CHAPTER 5: RARE INVERTEBRATE MANAGEMENT

5.1 Introduction to Rare Snail Management

The island of O`ahu has 41 listed endangered species of land snails (although many of these are probably already extinct) and, in fact, the entire genus of *Achatinella* is listed as endangered. Since 1970, ten species of *Achatinella* (as well as a few equally rare land snails of other genera) have been found on Army training lands on O`ahu. Included here are: *Achatinella apexfulva*, *A. byronii*, *A. curta*, *A. decipiens*, *A. leucorraphe*, *A. lila*, *A. livida*, *A. mustelina*, *A. pulcherima*, *A. sowerbyana*, *Amastra micans*, and *Laminella sanguinea*.

There are three steps in the Natural Resource Staff's (NRS) snail management approach: surveying to identify new populations of snails; monitoring known populations; and prioritization and management of known sites. NRS are presently working in close cooperation with Dr. Michael Hadfield, Professor of Zoology at the University of Hawai`i at Mānoa. Since 14 August 1997, NRS have been listed as sub-permittees on Dr. Hadfield's U.S. Fish and Wildlife Service (USFWS) permit to work with endangered snails. As sub-permittees, three NRS personnel are authorized to handle (capture, measure, mark, collect tissue samples, and release) the O`ahu tree snails (*Achatinella* spp.) for the purposes of gathering ecological and life history data, and re-establishing wild populations.

In July 2002, the Snail Working Group was reorganized with the help of the USFWS. This multi-agency group discusses snail management statewide and helps to direct future management actions. The group met in October 2002 and again in February and July 2003. Most recently NRS met with Dr. Hadfield in May and September 2004 to discuss the Urgent Actions projects for 2002 to 2004, and also the O`ahu Implementation Plan.

5.2 Rare Snail Surveys

Snail surveying involves hiking in areas expected to contain rare snails, searching trees for arboreal tree snails and appropriate ground substrate for terrestrial snails. NRS have concentrated survey efforts in areas of known snail habitation as reported in the 1984 and 1985 surveys and from other documented sightings. Some specific snail surveys focus on taxa of which no populations are currently known but which have been observed within the past ten to thirty years. Survey routes are mapped via GPS/hand mapping and maintained in the NRS GIS system. Sites are mapped and provided at the end of this chapter. NRS have obtained maps from the Hawaii Natural Heritage Program (HINHP) with points designating past sightings to help in survey efforts. NRS have surveyed with malacological experts including Dr. Hadfield and his associates of the University of Hawai`i, Dr. Daniel Chung of Kapiolani Community College, and USFWS Field Staff.

5.3 Rare Snail Threats

Various factors are thought to be responsible for the swift decline of land snails in Hawai`i: loss of habitat, predation by rats and *Euglandina rosea* (a carnivorous snail), drought, change in climate, disease, and over-collection by humans. Predation pressures on *Achatinella* are compounded by its slow growth, late maturity, low motility, and a low rate of fecundity (approximately one offspring per adult per year) (Hadfield and Mountain, 1980). In addition, during years of drought chances of survival are diminished, further reducing fecundity. *Achatinella* probably had few predators in pre-human times and it is believed that they were able to form dense populations. Post human contact, tree snails survived nearly 150 years of European rat predation and more than 1,000 years of predation by the Polynesian rat. It is not definitively known whether or not this long-term predation significantly reduced snail numbers. The Hawai`i Department of Agriculture introduced *E. rosea* in 1958 to control the African snail, *Achatina fulica*. Its effect on Hawaiian snails has been much more devastating than that of rats. Like many other plants and animals of oceanic islands, native snails have lost all defenses against introduced predators and competitors. The destructive forces of rats and predatory snails present a picture of imminent extinction. Dr. Hadfield had acquired an Experimental Use Permit for bait developed to control *E. rosea*. The bait consisted of ground "apple snail" flesh (*Pomacea sp*.), 2% metaldehyde (the toxin), and 5% propionic acid (a food preservative). The cost to patent this product for widespread use against predatory snails is astronomical and thus impossible with the current funding available.

5.4 Rare Snail Monitoring

NRS employ two types of monitoring techniques. In the simplest form of monitoring, trees in which snails are found are tagged and the total number of snails in each tree recorded. Trees within sites are then mapped. NRS sometimes also utilize a more extensive mark and recapture technique. This method entails marking individual snails with a unique number and/or color combination to track them over time. In this manner, NRS are able to observe the growth rate, death rate, and the movement of snails between trees. An estimate of total population size can be made using the proportion of marked to unmarked snails captured on subsequent visits. Marking the snails poses many difficulties, as conditions must be dry for the paint to set. NRS record pertinent snail data on a Rare Snail Monitoring Form and keep accurate records to be able to measure changes in snail populations over time.

5.4.a Rare Snail Observation Forms

NRS made great improvements in the snail data management program this year. NRS revised the rare snail monitoring form (Appendix 5A) to incorporate new fields. A significant addition is the delineation of size classes based on data collected by Dr. Michael Hadfield from snails that he reared in captive propagation. Size class definitions differ between Ko`olau *Achatinella* taxa and *A. mustelina* from the Wai`anaes. In addition, there are fields to record information on predator presence in the area and any evidence of predation. Also, the number of person hours spent searching is recorded so that variability in numbers of snails observed can be better understood. Another significant addition to the form is the field for a population reference code.

This allows NRS to track data on population structure in a spreadsheet. Population reference codes are composed of a three-letter abbreviation for either the Hawaiian gulch name or a training area where a population is found and a single letter following it that is simply assigned in the order that populations are discovered. For example, SBW-A is the reference code for the first *A. mustelina* site discovered in Schofield Barracks West Range. In addition these reference codes are the common field that ties a rare snail observation form to a point location in the GIS database. NRS plan to link the spreadsheet/database to the GIS database, making data entry and retrieval easier and more effective in the future.

5.5 Rare Snail Management

In the following sections each rare snail species reported from O`ahu Army lands since 1982 is discussed. The status of each species and the management conducted for it is described.

Thus far NRS have deployed a total of 49 rat bait stations stocked with diphacinone in snail populations in both the Wai'anae and Ko`olau Mountains. In the Wai'anae Mountains four areas were selected. `Ōhikilolo "Pteralyxia Gulch" and SBS were selected because rat-eaten shells had been seen at both of the sites. Pu`u Hāpapa was chosen because of the rare *Amastra* snails that are found there, as well as a healthy population of *Achatinella mustelina*. Also, in December 1998 three rats were trapped here during an overnight camp. The area surrounding the snail enclosure in Kahanahāiki is baited to help reduce pressure. Although the enclosure is designed to be rat-free, NRS have trapped rats on two occasions inside the enclosure during the past year. Seven sites are baited in the Ko`olau Mountains and these are primarily small pockets of snails that remain along the Summit Trail where a couple of hiking hours separates known snail populations. NRS also perform weed control in areas of high snail density as a means of habitat restoration. More will be discussed in the individual snail sections pertaining to specific site management.

