sizes may be absolute or relative. Absolute methods are expressed as numbers per unit area and are more accurate than relative ones, but labor intensive. Such methods include soil core flooding (to drive all slugs to the surface) or branding of slugs for use in mark-recapture analyses. Relative estimates are usually related to some measure of slug-activity, such as catch per unit effort (*e.g.* time searching) or numbers obtained by some form of trapping (such as in the field trial described here). Since slug activity is largely governed by the weather, relative estimates are an imperfect measure of slug abundance and tend to vary more than absolute methods. Given our labor and time constraints, however, relative methods are more immediately practical. In the event that relative methods fail to provide us with consistent or sufficient numbers of slugs to evaluate future control activities then absolute methods may be necessary.

Methods: Here, we present results from a field trial using a relative method for estimating the size of slug populations (*e.g.* count of slugs using daytime refugia) wherein we tested the ability of three materials, wood, weed plastic, and cardboard to attract slugs. Thirty sampling sheets of each material, measuring 0.25 m^2, were deployed in Kahanahāiki on October 26 and monitored weekly until November 30 after which the study was concluded and a new configuration involving larger sheets attempted (discussed later). When checked, sheets were carefully lifted to minimize disturbance to animals beneath and the number of slugs, snails and planarians (alien terrestrial flatworms) recorded.

These latter two groups of invertebrates, though not the focus of this study, were of interest for several reasons. Snails, because they are among the non-target groups potentially affected by the application of molluscacides and include the predatory snail, *Euglandina rosea*. Planarians, because they prey upon slugs and snails and may reflect slug numbers secondarily in the event that slugs cannot be observed directly. In Hawaii, planarians have only been documented as feeding on alien snails, however, whether their diet is limited to aliens in areas where native snails exist, such as Kahanahāiki, is unknown. Therefore, numbers of planarians may be of concern for purposes of native snail conservation.

Results: Slugs were rarely found and made up only a small percent of all catches (Fig. 1); a result which may reflect either low slug numbers or low sampling sheet attractiveness. It should be noted, however, that when found, slugs were always beneath cardboard rather than plastic or wood. Compared to plastic or wood, cardboard sampling sheets were the most

consistently occupied over time by at least one or more of the target invertebrates (Fig. 2). As they weathered, cardboard sheets attracted higher numbers of invertebrates; a fact that suggests wood sheets might function similarly, given time. Studies demonstrate high soil moisture has a positive effect on slug activity and population size. Given these findings, it is perhaps unsurprising to find that slugs generally preferred materials (like cardboard) which hold moisture. Soil was driest beneath the weed plastic, which, being both dark colored and breathable, dried quickly.

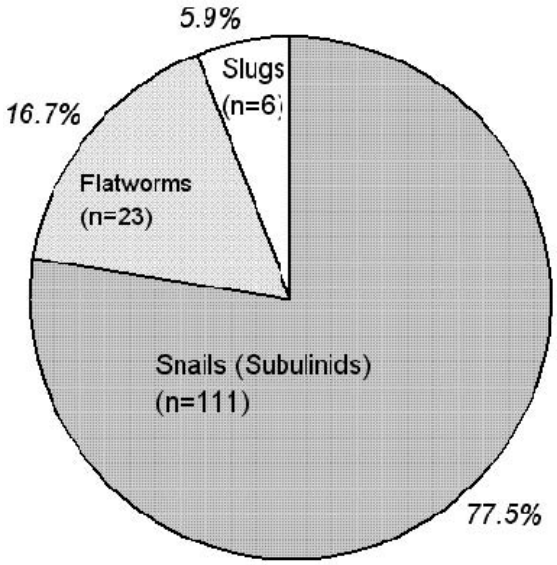

Fig. 1. Count of target invertebrates (by group) found utilizing sampling sheets from October 26-November 30, 2005. Snails are the most frequently encountered invertebrate followed by flatworms.

