CHAPTER 7: RESEARCH PROGRAM

This chapter describes the status and outcome of actions carried out under the direction of the program's Research Specialist (RS) and Small Vertebrate Pest Program Manager. This section does not include all research projects supported by the program. Please refer to the appendices of this document to view additional research publications.

Pest species listed in Chapter 6 of the Status Reports for the Makua Implementation Plan and the Draft Oahu Implementation Plan 2006[12] included slugs (Mollusca: Gastropoda), the black twig borer (*Xylosandrus compactus*) and invasive ants. In the most recent year end report (2009[13]), we added *Sphagnum palustre* (an introduced bog moss) to our list of research subjects and described the installation of a large scale trapping grid for rats and mice. In conjunction with the trapping grid we are monitoring changes in native and alien vegetation, arthropods and mollusks, all of which are part of the diet of rats and may be affected by rat removal. Research findings are organized by pest species.

Statistical analyses in this section were performed with Minitab Release 14 software of Minitab Inc. (Ryan *et al*. 2005)[14]. Significance during hypothesis testing was characterized by p-values less than 0.05. Nonparametric statistical methods were used to analyze datasets with non-normally distributed residuals and dissimilar variation between groups, otherwise parametric methods were used.

7.1 BLACK TWIG BORER (BTB) TRAP DEPLOYMENT

7.1.1 Introduction

Xylosandrus compactus (black twig borer or BTB) is a major threat to a number of rare and endangered plants, notably *Flueggea neowawraea* (Euphorbiaceae). Published documentation is lacking, however OANRP and the DLNR have observed these species to suffer under BTB attack. Sequestered within the plant pith, BTB cannot be removed manually or with pesticides applied on the plant surface. Greenhouse collections of *F. neowawraea* are treated with the systemic insecticides Merit (Bayer Crop Research, Triangle Park, NC) applied as a root drench and Marathon (Olympic Horticultural Products, Mainland, PA) applied to the base of the plant in granular form. Neither is legal to use in a natural setting, but a Special Local Needs (SLN) Label (Nagamine and Kobashigawa 2003)[15] could be pursued with permission from the manufacturer, HDOA and USFWS. OANRP is currently engaged in the process of SLN approval for a molluscicide, Sluggo and have found the process to be lengthy. Rather than embark on this long process for BTB management, OANRP looked for solutions which could be put into use immediately if found to be effective.

In 2007 OANRP tested the efficacy of modified Japanese Beetle Traps equipped with high-release ethanol bait (AlphaScents, NJ) and insecticidal strips (Vaportape II™, Hercon® Environmental, Emigsville, PA) to reduce BTB gallery formation in a target tree species (*F. neowawraea*). Earlier tests

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[12] OANRP 2005-2006 Status Reports for the Mākua Implementation Plan and the Draft Oʻahu Implementation Plan Chapter 6.1-6.13 http://manoa.hawaii.edu/hpicesu/DPW/2006_MIP/06.pdf. Accessed October 13, 2010.
[13] OANRP 2008-2009 Year End Report Chapter 6.1-6.6 http://manoa.hawaii.edu/hpicesu/DPW/2009_OIP/007.pdf. Accessed October 13, 2010.
[14] Ryan, B., B. Joiner and J. Cryer (2005) Minitab Handbook, Fifth Edition. Thomson Brooks/Cole, Belmont, CA, 505 pp.
[15] Nagamine, C. and L. Kobashigawa (2003) Special Local Need Labeling for Pesticides in Hawaii. *Pesticide Risk Reduction Education* 4: 1-4.

demonstrated this lure to effectively capture BTB (OANRP 2007)[16] but, prior to our experiment, it was unknown whether traps could be used to control BTB populations locally. We conducted a field experiment to determine whether a ring of traps placed around *F. neowawraea* could reduce attack rates relative to a control group.

Post-treatment results were mixed. While those trees receiving traps had a consistently lower rate of attack compared to the controls, these differences were not significant when adjusted for pre-existing differences between the two groups.

Despite the failure of trapping to appreciably reduce damage to *F. neowawraea*, the following conclusions may be made. First, it was discovered that baseline levels of attack were extremely high. At the peak of twig-borer season trees in the control group accumulated three new entry holes per 1 meter of bole length every two days. Second, the traps consistently yielded a steady number of beetles, at times as high as 100 or more. Each insect trapped was a gravid female due to the insects' somewhat unique reproductive behavior (Hara and Beardsley 1979[17]). Third, the traps did not exhibit a hypothesized potential counter-productive effect of increasing attack. Those trees that received traps had, on average, lower rates of attack than those trees without.

BTB research is now focused on the development of semiochemicals to reduce attack (Elsie Burbano, University of Hawaii Plant Environmental Protection Program *pers. comm.*) as well as the registration of the systemic insecticide Admire Pro® (Bayer Crop Sciences) for use in Koa tree plantations. This product is applied as a soil drench. Other possible avenues of BTB include the use of repellents. Also possible is the use of injection systems to more safely deliver systemic insecticides to the plant. OANRP will pursue work with outside researchers to test these products. Safe, legal deployment of any insecticide requires a change in its label. These changes are a minimum of three years away.

7.1.2 2009-2010 BTB Activities

No new BTB research was conducted this year. As the only available means of controlling BTB, traps were deployed in March 2009 in conjunction with *F. neowawraea* outplantings.

7.1.3 Methods

We deployed 30 modified Japanese Beetle Traps equipped with a high-release ethanol bait (AlphaScents, NJ) to serve as a sink for BTB at three *F. neowawraea* planting sites in Makaha MU (Population Reference Codes MAK-G, MAK-H, MAK-I). There are 10 traps at each site. Traps were placed at 5 m intervals throughout the outplanting area.

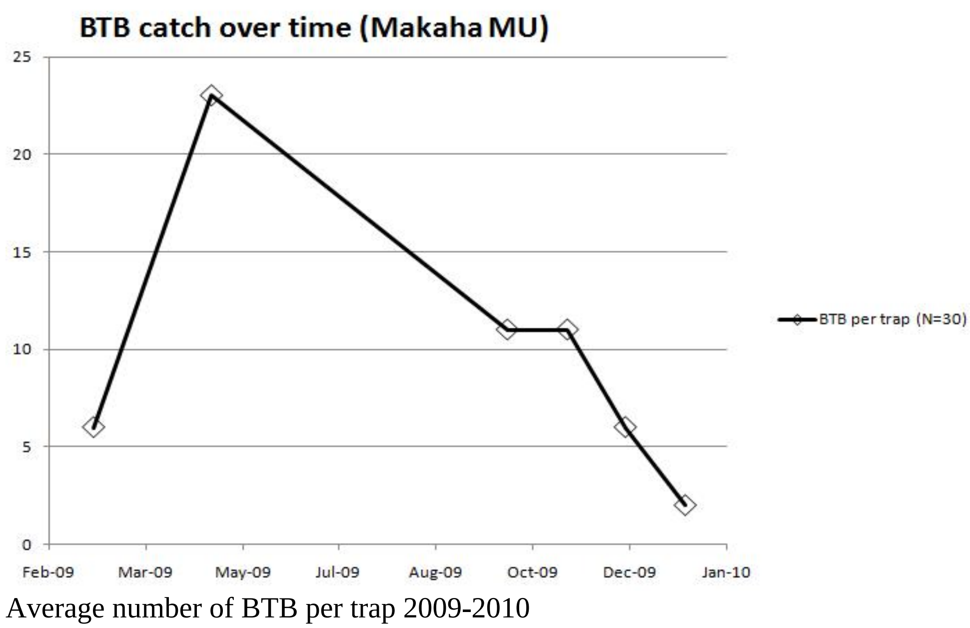
[16] OANRP 2007 Status Reports for the Mākua Implementation Plan and the Draft Oʻahu Implementation Plan Chapter 5.1-5.2 http://manoa.hawaii.edu/hpicesu/DPW/2007_YER/005.pdf. Accessed October 13, 2010.
[17] Hara, A. H. and J. W. Beardsley, Jr. (1979) The biology of the black twig borer, *Xylosandrus compactus* (Eichhoff), in Hawaii. *Pro. Hawaiian Entomol Soc.* 18 (1): 55-70

Map removed, available upon request

Three *F. neowawraea* outplanting sites where BTB traps were deployed.

Traps were deployed in March 2009 and visited approximately every two months through March 2010. It should be noted that the insecticidal strips need replacement every three weeks, therefore, it is likely that at least 50% of the time traps were inactive. Traps were discontinued in March 2010 following feedback that there was insufficient evidence to prove they reduce new BTB gallery formation in *F. neowawraea*. Please refer to 6.1.1 – 6.1.3 of the 2009 year end report (http://manoa.hawaii.edu/hpicesu/DPW/2009_OIP/007.pdf) for a full description of the BTB trap-out study which was used to inform our decision to discontinue traps.

7.1.4 Results



Average number of BTB per trap 2009-2010

Baits and insecticidal strips were replaced opportunistically through March 2010. Interpretation of the results, therefore, is limited to average number of BTB caught per trap on each of the dates shown in the figure above. Seasonal fluctuation of BTB at this site is difficult to determine given the irregular collection intervals.

7.2 Seedling Response to Label and Low Dose Application of Iron Phosphate (Sluggo®) in a Forested Area

7.2.1 Introduction

The purpose of this on-going experiment is to determine whether Sluggo® applied at a rate of 0.01lbs. a.i./93m^2 once a month is equal to application bi-monthly as indicated by the survival of naturally occurring *Cyanea superba* subsp. *superba* (hereafter referred to as *C. superba*) seedlings over 1 year. This experiment directly relates to how Sluggo would be applied to maximize native plant recruitment in a forest setting should a Special Local Needs (24c) label be granted for this product within the State of Hawaii.

7.2.2 Methods

Thirty six *C. superba* in the Kahanahaiki Management Unit (KMU) produced fruit in the 2009-2010 season. This unprecedented fruiting event allowed us to compare, for the first time, the efficacy of Sluggo at intervals less frequent than two weeks while controlling for other factors likely to affect seedling recruitment (fruit production per plant and rat predation of fruit). Following a successful petition to the HDOA to allow for this experiment, we randomly divided these plants into two groups, one of which received Sluggo every two weeks to a distance of two m from the base of the plant (area per plant = 12.5 m^2), the other which received Sluggo once month. Any differences found between the two groups after one year (March 2010-March 2011) would be used to guide OANRP in long-term management of *C. superba* should additional SLN labeling be approved for Sluggo.

7.2.3 Results

Naturally occurring seedlings were observed at 18 of the 36 (50%) of fruiting plants. Four of these plants fruited in the 2008-2009 season and produced seedlings which are still extant (86 seedlings). Combined with the new seedlings from the last season, there were 163 immature plants remaining in July 2010. No difference in germination between the high and low dose groups are evident at this time, however, six additional months of data collection remain.

7.3 Molluscicide Special Local Needs Labeling (SLN) Status

7.3.1 Introduction

Since 2007 OANRP has been working with the manufacturer of Sluggo (Neudorff Co., Fresno, CA), to complete research in support of a label expansion which would allow it to be used for the protection of native plants. Under an Experimental Use Permit (EUP) granted by the Hawaii Department of Agriculture in 2007-2008, OANRP demonstrated that forest application successfully controls the target pest for up to two months after application with no detectable impacts to native snails. An EUP extension through the following year allowed OANRP to investigate Sluggo application on seedling emergence. Results from this study were presented in a summary of OANRP projects at the Center for Plant Conservation Symposium (St Louis, MO October 2009) and are included in proceedings planned for publication later in 2010.