Recently, NRS discussed the prioritization of snail management and questioned why baiting is done in certain areas and not done in others. There are small populations of Ko`olau snails that are being protected with rat bait stations and there are other large populations (248 snails) that are not being protected. To rectify this discrepancy it was decided that in the future some of the larger unprotected sites would be monitored and surveyed specifically looking for signs of rat or *E. rosea* predation. In the past emphasis was placed more on counting the live snails and not searching for predated shells on the ground. It is generally accepted that rats are ubiquitous on the island but, for whatever reasons, are more problematic in certain areas. It has been the policy of NRS not to bait around some of the larger populations without first seeing signs of rat predation. Although the bait is designed to kill rats, it might also act as an attractant and NRS would not wish to create a problem where none exists. Then again, NRS do not want to fail to recognize a rat predation problem because it has not been adequately looked for. NRS will conduct surveys to include live snail counts, specifically monitoring for evidence of predation. This is a new development in snail management and an attempt to utilize the available resources in the best possible manner to ensure the survival of native snails on Army training lands on O`ahu.

5.5.a *Achatinella apexfulva*

The historical range of *A. apexfulva* (Pop Ref Code: KLO-A) comprises parts of the KLOA. In recent years, this species has only been found along the Poamoho Trail. It is considered extremely rare and its present range is very restricted. One new snail was seen in this area during a hike on 26 February 2004. Another search was made 18-20 May 2004. A group of four NRS surveyed the areas south of the Poamoho Stream on a ridge where d'Alte Welch had recorded snails during the 1930s. Much of this habitat looked promising for snails, but the end result was the usual one; searching so far from the summit at lower elevations is very unlikely to yield snails. No additional *Achatinella apexfulva* were identified.

During a trip to the Poamoho Trail area in April 2003 a tissue sample was taken of a dark colored snail. Genetic analysis showed this snail was actually *A. sowerbyana* and not *A. apexfulva.* If more individuals are discovered in the future, NRS will discuss bringing them into captivity with Dr. Hadfield and the State of Hawai`i.

This species has been slow to reproduce in captivity. Dr. Hadfield theorized that this might be because it is found at lower elevations where the temperature is a bit warmer than in the captive facility. A new refrigerated chamber that can be maintained at a slightly warmer temperature was added to the tree snail lab two years ago. Early signs are that this higher temperature may be more suitable for these snails. In 2001, pathogens negatively affected the lab populations of snails. More time and effort has been given towards making sure that the environment is as clean as possible, and other experts were consulted to help solve the problem. The problem has not reappeared this year. NRS will continue to search the Poamoho Trail site on an annual basis. As of September 2004 the total number of individuals in the lab was 10. Unfortunately, only one of these is an adult.

5.5.b *Achatinella byronii/decipiens*

There is some confusion amongst Hawaiian malacologists as to the distinction between *Achatinella byronii* and *Achatinella decipiens.* For simplicity, NRS have treated both as one taxon. This snail was historically known from the southern boundary of KLOA and areas to the south, primarily along the Summit Trail and upper elevations above 2,000 ft. It is considered to be extant with some recent sightings by Dr. Hadfield (USFWS 1992). A healthy population of 178 *A. byronii* (Pop Ref Code KLO-E) was counted in the Schofield-Waikāne Trail area on 9 August 2000. On 21 August 2002, a total of 93 snails were found on a ridge closer to the summit in a previously unexplored area. Including the 79 snails seen at the original site, a total of 172 snails were counted on this trip. On the most recent survey on 15 December 2003 there were 72 snails counted in the second, newer area. Figure 5-1 shows the number of snails counted as well as the amount of time spent searching.

Figure 5-1 *Achatinella byronii* Survey Trend

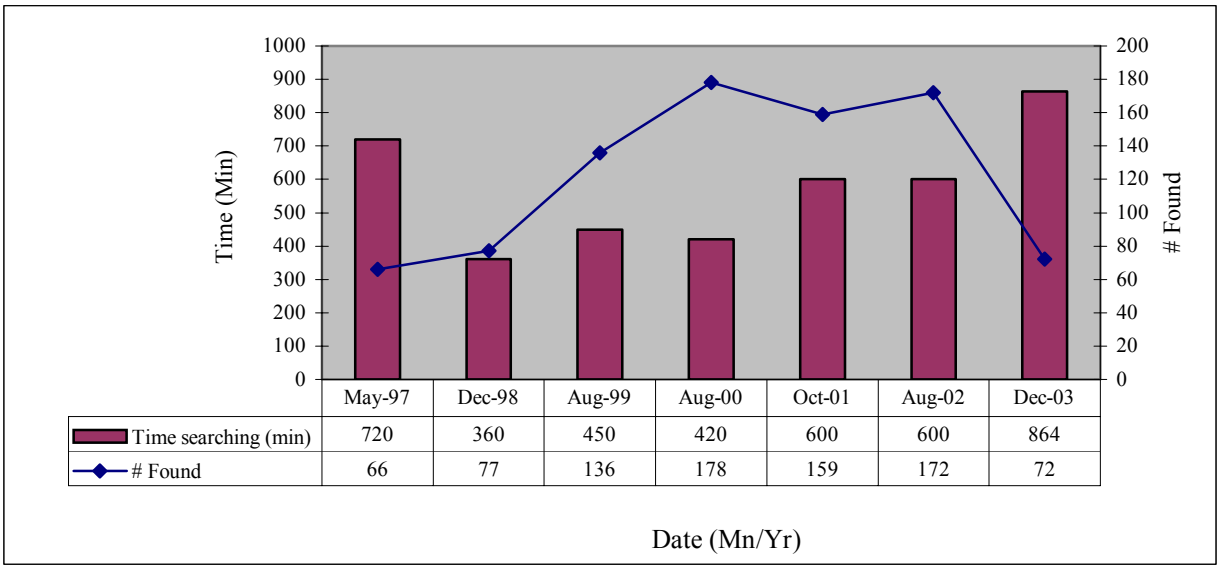


Figure 5-1 gives information about the main site just north of the Schofield-Waikāne Trail. Numbers of snails observed on five trips over the past seven years are given as well as an estimate of the amount of time spent searching. The rising numbers should not necessarily be interpreted as increases in snail populations, but rather are more likely indications that searchers are becoming more familiar with preferred snail habitat, so that more snails are found with less time searching. Sometimes, as in the December 2003 trip, fewer snails are counted with more time spent searching because new areas are surveyed.

Because this is the largest population of *Achatinella* snails known in the Ko`olau Mountains, its protection and management are very important. NRS does not bait for rats at this site because no signs of rat predation have been discovered here. It was decided in 2002 to visit the area twice per year to survey for rat or *E. rosea* predation and continue monitoring once a year to perform a snail count.

During an April 2003 survey of the Poamoho Trail area, UH staff collected tissue samples from a low elevation population of snails that were thought to be *A. sowerbyana*. Surprisingly, the genetic analyses matched them with the *A. byronii/decipiens* population from the Schofield-Waikāne Trail. There are a couple of miles of forest that separate these two populations and no known snails between the two sites.

5.5.c *Achatinella curta*

A. curta was historically found throughout KLOA. In the past eighteen years only two snails have been seen; one on the Kawailoa Trail and one on the Pe`ahināi`a Trail. None have been seen in the past fifteen years. NRS have been searching the areas where these snails were last seen for the past nine years and have not been able to find any. Although additional surveys were planned for this year, none were conducted due to helicopter restrictions and other priorities.