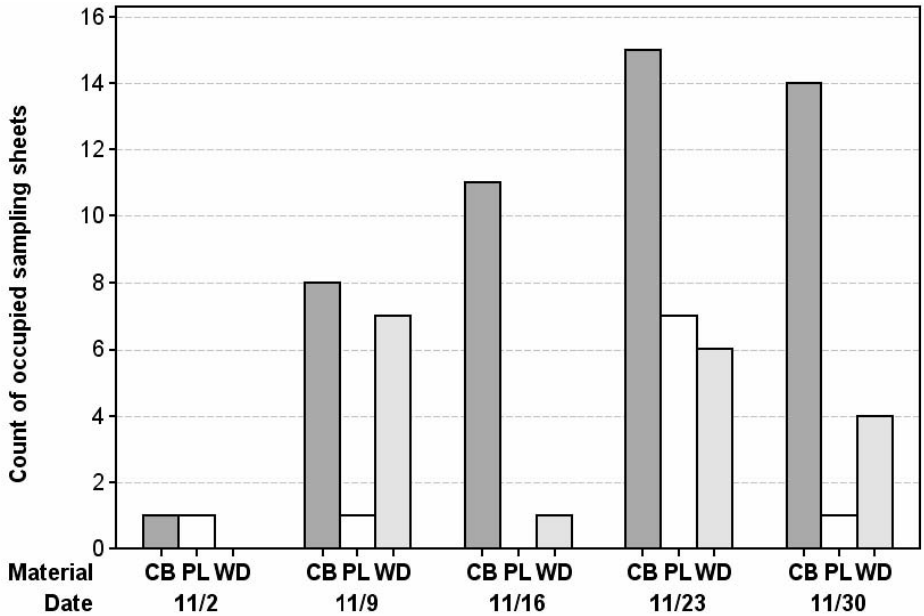

Fig. 2. Number of occupied sampling sheets by material over time (n=30). Key to materials: CB=Cardboard PL=Plastic WD= Wood. A sampling sheet is "occupied" when it harbors one or more of the target invertebrates (slugs, snails or flatworms).

Conclusion: Despite the low numbers of slugs utilizing the sampling sheets, slight modifications

to the design could be made to improve catch rate. Prior studies of this kind used cardboard sheets 1 m^2 in size (Hawkins *et al*. 1998)[i]. It is possible 0.25 m^2 was simply too small to create an attractive habitat for slugs. On November 30, 2005, we pulled all the plastic sheets and increased the size of the remaining wood and cardboard stations to 0.75 m^2. Preliminary results are promising and suggest this size to be more attractive to both slugs and other invertebrates (Table 1).

Date	Stations occupied (out of 30)	Material	# Slugs	# Flatworms	# Snails (Subulinidae)	# *Euglandina rosa*
12/08/05	13	Wood	0	2	59	0
12/08/05	24	Cardboard	9	1	106	1
12/14/05	16	Wood	0	10	42	0
12/14/05	26	Cardboard	7	7	113	0
01/12/06	5	Wood	1	4	2	0
01/12/06	15	Cardboard	8	6	32	0

Table 1. Slugs (and other invertebrates) counted beneath sampling sheets on December 8.

[i] Hawkins, J.W., M.W. Lankester and R.R.A. Nelson. 1998. Sampling terrestrial gastropods using cardboard sheets. *Malacologia* **39**: 1-9.

Appendix XII: *Achatinella* sp. research proposal

Abstract:
Hawaii's *Achatinella* tree snails are disappearing at an alarming rate, with fewer than 10 of the 41 described species within this endemic Oahu genus extant today. All of the remaining fragmented and isolated populations (both wild and captive) may be at risk from inbreeding depression. Management strategies are now leaning towards translocation to minimize inbreeding depression, while also avoiding possible outbreeding depression. A three-year study has been initiated to observe the natural movement patterns of these snails with both harmonic radar and traditional capture-mark-recapture (CMR) methods, which will attempt to approximate the historical connectivity of remaining snail populations. Dispersal models developed in the context of population genetics theory will then be applied to determine the breeding compatibility between snails from these different locales. These results will be integrated with microsatellite data, thereby calibrating a less time-consuming and more cost-effective genetic shortcut to fieldwork.

Management Issue To Be Addressed:
Many years of observations have suggested that these long-lived arboreal snails have a very limited dispersal capability and sometimes spend their entire lives in a single tree (Pilsbry and Cooke 1912, Hadfield unpublished data). However, in previous achatinelline CMR studies (Hadfield and Miller 1989, Hadfield and Mountain 1980, Hadway and Hadfield 1997), it was found that either a moderate percentage of marked snails were outside of their original trees, or unmarked snails had appeared in well-searched trees. If achatinellids have evolved by frequently dispersing as the results imply, this could have major conservation implications.
Could snail enclosures and captive breeding chambers create even more dispersal barriers, preventing potentially vital gene flow in these already severely fragmented populations? Addressing this question should help provide management direction to ensure our conservation efforts are not contributing to the extinction threat from excessive and unnatural inbreeding.

Initial Results from Disperal Tests:
One marked snail at Palikea was found recently to have traveled over 20 meters in 4 months, and was found during a CMR search. CMR has yielded initial population #'s of 160 at Kahanahaiki, 62 at Palikea, 128 near Poamoho, and 138 at the Hypalon. At the Pahole Natural Area Reserve during a pilot study with harmonic radar, one transponder tagged snails was found over 4 meters away in just over one week. Transponder-fitted snails have often been found in vegetation that is not normally thought to be a prime host for snails, data that would have been missed entirely without the assistance of the radar. Some relocations have occurred in dense foliage that would have been difficult to search, as well as on high branches, obscured and out of reach. Currently, 90 % recapture rates are being obtained with the radar

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