7.3.2 Methods (Status)

A draft label was submitted to HDOA in June 2010. After receiving feedback from HDOA, the label was revised and resubmitted in August. OANRP has remained in regular communication with HDOA on the status of the application which has not yet been finalized. The draft label (below) includes changes approved by reviewers at the EPA, the Department of Health (DOH) and DLNR.

7.3.3 Results

10 August 2010 Sluggo Special Local Needs Label. "X" is used intentionally as a placeholder for information to be provided by HDOA upon registration. Only proposed changes are shown here. Standard wording in the national label is omitted.

SECTION 24(c) REGISTRATION

NEU1165M
SLUG AND SNAIL BAIT
FOR CONSERVATION PURPOSES
EPA Reg. No. 67702-3
EPA SLN No. HI – 10XXXXX

SUPPLEMENTAL LABELING INFORMATION FOR DISTRIBUTION AND USE ONLY IN FORESTED AREAS WITHIN THE STATE OF HAWAII

This label is valid until xx xx, 2015 or until otherwise amended, withdrawn, cancelled or suspended.

GENERAL INFORMATION FOR USE IN FORESTED AREAS

Purpose: For the control of slugs in forests and other natural areas to protect native, threatened and endangered Hawaiian plants.

GENERAL: NEU1165 Slug and Snail Bait is a unique blend of an iron phosphate active ingredient, originating from soil, with slug and snail bait additives. It is used as an ingredient in fertilizers. The bait which is not ingested by snails and slugs will degrade and become a part of the soil.

The bait is ingested by slugs and snails when they travel from their hiding places to plants. Ingestion, even in small amounts, will cause them to cease feeding. This physiological effect of the bait gives immediate protection to the plants even though the slugs and snails may remain in the area. After eating the bait, the slugs and snails may not be visible as they often crawl away to secluded places to die. Plant protection will be observed in the decrease in plant damage and the increase in seed germination and seedling survival. NEU1165M is effective against a wide variety of slugs and snails.

USE RESTRICTIONS: For control only of slugs and non-native snails in forests, offshore islands and other natural areas to protect native, threatened and endangered Hawaiian plants.

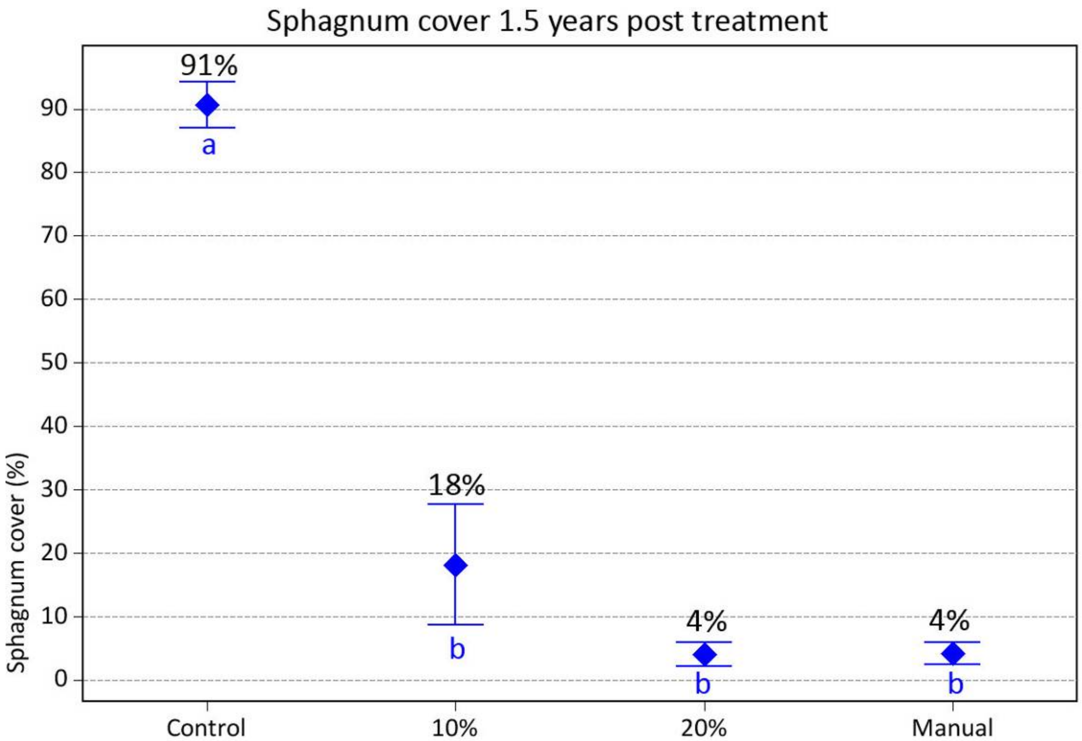
Area must be thoroughly searched by experienced malacologists during the day and at least one night prior to application of NEU1165M Slug and Snail Bait granules to ensure that non-target endemic Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known populations of endemic Hawaiian snail species from the following rare families or subfamilies: *Amastridae*, *Achatinellinae* and *Endodontidae*). Bait cannot be applied within 20 m of any tree known to harbor endangered Hawaiian tree snails (*Achatinella* spp.). Report any evidence of suspected poisoning of Hawaiian snails to the Pesticides Branch of the Hawaii Department of Agriculture, phone: (808) 973-9401.

7.4 A Test of the Long Term Efficacy (1 year +) of St. Gabriel's Moss Killer (SGMK) to Prevent *Sphagnum palustre* Regrowth

7.4.1 Introduction

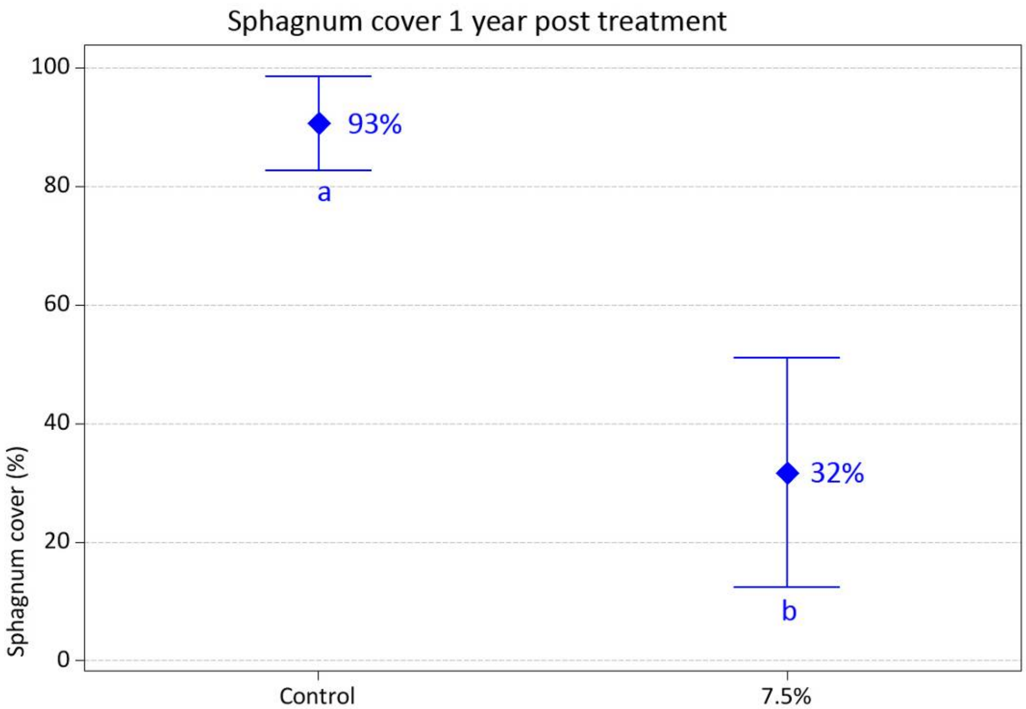
The following research was presented as a poster at the 2010 Hawaii Conservation Conference (Honolulu Convention Center, Honolulu HI) under the title: Efforts to Eradicate Invasive *Sphagnum* Moss from a Hawaiian Bog[18]. Data from this poster has been used to develop a *Sphagnum* control plan for Ka'ala Management Unit (Appendix 1-4, this document).

7.4.2 Results

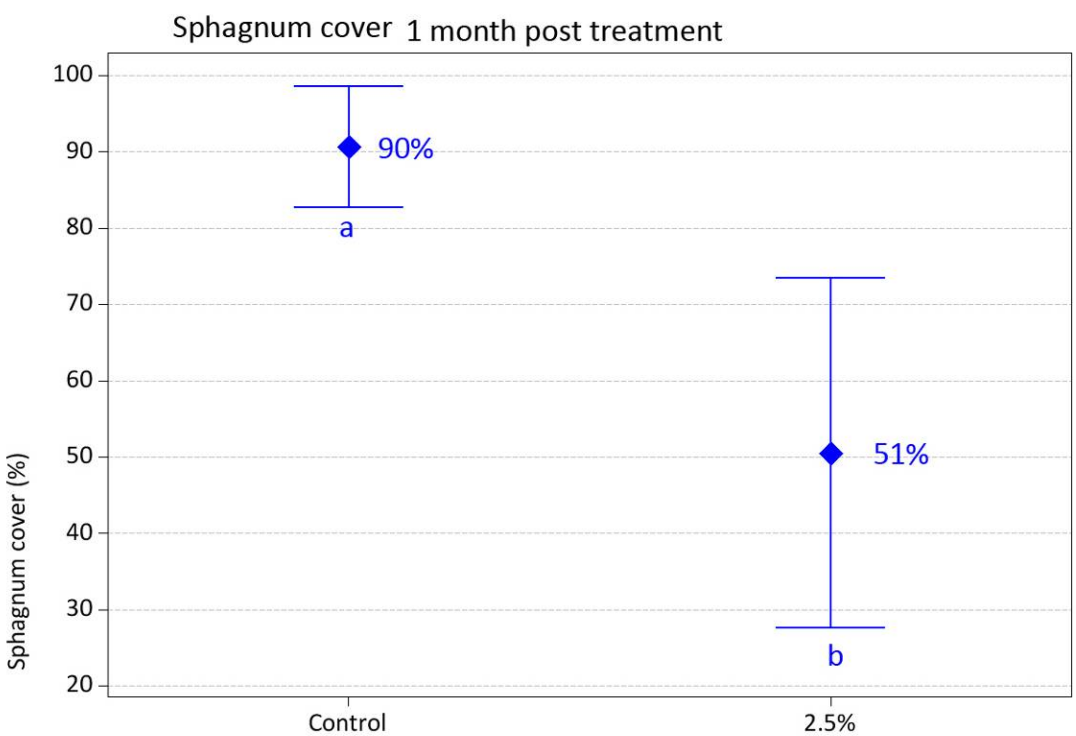


Sphagnum survival over 1.5 years by treatment (10% and 20% concentration of SGMK, manual removal of moss vs. a control group). Average *Sphagnum* survival given above error bars. Significant differences between groups indicated by letters (*e.g.*no difference between all three groups marked 'b', only between the 'a' and 'b' groups.)