NRS recommend continuing these periodic searches in areas where *A. curta* were known to live. NRS will collect specimens for captive propagation, if found, before the species goes extinct in the wild.

5.5.d *Achatinella leucorraphe*

A. leucorraphe is considered critically rare and may only be surviving in a very restricted habitat. Historically, it was found in SBE and further south. Only one snail has been identified in the past fifteen years and it was found along the Schofield-Waikāne Trail. NRS have searched appropriate habitat in the SBE, including the area where Dr. Steve Miller of USFWS last reported seeing one *A. leucorraphe* in 1989, and have been unsuccessful in finding any more. This species may also be extinct because it was known to thrive in lower elevations where *E. rosea* first invaded and the 1989 sighting is the only documented one for the past 44 years. NRS will continue surveying SBE to find *A. leucorraphe* and will collect it for captive propagation, if found. Two of the surveys that were conducted during 2000-2001 were in *A. leucorraphe* historical habitat but none were found. In February 2002 NRS spent two days searching for snails in the SBE but did not find any *A. leucorraphe*. However two new helicopter landing zones were established so in the future NRS will be able to land closer to prime unexplored forest areas and thus conduct more searches. Further searching will be required before this species can be considered extinct. NRS plan to conduct searches next year to look for *A. leucorraphe*.

5.5.e *Achatinella lila*

This species is historically known from the Schofield-Waikāne Trail, Poamoho Trail and connecting Summit Trail areas. NRS no longer find it in the southern regions around Schofield-Waikāne but have seen individuals north and south of the Poamoho Trail and Summit Trail junctions. It is considered to be uncommon within a very restricted range. NRS have identified *A. lila* from four different areas and presently bait for rats at two of these sites. One site that has the largest known population of *A. lila* was surveyed in March 2003. NRS decided that it would be prudent to bait for rats at this site because, although there are no signs of rat predation nor is any decline recognized in the snail population, the nearby snail sites are showing decline. This is a fragile habitat due to low vegetation and steep terrain, and the potential benefits of rat baiting here will need to be considered against any possible trampling and destruction of vegetation. NRS will continue monitoring the known populations for evidence of predation while searching new areas for *A. lila*.

Five snails were counted at the Pe`ahināi`a Trail and Summit Trail junction on the 14 January 2003 trip. A large portion of this site is now protected within the exclosure. NRS have been putting out diphacinone bait blocks at this site since August 1999. In 2002 NRS also began using snap traps that are reset when the bait stations are restocked. Presently, there are five rat bait stations and ten snap traps at this site. Helicopter support is used to restock bait which used to be done biannually, but now is done bimonthly. Bait "take" at this site has consistently been at approximately 50%. NRS will continue following the present schedule of restocking and will reevaluate the project, if the bait take continues at a high rate.

On 25 September 2000 Dr. Hadfield led a group of six people to survey some of his old sites along the Summit Trail. One site is approximately five minutes hiking south of the Poamoho/summit junction on the windward side and another is approximately five minutes north of the junction. Five *A. lila* were found at the southern site. Unfortunately, a live *Euglandina rosea* was also found at this site; this shows the precarious circumstances that threaten native Hawaiian tree snails. On the 18 March 2003 survey no *A. lila* were seen at this site. During the 18 March 2003 survey a total of 14 *A. lila* were counted at the site north of the Poamoho Trail monument. Because of the importance of this site NRS set up eight rat bait stations and eight snap traps on 19 August 2003 and plan to restock on the usual bimonthly schedule.

At the present time there are 218 *A. lila* living in the lab at UH.

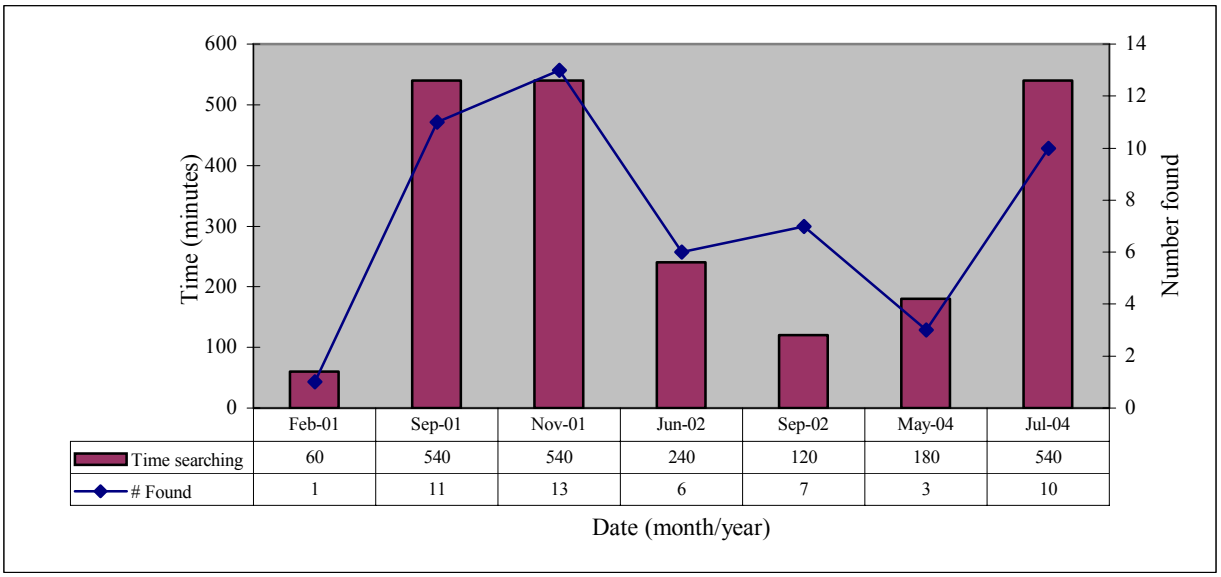
5.5.f *Achatinella livida*

A. livida is a species known from KLOA. In 1981, one live snail was found in the area where the Lā`ie Trail meets the Summit Trail. No snails have been found this far north in recent surveys, but NRS do know of individuals at some of Dr. Hadfield's study sites further south near the old Kahuku Cabin. The following three sites are presently monitored by NRS: "Northern", "Crispa Rock", and "Radio LZ".

Five years ago NRS initiated predator control at the "Northern" (northernmost) site north of the old Kahuku Cabin. At this site six bait stations and 12 snap traps are used to control rats. The number of snap traps was increased from six to 12 traps in 2004. A total of 185 blocks (5.2 kg) of rodenticide were taken from bait stations during the first seven months of 2004. 96.3% of the total bait deployed was consumed. Ten rats were caught in snap traps during the first seven months of 2004 with an average of five rats per monitoring trip (2 monitoring trips). The take of bait from this site has generally been high over the years and NRS are considering expanding the number of bait stations.