[18] Joe, S. Poster Presentation. Efforts to Eradicate Invasive *Sphagnum* Moss from a Hawaiian Bog. Contributions to the 18th Annual Hawai'i Conservation Conference. Pacific Ecosystem Management and Restoration: Applying Traditional and Western Knowledge Systems. August 4-6, 2010. Convention Center, Honolulu, HI. http://manoa.hawaii.edu/hpicesu/DPW/HCC-2010/sphagnumpdf.pdf Accessed October 13, 2010



Sphagnum survival after 1 year at 7.5% SGMK. Average *Sphagnum* survival given adjacent error bars. Significant difference between groups indicated by letters.



Sphagnum survival at 2.5% SGMK concentration. Average survival given adjacent error bars. Significant difference between groups indicated by letters.

7.4.3 Discussion

Although all *Sphagnum* removal methods significantly reduced cover relative to the control (see the three figures above). *Sphagnum* showed signs of recovery after 1 year in the 10% treatment group, which at six months was identical to the manual and 20% treatment. These latter two treatments, however, have persisted in suppressing *Sphagnum* over 1.5 years. Disadvantages to manual and 20% SGMK treatment, though not significant, include reductions in native plant species (Joe *et al*. 2009[19]). Additionally, manual removal contributes to the spread of moss via contaminated equipment and footwear. Results from the 7.5 and 2.5% treatments were not 100% effective, however the former treatment did succeed in a 2/3 reduction in moss cover which persisted for one year. It is likely the 2.5% treatment will recover in a few months and therefore should be avoided. Our recommendation is to proceed with either two discreet treatments of the 7.5% concentration or with a single treatment of 10% or above.

7.5 Final Report: Survey of Invasive Ant Species Within Makua and Oahu Implementation Plan Management Units, Oahu, Hawaii 2004-2009

7.5.1 Introduction

OANRP conducted a thorough survey of ants in all Management Units with native endangered *Achatinella* species using a protocol developed by S. M. Plentovich, PhD (University of Hawaii at Manoa Zoology) and P. D. Krushelnycky, PhD (University of Hawaii at Manoa Plant Environmental Pest Program) (see Appendix 6-1 this document). Management implications and analysis of these findings appear in a final report by Dr. Sheldon Plentovich (see Appendix 6-2, this document) but highlights and excerpts from this document appear here. Recommendations made at the end of this section include plans to be carried out by the RS in year 2010-2011.

7.5.2 Highlights

Twenty species of ants were found from sea level to 1112.8m. *Solenopsis papuana* was the most commonly sampled species in forest settings while *Anoplolepis gracilipes* and *Pheidole megacephala* appear to be confined to isolated sites disturbed by humans. *Anoplolepis gracilipes* was first sampled in January 2008 at the Nike Greenhouse. Multiple site visits suggest that the *A. gracilipes* infestation is confined to a relatively small (<1 acre) area within and around the greenhouse. *Pheidole megacephala* was found on at least three occasions in 2008 at Ohikilolo above 880 m (2890 ft).
The presence of *A. gracilipes* and *P. megacephala* at high elevations in or near some of the last intact native forest is troubling. Although we do not have experimental evidence, observations indicate that some invasive ant species might cause declines in tree snails via depredation of adults, eggs, and juveniles.

There is significant overlap between endangered snail populations and *S. papuana*. It is possible that, although *S. papuana* does coexist with tree snails, the species may still have some negative effects. Regardless, there is currently no feasible way to eradicate *S. papuana* at this time.
Preventing new ant invasions into relatively intact habitat in Hawaii and specifically, within the Makua and Oahu Implementation plan management units, is vital for the future of those native communities. This can be accomplished with careful monitoring of sensitive sites and adjacent areas where

[19] Joe, S., L. Tanaka, S. Ching-Harbin, J. Beachy and K. Wong. Poster Presentation. Smothered in Sphagnum: Managing Moss at Ka‘ala. Contributions to the 17th Annual Hawai‘i Conservation Conference. July 28-30, 2009. Convention Center, Honolulu, HI.. Convention Center, Honolulu, HI. http://manoa.hawaii.edu/hpicesu/DPW/HCC-2009/sphagnum.pdf. Accessed October 13, 2010

introductions are likely to occur. Sites requiring special attention may include, but are not limited to camping areas, trails, fence lines, helipads, and roads. Many harmful invasive ant species, such as *P. megacephala* and *A. gracilipes* primarily reproduce via budding (i.e., mated females walk rather than fly to nearby areas to found colonies) vs. mated flights. In these cases it is relatively easy to identify areas of encroachment by invasive ants into native forest.

7.5.3 Recommendations

1) Map the boundaries of the *A. gracilipes* infestation at the Nike Site. This can be accomplished by either setting a grid of bait cards or, if ant numbers are high enough, by having 3 people walk the boundary of the infestation; the inside person staying within the infestation, the outside person staying outside the infestation and the middle person recording waypoints along the boundary.

2) Attempt to eradicate *A. gracilipes* from Nike Greenhouse site.
Bait preference trials to begin in October 2010 with assistance from HDOA staff

3) Identify areas of encroachment by *P. megacephala* into native forest. Control using hydramethylnon suspended in a corn-grit matrix (*e.g.*, AMDRO®) if warranted. Apply according to label specifications.

4) Use bait cards to conduct yearly monitoring of sensitive areas so that any new infestations can be identified and addressed. Ants are most likely to become established around disturbed areas frequented by humans such as bathrooms, campgrounds, fence lines, helipads, and roads. Areas undergoing construction of fences or other structures should be carefully monitored for new introductions. Activities including the transfer of soil, such as out-planting, should also be carefully monitored. Careful monitoring will increase chances of early detection, and early detection is the key to successful eradication or control.

5) Conduct additional surveys of high elevation sites in the Koolau Mountains.

6) Protect the Mount Kaala boardwalk area from invasion by ants.
Our data indicate that invasive ants have penetrated almost all areas with the exception of the highest elevation sites with intact native communities, such as the boardwalk area of Mount Kaala. Although ants were found at the gated entryway to the bog, none were found along the boardwalk. Every effort should be made to keep ants from penetrating this habitat.

7.6 RAT – KAHANAHAIKI: LARGE SCALE TRAPPING GRID

7.6.1 Introduction

In May 2009, OANRP initiated a large scale kill trapping grid for rat (*Rattus* sp.) control over an area of 65 acres (26 ha) at the Kahanahaiki MU (see map below). The control grid follows the New Zealand Department of Conservation's current best practices for kill trapping rats. Wooden rat trap boxes and tracking tunnel monitoring equipment were purchased from New Zealand in 2009 to facilitate this method of control (see photos below). The large scale trapping grid was established as a pilot study with a goal of reducing rat activity within the MU to a level that would benefit the endangered plants, tree snails and overall forest health. This approach moved away from our traditional rat control method of using small scale bait station grids centered around individual plants and/or small groupings of plant and/or around individual snail trees to a landscape level that would benefit the native ecosystem as a whole.

The grid encompasses 11 endangered plant species, including both wild and reintroduced populations, and a large population of endangered *Achatinella mustelina* (Oahu tree snail). The focal endangered taxa that have continued to be monitored closely are *Cyanea superba* subsp. *superba* and *Achatinella* *mustelina*. The additional monitoring of seedlings, seed fall, arthropod composition and abundance, slug, and *Euglandina rosea* populations has continued through the reporting year. The Pahole Natural Area Reserve (NAR) has continued to serve as a comparison "control" site (outside the trapping grid) where rats remain at pre-trapping levels.

The overall purpose of this study is to assess the effects of rat removal on the following groups:

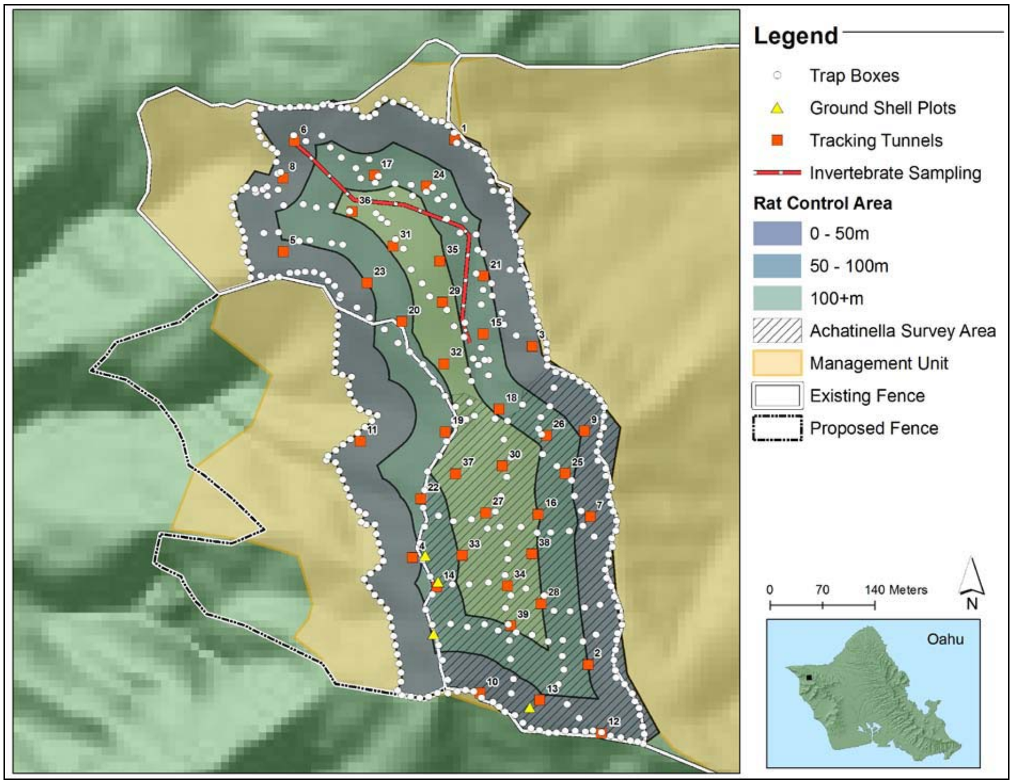
a. Slugs (*Limax maximus, Veronicella cubensis, Deroceras leave, Meghimatium striatum)*
b. Predatory snails (*Euglandina rosea*)
c. Arthropods (multiple species)
d. *Cyanea superba* subsp. *superba* (via fruit predation)
e. Seedling plots (multiple species)
f. Seed rain buckets (*Diospyros* sp. and *Psidium cattleianum*)
g. *Achatinella mustelina*

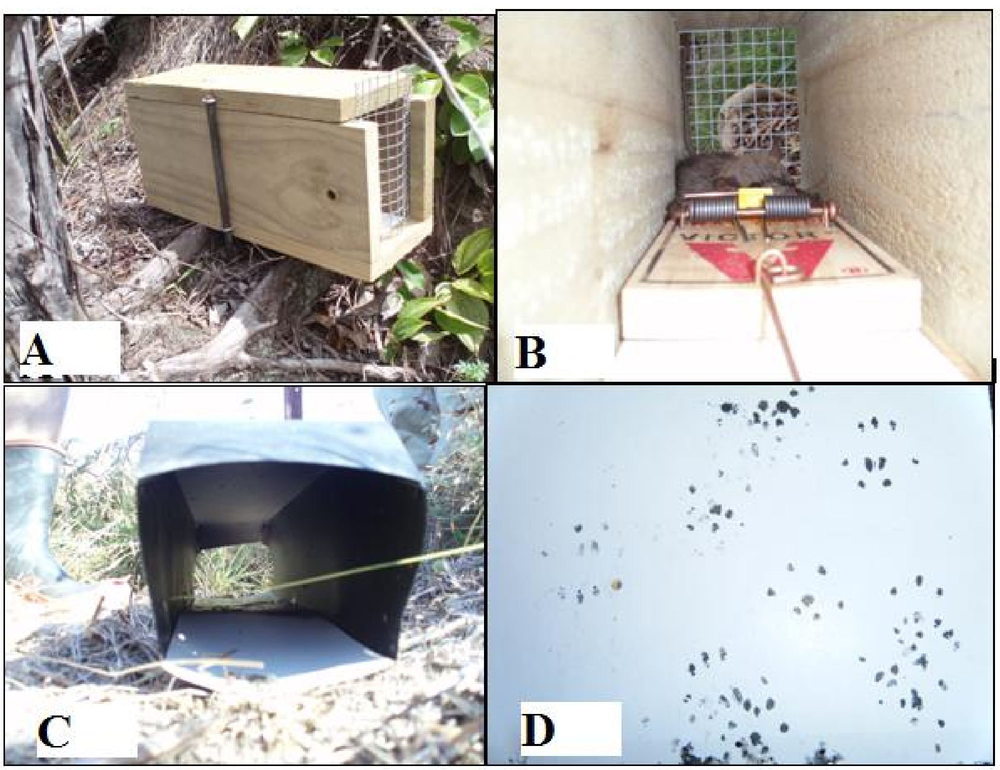
Since rat diets may include all of the above groups, it is expected that their numbers will increase with rat removal. The experiment is on-going. Changes in plant and animal groups as rodent populations are suppressed over longer time periods are anticipated. Data collection for all groups which may be impacted by rats was collected over one year in both areas.

Management and monitoring actions by site

Management & Monitoring Actions	**Kahanahaiki**	**Pahole**
Rat Control	Yes	No
Rat Tracking Tunnel Monitoring	Yes	Yes
Slug Monitoring	Yes	Yes
Euglandina rosea Monitoring	Yes	Yes
Arthropod Monitoring	Yes	Yes
Cyanea superba subsp. *superba* Fruit Predation Monitoring	Yes	Yes
Seedling Plot Monitoring	Yes	Yes
Seed Rain Bucket Monitoring	Yes	No
Oahu Tree Snail (*Achatinella mustelina*) Monitoring	Yes	No

Kahanahaiki large scale trapping grid with trap, tracking tunnel locations, and sampling locations.





(A) Wooden rat trap box deployed. (B) Wooden rat trap box with Victor rat trap.
(C) Plastic tracking tunnel with inked tracking card. (D) Tracking card with rat tracks.

7.6.2 Methods and Results

Please refer to chapter 6.6 of the 2009 Status Report For the Makua and Oahu Implementation Plans for a full description of methods used. (http://manoa.hawaii.edu/hpicesu/DPW/2009_OIP/007.pdf). Methods are paraphrased here to better understand results.

7.6.2.1 Rat Control (Kahanahaiki MU)

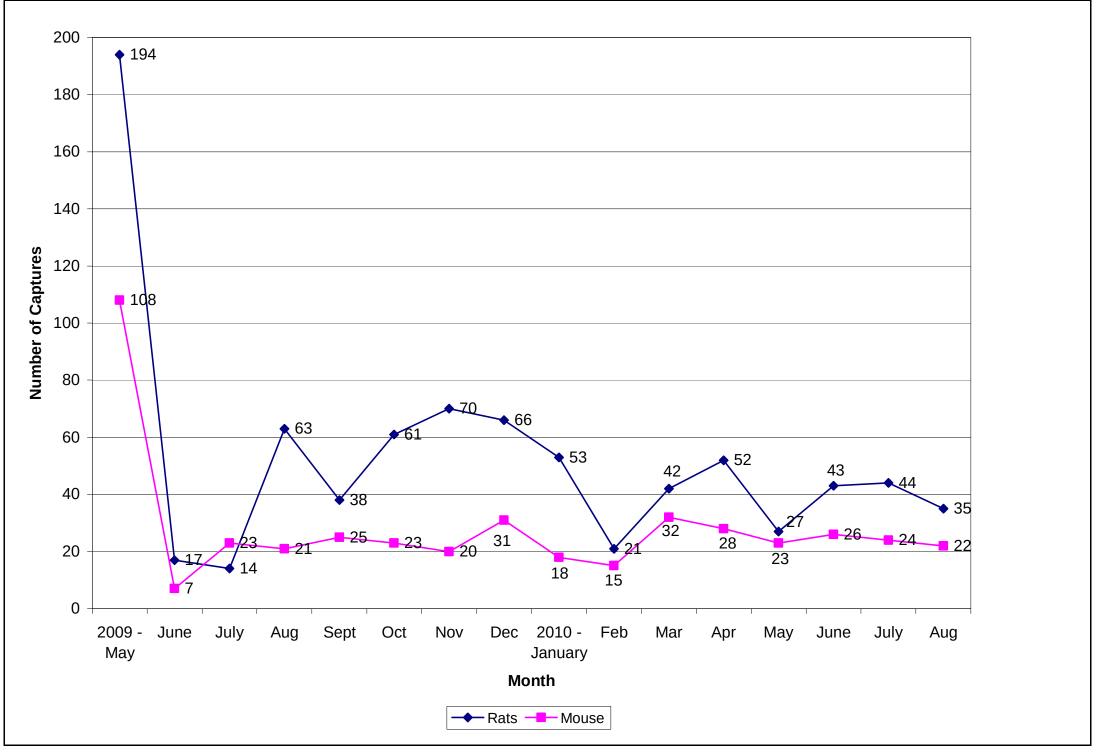
Study design

The grid was initially established in May 2009 with 402 traps and later expanded to 480 traps. The perimeter consists of 234 traps spaced at 12.5 meters apart. The interior contains 246 traps established on transects and existing trails (14 trap lines) at a spacing of 25 meters between traps. Traps were checked daily for approximately the first two weeks, then on a weekly basis for eight weeks, then two three week intervals, with the current checking interval bi-weekly.

Results

The trapping grid has been checked 49 times over a 16 month period (May 2009-August 2010) with a total of 840 rats and 444 mice trapped (See figure below). Approximately, a quarter of the total rats captured occurred in the first month (May 2009) of trapping. On average, 43 rats were captured per month after the initial knockdown occurred, with approximately 17 rats captured per grid check.

Monthly captures of rats and mice (May-2009 to August-2010)



Slug Interference

Over the past 16 months that the trapping grid has been in operation, invasive slugs continue to be a major problem in consuming bait placed on rat traps. Slugs are able to consume a quarter sized glob of peanut butter in one night, consume a half of macadamia nut in three nights, and a ¾" square chuck of coconut within a week. A variety of baits have been used in an effort to find a bait that is less susceptible to slug consumption, weathers well and is still attractive to rats. Baits that have been used include: peanut butter, coconut chunks, macadamia nuts, flavored wax coils, chocolate chips, Ferafeed® (non-toxic pre-feed bait from Connovation Ltd., New Zealand), sponges with food grade flavor concentrates, and peanut butter flavored rodent chew tab census tag wax. Slugs were able to consume all baits except the wax coils and sponges, both of these bait types had few captures. Slugs were not deterred from consuming rock salted peanut butter and Ferafeed®. In many instances, slugs would consume the salted baits and die on the trap. In an effort to keep slugs from consuming bait, some trap boxes were elevated 6 inches above the ground on rebar with 2 inches of copper tape. Slugs were able to breech the copper tape within a few days.

Rat trap with no bait, consumed by slugs (Left photo). *Limax maximus* consuming peanut butter (Right photo).

7.6.2.2 Tracking Tunnel Monitoring (Kahanahaiki MU)

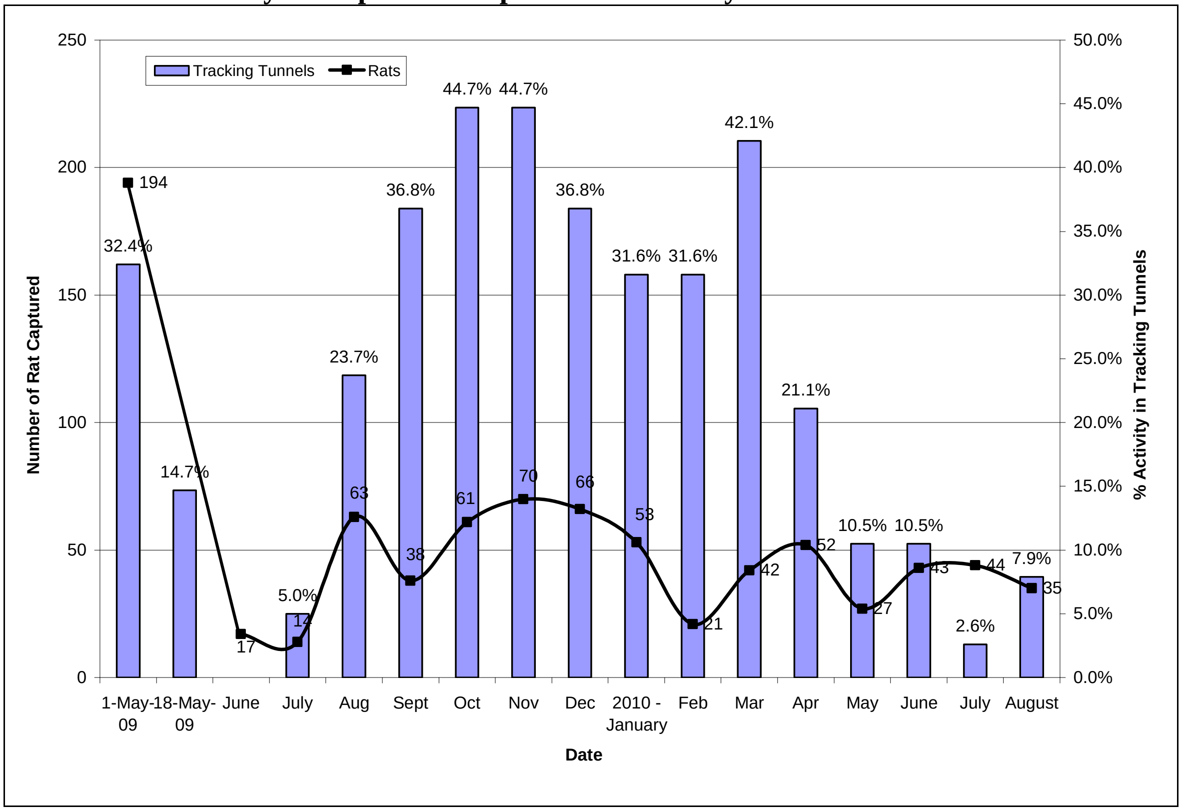
Study design

A total of 38 tracking tunnels have been run at the Kahanahaiki MU 16 times over a 16 month period (01 May – 21 August 2010) (See figure below). During each tracking tunnel session, tunnels are baited and run for one night. The initial running of tracking tunnels occurred four days before the start of the trapping grid, with tunnels being run approximately monthly thereafter.