The northernmost site is significant because there are no known snails further north and the only snails known to the south are about an hour's hike along the trail. During a bait-restocking trip in June 2002 a total of six snails were counted and on 10 March 2003 seven were recorded. On 18 May 2004, three *A. livida* were found, along with two live *Euglandina rosea*. The most recent survey was performed on 21 July 2004 and a total of 10 *A. livida* were observed during a night survey. Figure 5-2 shows the number of snails found at the "Northern" site. NRS plan to visit the site bimonthly in the coming year.

Figure 5-2 Snail Surveys For "Northern" Site



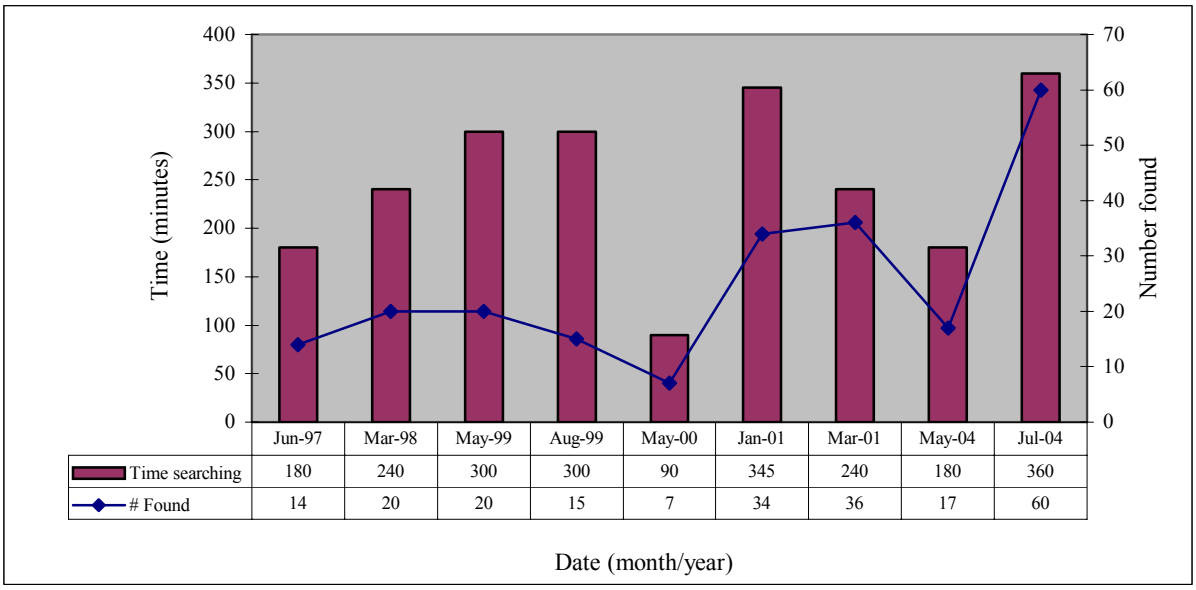
The "Crispa Rock" site supports a vibrant population found in an area where there are otherwise only scattered individual snails.

On 10 August 1999, staff visited these sites with Dr. Hadfield and his associates: Chela Zabin, Kevin Olival, and Dr. Brenden Holland. Dr. Holland was doing genetic research on the different *Achatinella* species and took samples from four sites along the Summit Trail back to the University of Hawai`i to analyze. This genetic research will help clarify relationships between and within species. Initial data indicates that *A. livida* and *A. sowerbyana* are closely related and their low genetic diversity suggests a relatively recent evolutionary separation.

In order to control rats at the Crispa Rock site the number of bait stations has increased from an original of two stations when baiting started 5 years ago to six stations at present. The number of snap traps was increased from six to 12 in 2004. A total of 180 blocks (5.1kg) of rodenticide were taken from bait stations during the first seven months of 2004. The bait consumed was 93.8% of the total bait put into the bait stations. Eleven rats were caught in snap traps during the first seven months of 2004 with an average of 5.5 rats per monitoring visit (2 monitoring trips). NRS recorded high rates of bait take over the years and will continue monitoring to determine whether or not more stations need to be added. Restocking here has also been increased from quarterly to twice a quarter.

On 18 May 2004, a total of seventeen snails were marked at this site. When NRS returned on 21 July 2004 only six marked snails were positively identified. Other unmarked snails were found in the marked trees but it is likely that the water resistant acrylic paint used was not readable after two months of Ko`olau weather. A total of 36 snails were counted in the ten marked trees and another 24 snails in neighboring vegetation. This total of 60 snails is the largest number recorded at this site (Fig. 5-3).

Figure 5-3 Snail Surveys For "Crispa Rock" Site



	Jun-97	Mar-98	May-99	Aug-99	May-00	Jan-01	Mar-01	May-04	Jul-04
Time searching	180	240	300	300	90	345	240	180	360
# Found	14	20	20	15	7	34	36	17	60

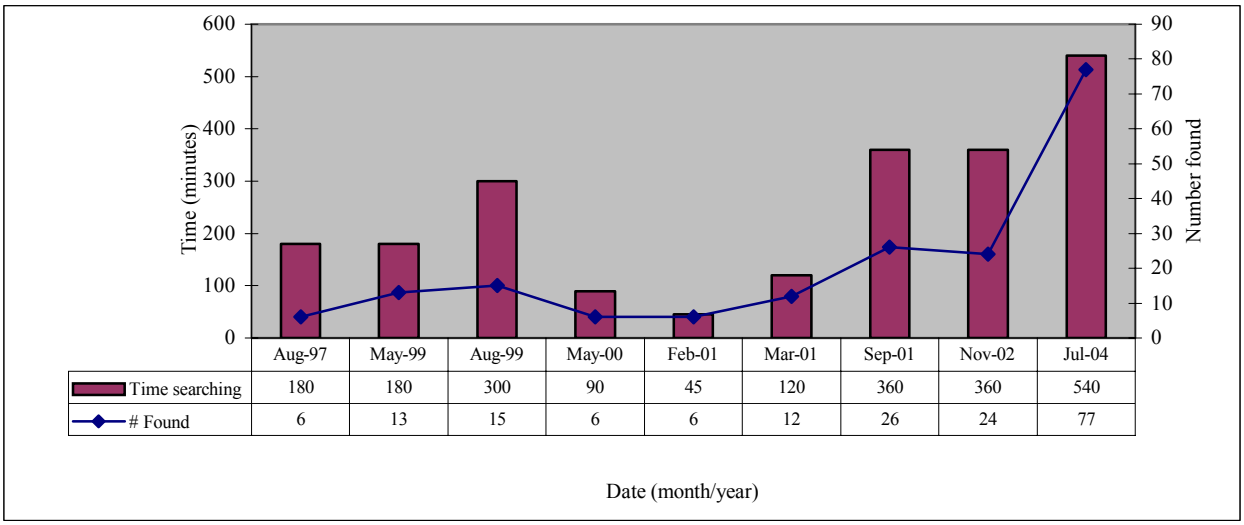
The "Radio LZ" site is another one of Dr. Hadfield's old study sites and it is now monitored six times per year. Samples were collected from this site during the snail sample collection surveys of August 1999. This location is an isolated pocket of snails. Searches of the surrounding areas have found no new snails. The bait stations at this site were increased from two to four in 2001, and for better coverage in 2003 the total was increased to six. Snap traps were increased from six to 12 in 2004. A total of 175 blocks (5.0kg) of rodenticide were taken from bait stations during the first seven months of 2004. Total bait consumed was 92.1% of the total bait put into the bait stations. An average of 3.5 rats were caught per monitoring visit (2 monitoring visits) during the first seven months of 2004. If the bait continues to be taken at the present rate, NRS will consider adding more bait stations.