Results

Tracking results have been variable with the peak in rat activity occurring in October and November 2009. The lowest level of rat activity detected occurred in July of 2009 and 2010. Mouse activity tracked similarly to rat activity over the same time period. The high rat activity occurring in the fall and winter appears to have been tracking the natural cycle of the rat population outside of the grid. The perimeter to the interior of the grid is approximately 125 meters which allows for incursion of rats in a short period of time. We don't have rat activity levels prior to the start of rat control, so the continued monthly running of tracking tunnels will give us a better understanding of rat activity within the grid.

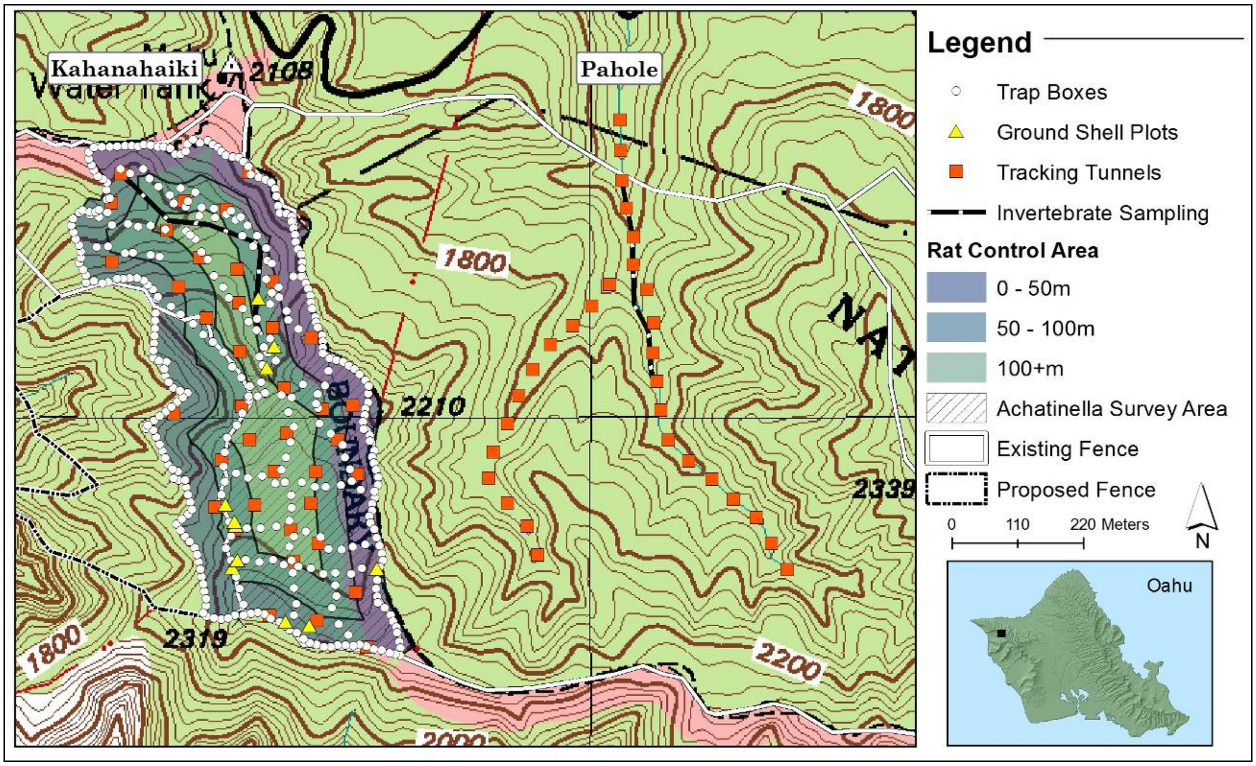
Kahanahaiki monthly rat captures and percent rat activity



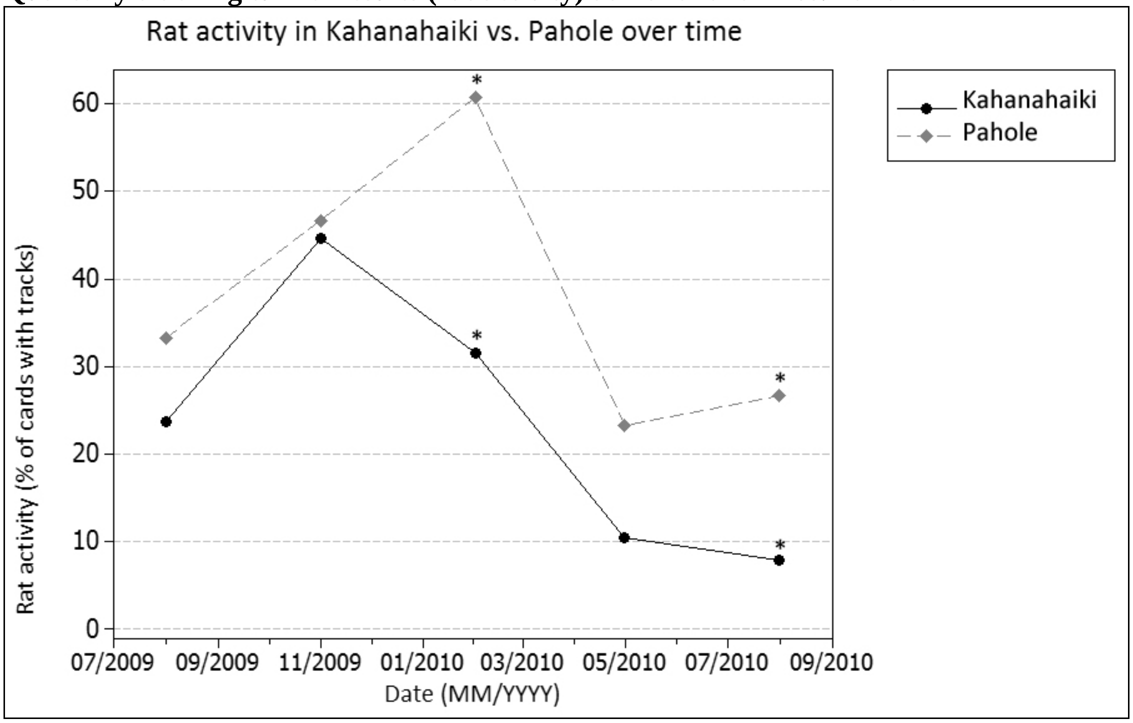
7.6.2.3 Tracking Tunnel Monitoring – Kahanahaiki vs. Pahole

Starting on Day 106 (18 August 2009) tracking tunnels were simultaneously run quarterly at both the Kahanahaiki MU (38 tracking tunnels) and the Pahole NAR (30 tracking tunnels; See map below) to compare the two sites (Management vs. Control). Rat activity did not differ significantly between sites three out of the five time periods sampled (see graph below), though it was consistently higher outside of the trapping grid. There were significant differences in rat activity between sites in February and August of 2010. Another year of data collect will help in determining trends in rat activity for both sites. Some of this data was presented by S. Mosher at the 2010 Hawaii Conservation Conference (HCC 2010) in Honolulu, HI in a talk titled: Controlling Invasive Rats (*Rattus* spp.) with a Large Scale Trapping Grid for Endangered Species Conservation on Oahu Hawaii (http://manoa.hawaii.edu/hpicesu/DPW/HCC-2010/default.htm.

Location of tracking tunnels at Kahanahaiki MU and Pahole NAR



Quarterly tracking tunnel results (rat activity) at Kahanahaiki vs. Pahole



* = significant difference between groups <0.05 (Chi-Square analysis).

7.6.2.4 Slug Monitoring (Kahanahaiki MU & Pahole NAR)

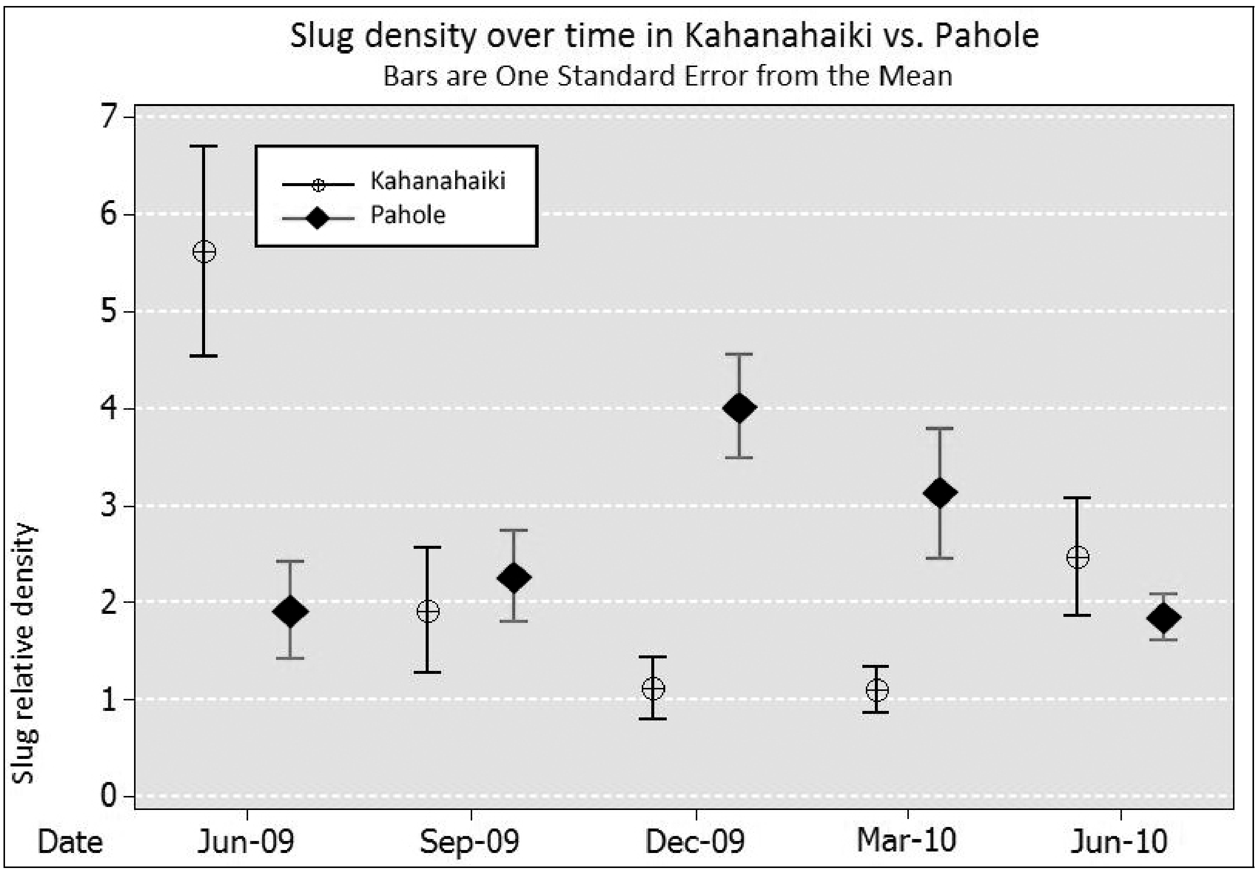
Study design

Slugs found in beer baits left out for one week were used to estimate slug numbers. Forty 8 ounce jars were deployed at 25 meter intervals along a 400 meter transect in the Kahanahaiki gulch bottom and in the main drainage of the Pahole NAR (Gulch 2). Once a quarter (in March, June, Sept. and December) traps were baited with 5 ounces of Guinness beer and the number and species of slugs caught recorded.