During the most recent surveys on 20 July 2004 a total of 77 snails were counted (Fig. 5-4). This is the largest number of snails observed at this site and this increase may be attributed to utilizing a night search as part of the survey.

Dr. Daniel Chung believes that the snails referred to in this report as *A. livida* are actually *A. sowerbyana* and that *A. livida* was a lower elevation snail that may possibly be extinct.

There are 72 *A. livida* at Dr. Hadfield's lab at UH.

Figure 5-4 Snail Surveys For "Radio LZ"



5.5.g *Achatinella mustelina*

5.5.g.1 *Achatinella mustelina* MIP requirements

The Final Mākua Implementation Plan 2003 (MIP) contains a stabilization plan for *A. mustelina*. The strategy for management outlined in this stabilization plan was based on unpublished genetics studies that were underway at the University of Hawai`i (Holland and Hadfield 2003). Since the Implementation Plan was finalized, these genetic studies were published (Holland and Hadfield 2002). The final results in this publication differ from the unpublished results used to build the stabilization plan for *A. mustelina*. Both studies are based on the concept of Evolutionarily Significant Units or ESUs. Each ESU is considered a genetically distinct group. In order to reach stability for *A. mustelina* the Army needs to ensure that threats at each of these ESUs are managed. In the unpublished paper, eight ESUs were identified but in the published paper there were only six. This discrepancy was discussed at a snail subcommittee meeting of the Mākua Implementation Team on 12 May 2004 and the group was in agreement that the published paper should be the basis for the stabilization plan. This means that the Army's requirement is to manage the six ESUs identified in Holland 2002. The Army will still manage two sites within the geographically large ESUs (ESU B and ESU D) as stated in the final stabilization plan for *A. mustelina* in order to represent the extreme ends of the ranges for these ESUs. The revised stabilization plan for *A. mustelina* reflecting ESU changes is below.

5.5.g.2 *Achatinella* Stabilization Plan Summary

Long Term Goals:

- Manage snail populations at 8 field locations to encompass the extant range of the species and to include all 6 genetically defined evolutionarily significant units (ESUs).
- Achieve at least 300 snails per population.
- Maintain captive populations for each of the 6 recognized ESUs.
- Control all threats at each managed field location.

Table 5.1 Field Sites for Stabilization Efforts

New ESU	Old ESU	Site No.	Location	# of Snails	Final Mākua IP Year 1 Recommended Actions	Revised Year 1 Recommended Actions
A	A	1	Kahanahāiki	55	Manage for stability (choose between Kahanahāiki and Pahole)	Manage for stability (together with Pahole)
A	A	2	Pahole	50+	Manage for stability (choose between Kahanahāiki and Pahole)	Manage for stability (together with Kahanahāiki)
A	A	3	Kapuna	~25	None	None
B	B	4	`Ōhikilolo	300+	Manage for stability; Collect for captive propagation	Manage for stability
B	B	5	Central Makaleha (culvert 39)	81	Select one of 3 candidate sites for management (site # 5, 6 or 7)	None
B	B	6	East Makaleha (culvert 45)	29	Select one of 3 candidate sites for management (site # 5, 6 or 7)	None
B	B	7	East Makaleha (culvert 67)	40	Select one of 3 candidate sites for management (site # 5, 6 or 7)	None
B	N/A	N/A	East Makaleha (culvert 69)	83	None	Manage for stability
C	C	8	Schofield West Range/ Hale`au`au	18	Manage for stability; Collect for captive propagation	Manage for stability
C	D	9	Alaiheihe	25	Survey; Collect for captive propagation	None
C	E	10	Palikea Gulch	7	Survey; Collect for captive propagation	None
C	N/A		Manuwai Gulch	?	None	Survey for substantial population for management. If found abandon Hale`au`au.
D	F	11	Wai`anae Kai (2 sites)	12	Survey for manageable population	None
D	F	12	Wai`anae Kai	20	Survey for manageable population	None
D	F	14	Pu`u Hāpapa	36	None	None
D	F	15	Schofield South Range	32	Select one of 2 candidate sites for management (site # 15 or 16)	None
D	F	16	Kalua`a and Wai`eli	50	Survey for manageable population; Select one of 2 candidate sites for management (site # 15 or 16)	Manage for stability
D	N/A	19	Mākaha	17	Determine management after genetics analysis is completed	Manage for stability

New ESU	Old ESU	Site No.	Location	# of Snails	Final Mākua IP Year 1 Recommended Actions	Revised Year 1 Recommended Actions
D	N/A	20	Mohiākea	10+	Determine management after genetics analysis is completed	None
D	N/A	21	Pu`u Kūmakali`i	~20	None	None
D	N/A	22	Central and North Kalua`a	5 (seen incidentally)	Determine management after genetics analysis is completed	None
E	G	17	Pu`u Kaua (`Ēkahanui)	12	Survey for manageable population; Collect for captive propagation	Manage for stability
E	N/A	23	Huliwai	30+	Determine management after genetics analysis is completed	None
F	H	18	Pu`u Palikea	~40	Manage for stability; Collect for captive propagation	Manage for stability

5.5.g.3 Captive Propagation

One of the requirements outlined in the MIP stabilization plan is to represent in captive propagation snails from each of the six ESUs and from the two extra sites in ESU-B and ESU-D. All but one site is represented and the snails are prospering at Dr. Hadfield's laboratory at the University of Hawai`i. Detailed snail captive propagation data are included in Attachment 1. In reviewing these data it appears that eight lab populations from 7 field sites that are designated as manage for stability are still growing in the laboratory. Snails should be collected from the East Branch of East Makaleha site since none have been taken into the laboratory yet. The MIP stabilization plan states that lab populations should be refreshed with wild stock if the lab population remains small or declines in numbers. In addition, it states that lab populations should be refreshed every two years and lab-reared snails rotated back out into the wild. NRS have concerns about the potential drain on the field population and the potential for lab borne pathogens to harm the wild population.

5.5.g.4 ESU Updates

5.5.g.4.a ESU A (Pahole to Kahanahāiki)

Table 5-2 Number of snails counted from ESU A

Pop Ref Code	No. Snails as of 8/04	Size Classes			Pigs/ Goats	Weeds	Rats	*Euglandina*
		Lg	Med	Sml				
MMR-A Kahanahāiki Exclosure	70	50	20		X	X	X	X
MMR-B Pahole Exclosure	39	39			X	X	X	X
MMR-C Maile Flats	157	117	32	8	X	X	X	X
TOTAL	**266**	**206**	**52**	**8**				

This table shows the number of snails, size classes, and threats to the snails in ESU A. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

Management for ESU A is well underway. This ESU encompasses a relatively flat forest area in the uppermost reaches of Kahanahāiki Valley. This area is dominated by *Acacia koa* and *Metrosideros polymorpha*. *Nestigis sandwicensis* is a common canopy tree in this area and is favored by *A. mustelina*. Two exclosures were constructed to protect snails from rats and *Euglandina rosea*. The numbers of snails in these exclosures from recent observations are shown above as MMR-A and MMR-B. MMR-C is the area between the two existing exclosures called "maile flats". *A. mustelina* from ESU-A are represented at the U.H. Tree Snail Laboratory.

5.5.g.4.a.1 MMR-A (Kahanahāiki Exclosure)

For a detailed description of the Kahanahāiki snail exclosure, see PCSU Report 2003. NRS continue to maintain and monitor the Kahanahāiki exclosure by re-stocking salt troughs, ensuring the electrical barrier is functioning and conducting rat control outside the exclosure. Rat control is conducted just outside the perimeter because rat damage on *N. sandwicensis* fruit has been observed inside the exclosure in past years. Bait is not placed within the exclosure because NRS do not want to provide any attractant that may encourage rats to cross the barrier. Rat control has been conducted since 2001 and a total of six bait station and 12 snap traps are deployed.

Table 5-3 Kahanahāiki Snail Enclosure Rat Information

Year	Rats Snapped	% Take	Bait Taken	Bait Available
2001	1			
2002	3	84%	404	479
2003	5	72%	647	896
2004	11	75%	533	706

The Kahanahāiki exclosure design has some flaws. The exclosure is not impenetrable to rats but does seem to be keeping out *Euglandina rosea*. The current design requires significant overstory clearing along the perimeter of the exclosure, which has created a drier environment within the exclosure. NRS have discovered *A. mustelina* in the salt trough of the snail exclosure; it is unclear if these snails were trying to enter or exit the exclosure. The electrical barrier is often not functioning properly because of rain or shorts in the system and requires monthly maintenance. NRS will investigate exclosure design modifications to address these issues before constructing any new exclosures.

NRS attempt to conduct an *A. mustelina* census each summer within the exclosure. This year a mark-recapture study was conducted inside the exclosure. On the 6 May 2004 survey, 68 snails were counted and marked. On the re-capture survey of 14 July 2004, 70 snails were counted, only 37 of which were observed to have marks from the original count. This potentially indicates a much larger number of snails in the exclosure than were counted, but because it is likely that the paint used to mark the snails wore off before the second count, further studies need to be done. At this time, NRS are only comfortable saying there are 70 snails in the exclosure.

5.5.g.4.a.2 PAH-A (Pahole Exclosure**)**

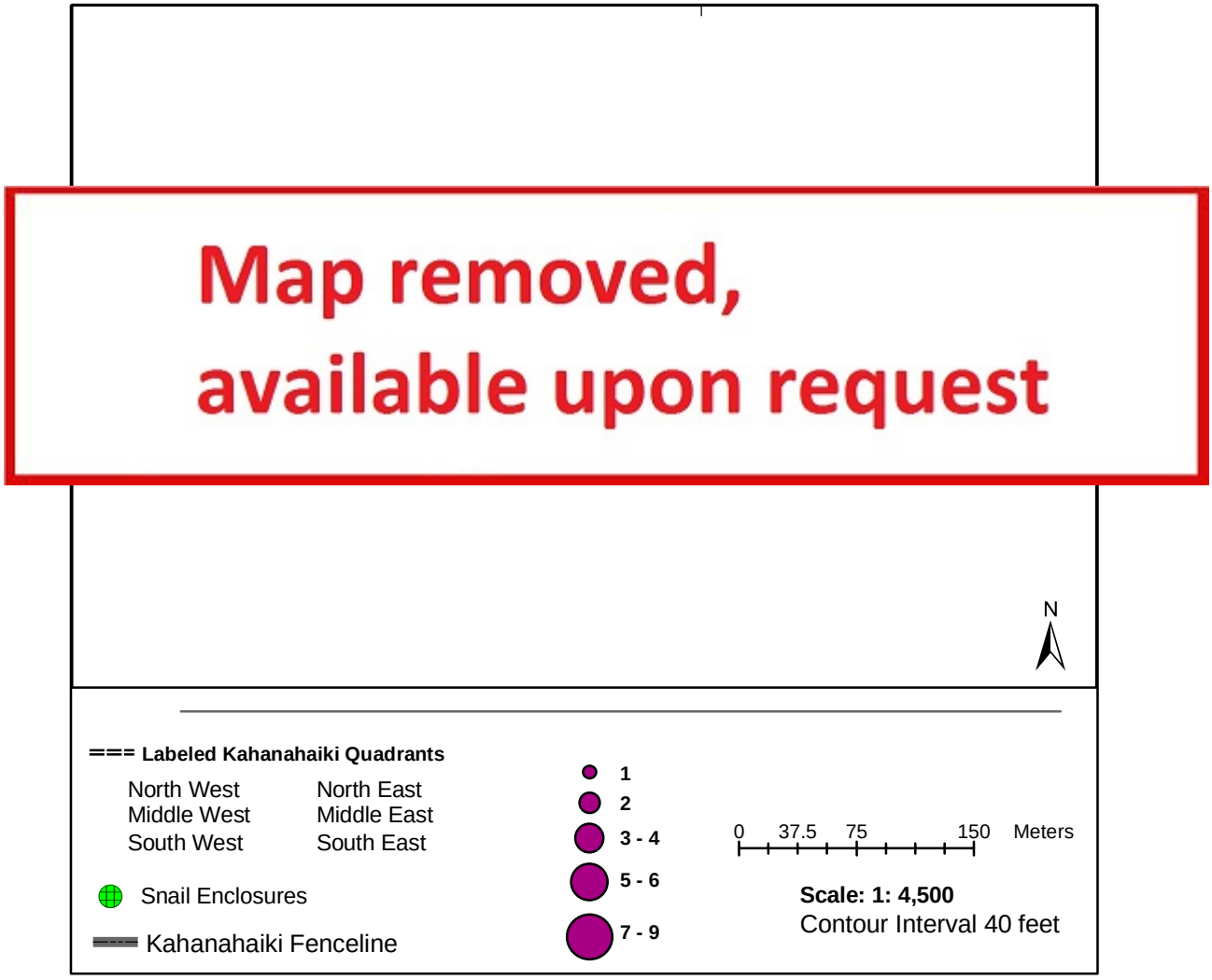
For a detailed description of the Pahole snail exclosure, see PCSU Report 2003. The Pahole snail exclosure is located on the Pahole side of the boundary between Mākua Military Reservation and the State of Hawai`i's Pahole Natural Area Reserve. This site protects what remains of the population, which University of Hawai`i researchers have been studying for over 20 years. On 27 May 2004, a total of 39 *A. mustelina* were counted. *Euglandina rosea* has penetrated the exclosure barriers in the past killing *A. mustelina*. Significant predation was documented and live *E. rosea* were found within the exclosure. Over the past year NRS have been assisting the State of Hawai`i with maintenance of this exclosure.

5.5.g.4.a.3 MMR-C (Maile Flats)

NRS conducted a thorough survey of the Maile Flats area this summer to determine if there are any large concentrations of snails outside the existing exclosures. NRS surveyed each of six quadrants that were installed for facilitating weed control efforts in the area. The results of this survey are described below and displayed spatially on the map (Figure 5.5).