Results

Data from April 2009 extending through June 2010 shows no correlation between rat activity and relative slug density in either site (Pearson's correlation r^2=13%; P=0.39). High variability in slug numbers over time and between sites was observed.

The graph below shows the relative slug density (mean number of slugs per beer trap) by site over time. No clear patterns are evident. Slug numbers fluctuate between sites and do not track one another seasonally. In Pahole slug numbers peak in December while in Kahanahiki the highest density of slugs is observed in June (both years). In September 2009, and June 2010 slug numbers at both sites were the same. The inconsistent numbers of slugs over time and between sites might be due to microhabitat (soil moisture or leaf litter).



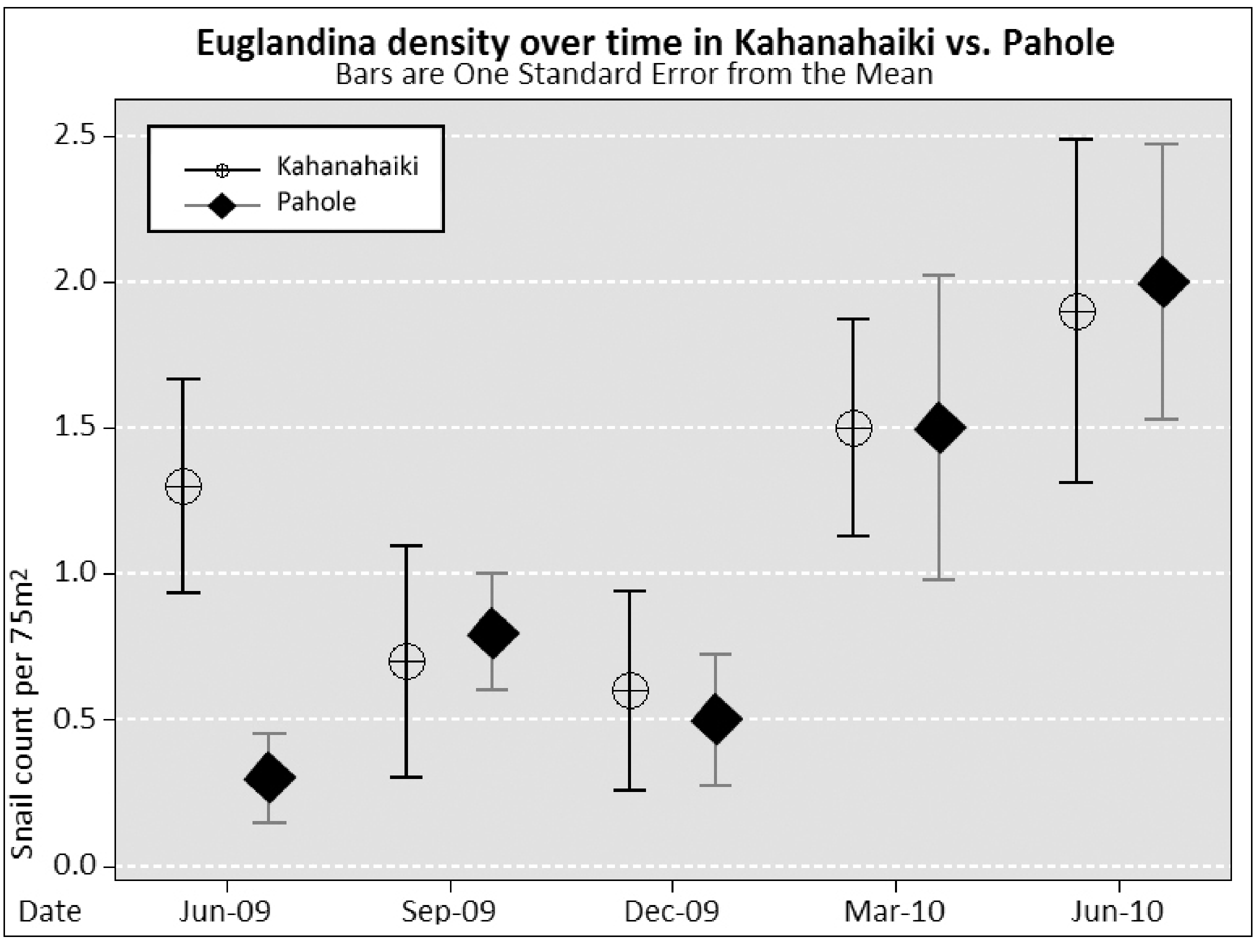
7.6.2.5 Euglandina Monitoring (Kahanahaiki MU & Pahole NAR)

Study design

Euglandina were sampled using timed searches (one person hour) at 10 discrete points along the 400 meter transect established for slug sampling. Each of the ten points marked the center of a 75 m^2 plots along which three people searched for *Euglandina* over 20 minutes (total time equal to one person hour per plot). Live *Euglandina* were counted, shell length recorded (mm) and left in place so as to not artificially control populations via manual removal. *Euglandina* shells were scored for damage (rat damaged or whole) and destroyed so as to not be re-counted at a later time.

Results

Seasonal variation in *Euglandina* over time was fairly consistent between sites despite differences in rat control effort (see graph below). As with slugs, no correlation between rat activity and predatory snails (*Euglandina)* was evident (Pearson's correlation r^2=16.7%; P=0.31). With one exception (June 2009) numbers of *Euglandina* were the same at both sites. This exception may have occurred because of a 4 day (rather than 1 day) interval in sampling between sites. Our failure to detect a relationship between rat activity and either *Euglandina* or slugs, however, suffers from a low number of sampling points over time (5 times per site).



7.6.2.6 Arthropod Composition and Abundance Sampling (Kahanahaiki MU & Pahole NAR)

Arthropod response to rat trapping was summarized in a poster presentation at the 2010 Hawaii Conservation Conference. The text and figures are provided here, however, the poster may be viewed on-line at: http://manoa.hawaii.edu/hpicesu/DPW/HCC-2010/Rat_arthropod_poster.pdf. Below is a condensed version of the poster.

Title: Patterns of Arthropod Diversity in Natural Areas Undergoing Rodent Management on Oahu

Author: P.D. Krushelnycky, Ph.D Plant Environmental Protection Sciences, University of Hawaii at Manoa

Above: native arthropods collected as part of this project.

Overview

Arthropods constitute a majority of the biodiversity in most terrestrial ecosystems. In addition, these animals often play important roles in ecosystem processes such as decomposition, soil turnover and pollination, and form critical links in food webs. Obtaining basic measures of the status and trends of native and invasive arthropod diversity should therefore be a fundamental component of any natural area management program.

The Oahu Army Natural Resource Program (OANRP) is implementing or planning rat removal operations in three areas in the Waianae Mountains. In conjunction with these efforts, I am conducting standardized, quantitative arthropod sampling before and after rat removal in two of these areas (Kahanahaiki and Palikea), as well as in adjacent control sites where rats will not be immediately removed, to estimate the impacts of rats on arthropod populations. This sampling will also serve as an arthropod inventory, providing important information on the biodiversity of these management areas.

Study design

I report here some preliminary results from a pair of sites in the northern Waianae Mountains: Kahanahaiki Valley, where a rat snapping grid has been implemented beginning in May 2009, and the adjacent Pahole Natural Area Reserve, where little or no rat management is currently being conducted.

Arthropod sampling was conducted at both sites in May/June 2009 (immediately prior to rat trapping), December 2009, and May/June 2010. Standardized sampling at each site included 16 pitfall traps, plus vegetation beating on 8 individuals of four plant species: *Charpentiera tomentosa*, *Pipturus albidus*, *Pisonia umbellifera* and *Psidium cattleianum*.

Does rat trapping result in recovery of arthropods?

Stomach contents from rats and mice caught at Kahanahaiki commonly include remains of caterpillars (immature Lepidoptera), beetles (Coleoptera) and spiders (Araneae), among other groups (A. Shiels unpub. data). But does this predation suppress arthropod populations?
I compared samples collected in May/June 2009, prior to rat trapping, with those collected in May/June 2010, to see if beetle, spider or caterpillar populations recovered at Kahanahaiki (where rats were trapped) relative to Pahole (where rats were not trapped). These samples included a total of 2149 specimens belonging to 87 species or morphospecies (in these three orders).

Early results suggest that neither native nor adventive beetle abundances on the trees sampled increased at Kahanahaiki relative to Pahole (Figure 1, top). This appeared to be true for changes in beetle richness as well (Figure 2, top). In contrast, changes in spider abundances and richness tended to increase at Kahanahaiki relative to Pahole, although the differences between trends at these two sites were not statistically significant (Figs. 1 and 2, middle panels). The strongest evidence for potential recovery after rat trapping involved caterpillars, which increased significantly more in both abundance and richness at Kahanahaiki relative to Pahole (Figs. 1 and 2, bottom panels).

While not definitive at this point, these results indicate that continued sampling is warranted, to track possible further arthropod community changes as rodent populations are suppressed over longer time periods. Replication at additional sites, such as Palikea, will help clarify whether these changes are likely to be due to rodent removal.