A. mustelina is most dense in the area just outside the Kahanahāiki snail exclosure and to the south into the Southeast and Southwest quadrants. One hundred and thirty-three person hours were spent searching trees in the Maile Flats area for live *A. mustelina*. Another 8 hours were spent conducting ground searches for evidence of predation in order to determine what threat control is needed. No evidence of recent rat or *E. rosea* predation was observed. However, evidence of significant historical *E. rosea* predation was found, mainly within small, scattered patches of *Pisonia sandwicensis*. Over 50 old, empty *A. mustelina* shells of varying size classes and a number of old, empty *E. rosea* shells were found centered within these *P. sandwicensis* patches. Perhaps *A. mustelina* is easier for *E. rosea* to track within these patches because of the large leaf size of these plants. Or perhaps *A. mustelina* reached high densities on *Pisonia sandwicensis*. Further study of this unique situation could provide insight into *E. rosea* feeding strategy and may help in determining where *Achatinella* are most susceptible to predation.

Figure 5-5 ESU MMR C



One live *E. rosea* was exterminated in the Middlewest quadrant near the Kahanahāiki snail exclosure. There is some concern among NRS that rat control designed to take predatory pressure off *A. mustelina*, may also relieve pressure on *E. rosea* and at the same time may serve as an *E. rosea* attractant. Further investigation should be done to ensure that by trying to control one predator we are not inadvertently increasing the numbers of the other.

The results of this survey show that *A. mustelina* is still abundant in areas outside the MMR-A and PAH-A exclosures. NRS will continue to monitor the high-density areas within the Southeast, Southwest and Middlewest quadrants for evidence of predation. NRS will respond by installing a rat predator control grid if evidence of rat predation is observed. NRS recently made contact with a graduate student from the University of Hawai`i who is interested in studying *E. rosea*. We will encourage him to follow-up on the observations that were made while conducting these surveys and to develop control techniques for *E rosea* that may be implemented on a large-scale.

5.5.g.4.b ESU B1 (`Ōhikilolo)

ESU B is very large. Based on Holland's 2002 genetic studies it stretches from East Makaleha to `Ōhikilolo Ridge. Because of this large range, two sites have been chosen within the ESU for management. These two sites are at the extreme ends of the ESU perimeter; they are the East Branch of East Makaleha (B2) and `Ōhikilolo (B1). The habitat present at these two sites is very different. See 2.3.c. ESU B2 for a description of the E. Makaleha site. Most of the snails found on `Ōhikilolo ridge are located within the `Ōhikilolo Forest Patch. This forest area is dominated by *Acacia koa* and *Metrosideros polymorpha*. *Myrsine lessertiana* is also a common canopy tree on `Ōhikilolo and is favored by *A. mustelina*. *M. lessertiana* underwent a dieback 3-5 years ago and is still recovering. Other common native trees at `Ōhikilolo preferred by *A. mustelina* are *Melicope spp*. and *Freycinetia arborea*. The number of snails and threats at each of these sites are presented in the tables below. *A. mustelina* from ESU-B1 are represented at the U.H. Tree Snail Laboratory. Rat control on `Ōhikilolo has always shown a pattern of high rat bait take. This is mainly because we only visit the site once every three months via helicopter because of the remote nature of `Ōhikilolo. This high-take pattern should be considered when designing and expanding rat baiting grids in order to compensate for the long period of time between visits.

Table 5-4 Number of Counted Snails at `Ōhikilolo

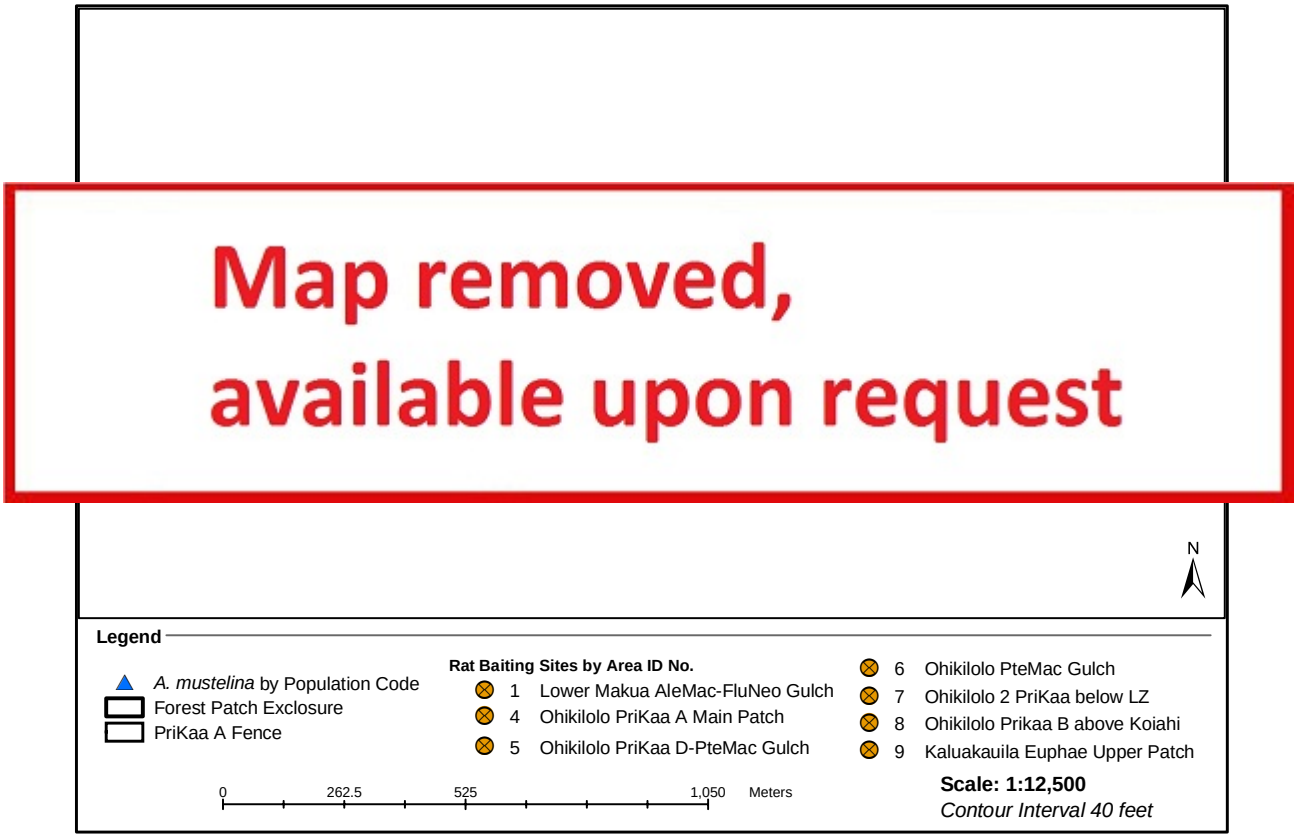
Pop Ref Code	No. Snails	Size Classes			Pigs/ Goats	Weeds	Rats	*Euglandina*
		Lg	Med	Sml				
MMR-E `Ōhikilolo Mauka	77	62	8	7	X	X	X	
MMR-F `Ōhikilolo Makai	210	166	22	22	X	X	X	
MMR-G Alemac Site	24	20	4		X	X	X	
MMR-H `Ōhikilolo Koi`ahi Prikaa Reintro Site	16	9	7		X	X	X	?
MMR-I Hedpar MMR-B	2	2			X	X	X	X
TOTAL	**329**	**259**	**41**	**29**				