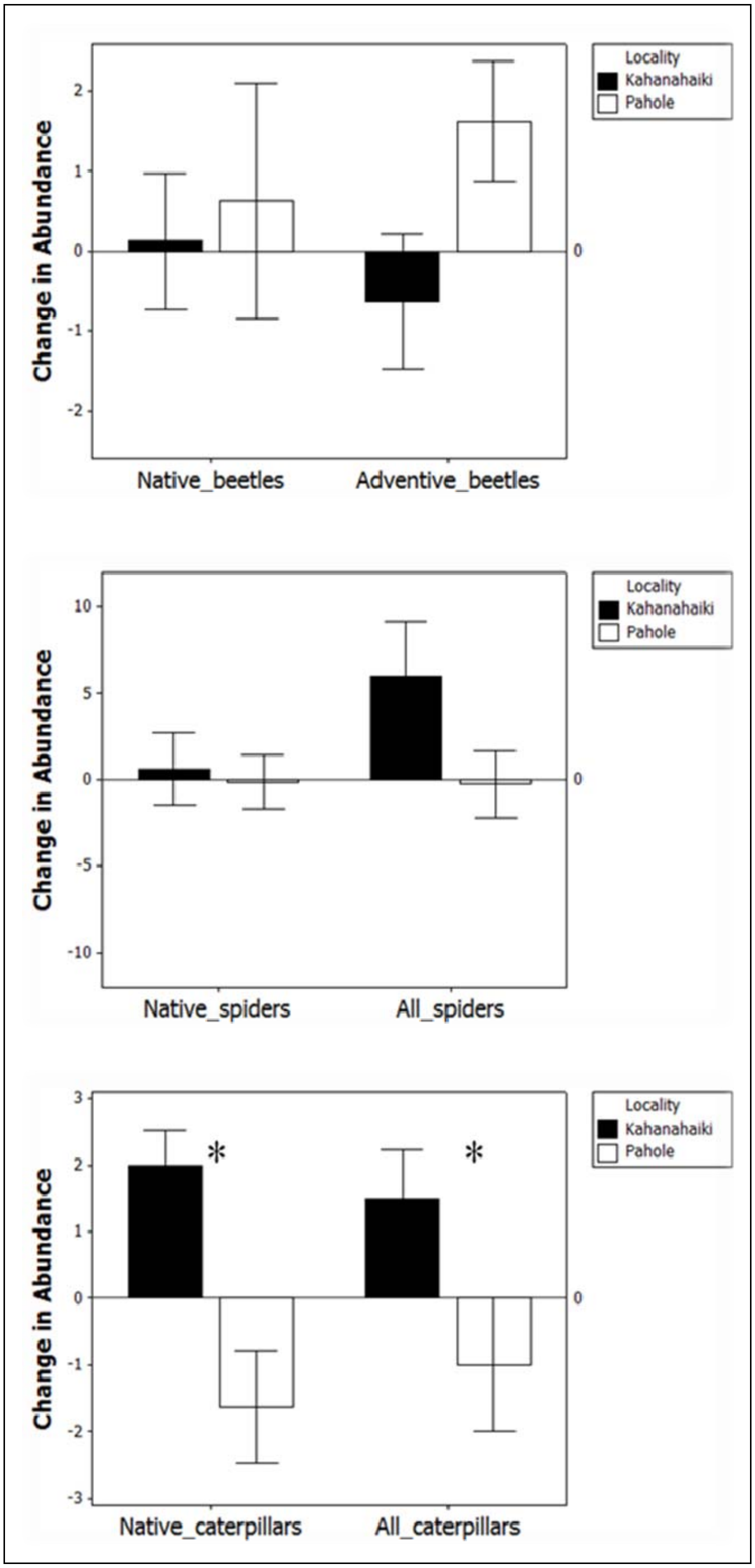


Figure 1. Changes in abundances in three arthropod orders from vegetation beating samples collected in May/June 2010 relative to those collected in May/June 2009 at Kahanahaiki and Pahole. Starred comparisons are significantly different (Mann-Whitney U test).

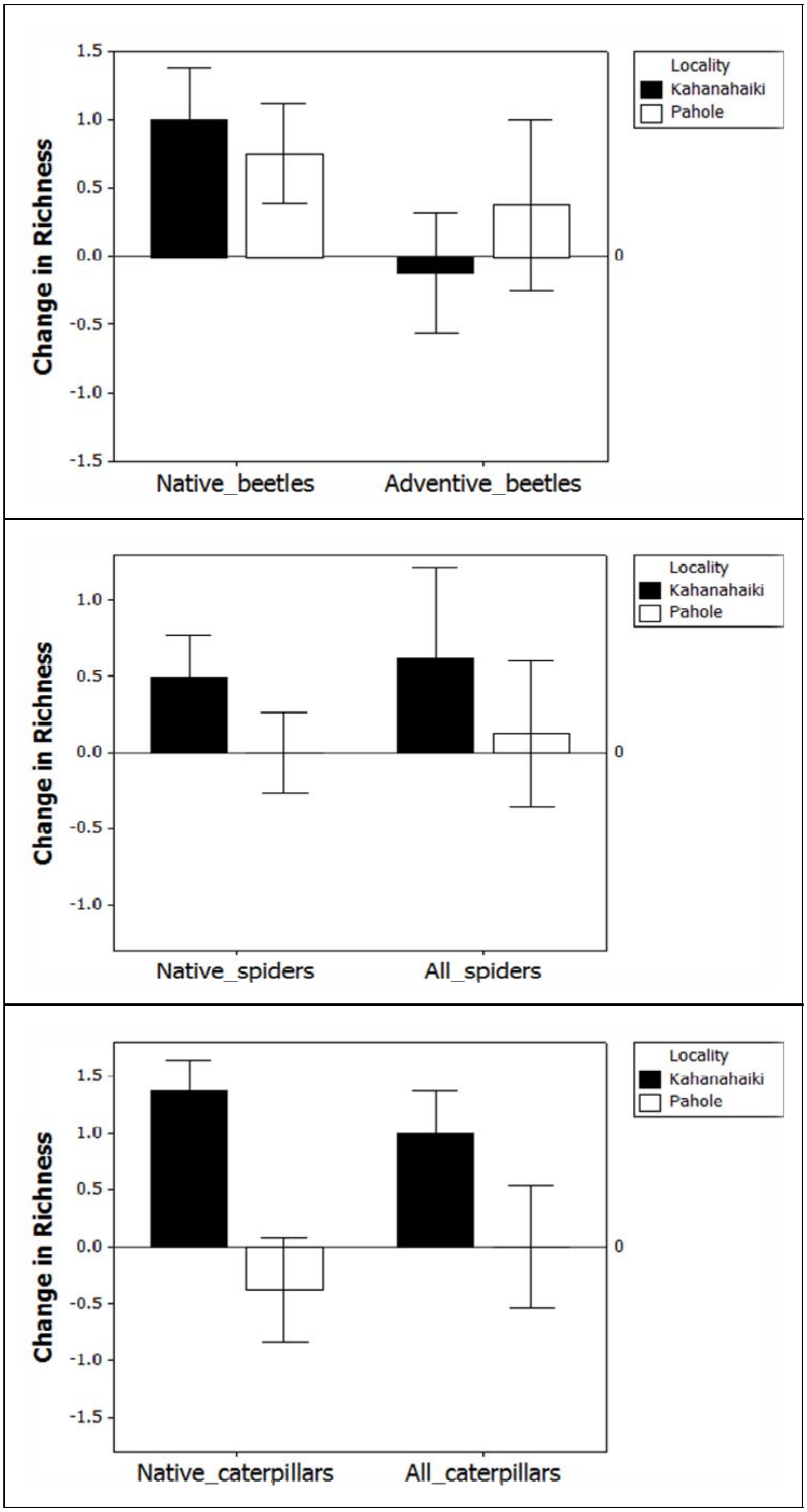


Figure 2. Changes in richness in three arthropod orders from vegetation beating samples collected in May/June 2010 relative to those collected in May/June 2009 at Kahanahaiki and Pahole. Starred comparisons are significantly different (Mann-Whitney U test).

Patterns in arthropod diversity

Native arthropods made up a much larger proportion of samples collected on four focal plant species, compared to those collected with pitfall traps, in terms of both richness and especially abundance (Figure 3). Perhaps somewhat surprisingly, the abundance and diversity of native arthropods was similar or higher on strawberry guava (*P. cattleianum*) relative to the three native tree species. However, this result applies only to three arthropod orders (Araneae, Coleoptera, Lepidoptera), and could change substantially when orders containing abundant and host-specific plant feeders (such as Hemiptera) are included.

The extensive sampling at the Palikea site (not shown) will also provide excellent information on relationships between plant community composition and patterns in diversity of native and introduced arthropods. These collections have already resulted in the discovery of at least one new endemic carabid beetle species.

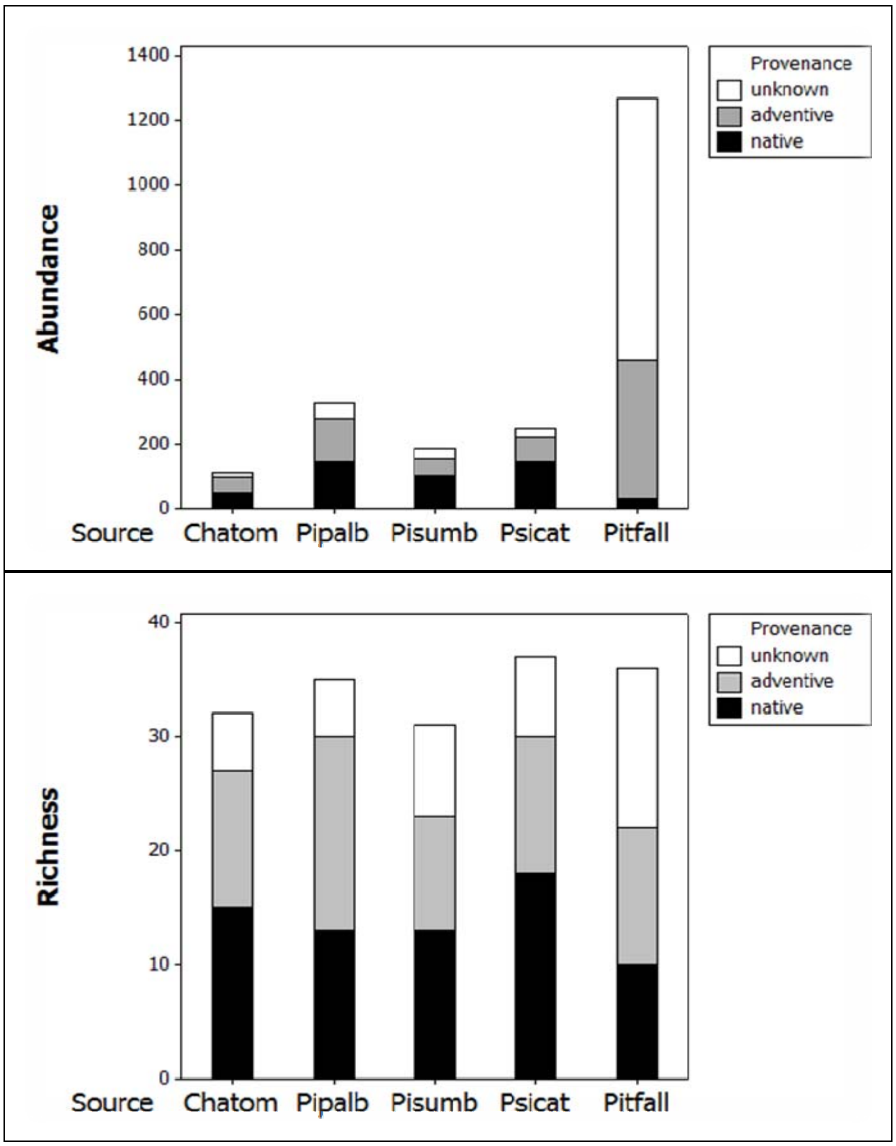


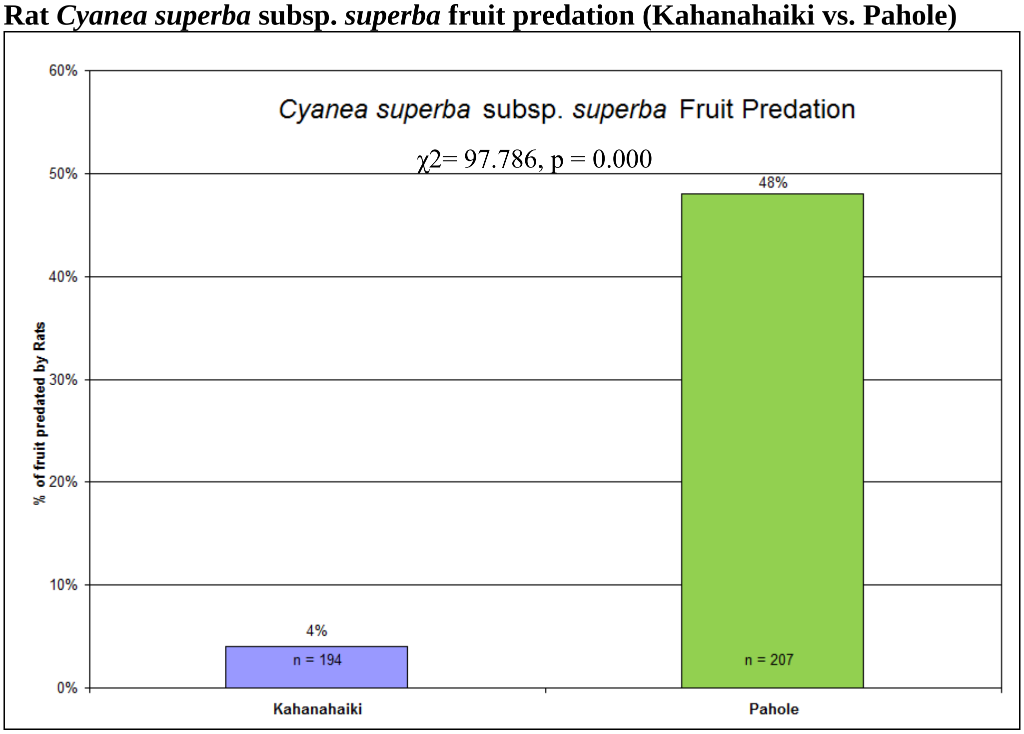
Figure 3. Patterns of abundance and richness of arthropods of native, adventive and unknown provenance on the four focal plant species sampled and in pitfall traps. Results are for Araneae, Coleoptera and Lepidoptera only (orders combined).

7.6.2.7 Cyanea superba subsp. superba Monitoring (Kahanahaiki MU & Pahole NAR)

The rat control grid was effective in reducing the amount of predation on *Cyanea superba* subsp. *superba* fruits at Kahanahaiki during the fruiting season (late-November 2009 through early-January 2010). There was a significant difference in fruit predation between sites with eight predated fruits out of 194 (4%) monitored at Kahanahaiki, as compared to 99 predated fruits out of 207 (48%) monitored at Pahole (see graph below). These data were presented as a poster at the Island Invasives: Eradication and Management Conference (Auckland NZ, February 2010) (see excerpt from poster). The poster may be viewed in full at the following URL: http://manoa.hawaii.edu/hpicesu/DPW/In_NZC/default.htm

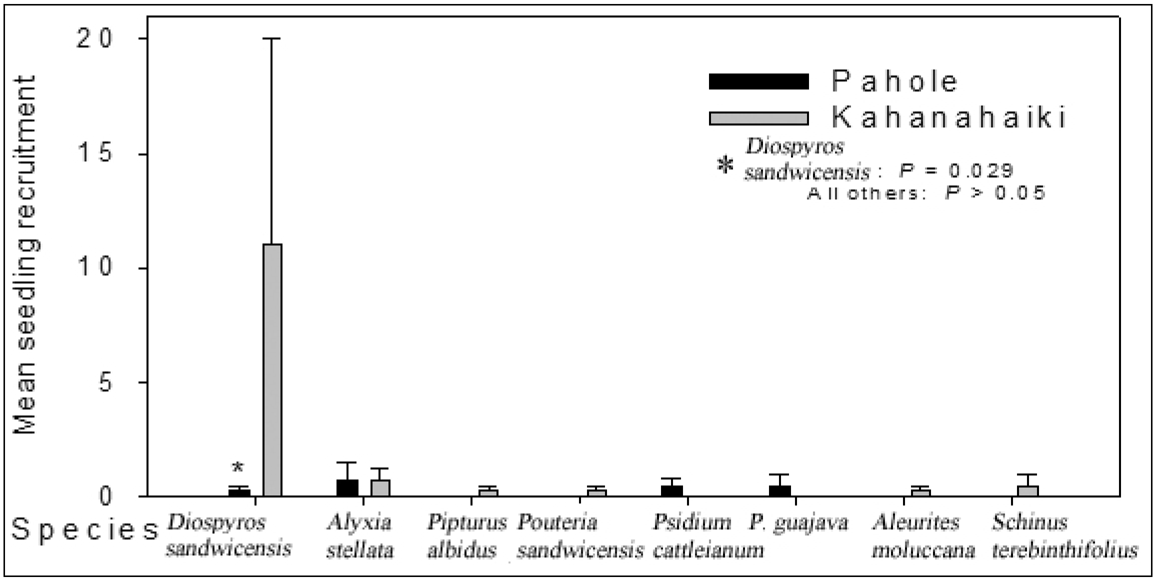
Rat climbing trunk of *Cyanea superba* subsp. *superba* (Left photo). *Cyanea superb* subsp. *superba* fruit consumed by rats (Right photo).

Rat *Cyanea superba* subsp. *superba* fruit predation (Kahanahaiki vs. Pahole)



7.6.2.8 Seedling Monitoring (Kahanahaiki MU & Pahole NAR)

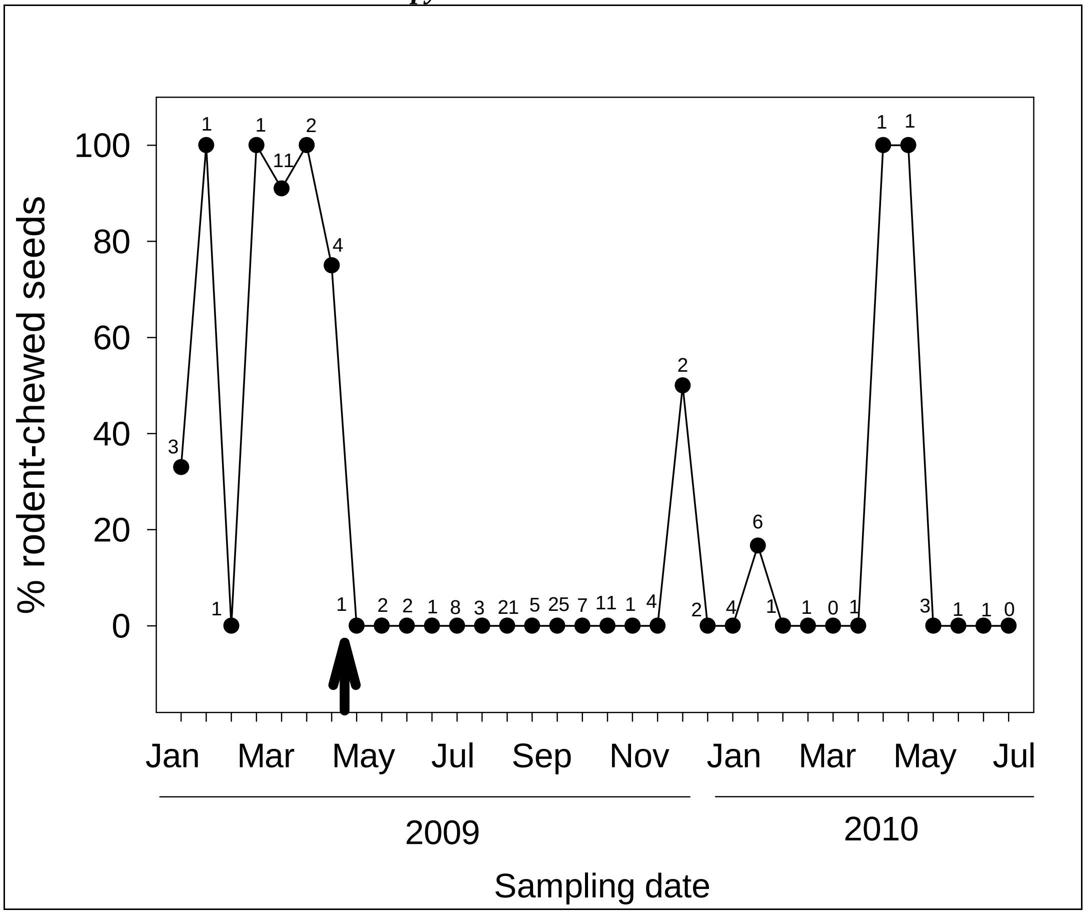
The figure below shows the mean ± SE of seedling recruitment during a 6 month period (August 2009-February 2010) at the Kahanahaiki and Pahole where rodents were not manipulated. Seedlings for four native and four introduced plant species were monitored (see figure below). Only seedling plots (32 per site) with *Diospyros sandwicensis* (lama) overstory within 15 meters of the plots were included for calculations at both sites. There was only a significant difference in seedling recruitment for *Diospyros* at Kahanahaiki vs. Pahole (Mann-Whitney U test; See figure below).



7.6.2.9 Seed Monitoring (Kahanahaiki MU only)

The figure below shows the percentage of rodent-chewed lama seeds recovered from seed rain buckets during each two week sampling period at Kahanahaiki (January 2009-July 2010). The numbers above data points indicate the total number of lama seeds collected from buckets. Trapping started in May 2009 with seven months of no chewed lama seeds until December 2009. During the peak in lama seed production there was no seed predation detected. Lama seed predation has remained low during the running of the trapping grid.

Seed rain bucket results for *Diospyros sandwicensis* from Kahanahaiki



7.6.2.10 Achatinella mustelina Monitoring (Kahanahaiki MU only)

A total of 212 *Achatinella mustelina* were counted during the August 2009 census of the Maile Flats area of the Kahanahaiki MU (for more information see MIP 2009 Snail section; http://manoa.hawaii.edu/hpicesu/DPW/2009_OIP/005.pdf). This count was an increase from the 157 snails counted in the summer of 2004. A census of this area will be conducted every three years. If necessary this interval will be reduced to annually. Two ground shell plots were monitored quarterly (April 2009-April 2010) in the Maile Flats area of the trapping grid with no detections of rat predated shells, however two live *Euglandina rosea* were found.

7.6.3 Summary

- The number of rat captures continues towards a downward trend from the initiation of the trapping grid.
- Tracking tunnel activity was high in the interior locations of the trapping grid when distances from the perimeter to the interior were less than 100m during the fall and winter months.
- The tracking tunnels appear to be potentially tracking the natural cycle of rat activity outside of the grid because to the short distance across the management unit.

- Data collected on slug and *Euglandina rosea* numbers suggests that rat reduction does not cause increases in these highly invasive species.

- There was a detectable increase of native caterpillars and spiders at Kahanahaiki vs. Pahole.

- The rat control grid was effective in reducing the amount of predation on *Cyanea superba* subsp. *superba* fruits at Kahanahaiki (Year 1).

- There was a significant difference in lama seedling recruitment between Kahanahaiki and Pahole.

- Rat predation on lama seeds was greatly reduced while running the trapping grid.

- Continued data collection of annual tree snail counts, seedling plots, arthropods and *Cyanea superba* subsp. *superba* fruit predation will give us a better understanding of what rat activity thresholds must be met to maintain and increase rare and common native species.

- Bait consumption by invasive slugs poses a hurdle that still needs to be overcome. Alternative baits are currently being pursued (wax baits and scented lures).

- All monitoring components will be continued through August 2011.

- Trapping grid effort: grid set up ~230 people hours; trapping checks (49 visits) ~915 people hours from May 2009 to August 2010; Tracking Tunnel efforts at Kahanahaiki (once a month) has taken ~245 people hours and Pahole (once a quarter) ~35 people hours.

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