This table shows the number of snails, size classes, and threats to the snails in ESU B1. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

5.5.g.4.b.1 MMR-E (`Ōhikilolo Mauka)

The `Ōhikilolo Mauka population encompasses the full area in the main forest patch "mauka" of the landing zone. NRS have been observing significant rat predation at this site since 1995 and began controlling rats in 1999. The rat control currently being conducted is centered on a high-density snail area and the rare plant *Pteralyxia macrocarpa*. There are a total of six bait stations in this area. *E. rosea* has never been observed at this site. Extensive surveys were conducted in August of 2004 and many snails were discovered outside the existing grid. NRS will continue to monitor for evidence of rat predation and will expand rat baiting based on the August 2004 data. Currently this site is protected from pigs because of the steep cliffs that surround the site. Goats within Mākua have almost been completely removed. Goat numbers are very low and remaining herds reside in other parts of the valley. No evidence of goat browse has been observed in the last two years. Weed control at this site is extensive and on-going.

Figure 5-6 ESU B1



5.5.g.4.b.2 MMR-F (`Ōhikilolo Makai)

The `Ōhikilolo Makai site consists of the main forest patch "makai" of the landing zone. The core of the *A. mustelina* population on `Ōhikilolo ridge is located here. NRS have observed significant rat damage to *Prichardia kaalae* fruit near `Ōhikilolo Makai snails and are currently baiting to protect this fruit year-round. Prior to this summer, no evidence of rat predation on snails had ever been observed at this site. Hence, rat control was never initiated at `Ōhikilolo Makai. However, comprehensive snail monitoring was conducted at `Ōhikilolo Makai this summer and eight rat-predated shells were observed at one site. All the predated shells were estimated to be between three and six years old. With this new information, NRS will reconsider the best rat control/monitoring approach for this site. No evidence of *Euglandina rosea* has ever been observed at this site. NRS will continue to monitor for *E. rosea* in `Ōhikilolo Makai. Care should be taken to ensure that all field gear that has the potential to transport *E. rosea* to the site is strictly inspected. This site is completely protected from ungulates by fencing. Extensive canopy and understory weed control efforts are underway.

5.5.g.4.b.3 MMR-G (*Alectryon macrococcus* Site)

MMR-G is located just below the `Ōhikilolo makai forest patch at the 2,700 ft. elevation. The endangered plant *Alectryon macrococcus* var. *macrococcus* is also located at this site and most

of the *A. mustelina* found were observed on these plants. NRS have not observed rat damage to *A. mustelina* at this site although NRS are certain that rats are present in the area. Neither has NRS observed *E. rosea* at this site. NRS will continue to monitor for any signs of predation. Currently this site is protected from pigs by the steep cliffs that surround the site. Threat from goats is minimal as there are few left in Mākua, and those left are found in other parts of the valley. Although some weed control has been conducted at this site, extensive weed control will be more difficult than at the Mauka and Makai sites because of the steep terrain and high density of weed cover.

5.5.g.4.b.4 MMR-H (`Ōhikilolo Koi`ahi *Pritchardia kaalae* Reintroduction Site)

MMR-H is located at 2200 ft., just below the junction of `Ōhikilolo and Koi`ahi ridges. This forest was dominated by *Myrsine lessertiana*, which experienced a large dieback over the last five years. NRS outplanted the endangered plant *Prichardia kaalae* into this site and have conducted weed control in combination with this effort. Observations indicate that *M. lessertiana* is making a comeback as numerous juveniles are now seen in areas previously dominated by this taxon. NRS have not observed rat damage to *A. mustelina* at this site although NRS are certain that rats are present in the area. NRS will conduct ground searches for *E. rosea* shells at this site in order to determine if it is present. Currently MMR-H is protected from pigs because of the steep cliffs that surround the site. The goats within Mākua have almost been completely removed and pose a very low threat to the site.

5.5.g.4.b.5 MMR-I (*Hedyotis parvula* MMR-B)

Only two individual *A. mustelina* have been observed at MMR-I, elevation 2,700 feet. They were found in tiny forest pockets on steep cliffs by NRS on rappel. The small forest pockets are dominated by *Metrosideros tremuloides*. This site does not have much management potential as this terrain is too steep to conduct meaningful management. In addition, *Schinus terebinthifolius* is abundant within most small forest pockets in this habitat type. Rats and *E. rosea* are both present at this site, but because of the terrain no ground searches have been conducted for predated shells. The *A. mustelina* habitat at this site has certainly benefited from goat control.

5.5.g.4.c ESU B2 (East Branch of East Makaleha)

Table 5-5 East Branch of East Makaleha

Pop Ref Code	No. Snails as of 6/04	Size Classes			Pigs/ Goats	Weeds	Rats	*Euglandina*
		Lg	Med	Sml				
LEH-C (culvert 69)	83	83			X		X	?
LEH-D (culvert 73)	19	10	3	6	X		X	?
TOTAL	**102**	**93**	**3**	**6**				

This table shows the number of snails, size classes, and threats to the snails in ESU B2. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

Figure 5-7 ESU B2

5.5.g.4.c.1 Culvert 69

Culvert 69 is off of the Mt. Ka`ala Access Road. The forest is fairly intact wet forest dominated by *Metrosideros polymorpha* and *Dicranopteris linearis*. *A. mustelina* is found along the crest of the ridge that starts at culvert 69. The ridge crest is moderately steep. It is narrow in most spots, being less than 10 meters wide. The ridge quickly becomes steep off both sides. Very few

weedy plant species are found along the section of ridge where *A. mustelina* is found, between 3,000 and 3,400 ft. Little effort has been spent looking for evidence of *E. rosea* and rat predation, but in the limited time spent no evidence was found. NRS will survey the eastern boundary ridge along the Dupont trail within this branch of East Makaleha to determine the presence and abundance of snails there. NRS will expand management of this area by first developing fencing plans. *A. mustelina* from ESU-B2 are represented at the U.H. Tree Snail Laboratory.

5.5.g.4.c.2 Culvert 73

Culvert 73 is off of the Mt. Ka`ala Access Road. The forest is fairly intact wet forest dominated by *Metrosideros polymorpha* and *Dicranopteris linearis*. *A. mustelina* is found along the crest of the ridge that starts at culvert 73. This ridge has similar characteristics as the ridge off of culvert 69. Very few weedy plant species are found along the section of ridge where *A. mustelina* is found, between 3,000 and 3,400 ft. Little effort has been spent in the area looking for evidence of *E. rosea* and rat predation, but in the limited time spent no evidence was found. Again NRS will place priority on developing fencing plans for this area and continue to survey to determine extent and abundance of *A. mustelina* in the area.

5.5.g.4.e ESU C

Table 5-6 Number of Counted in ESU C

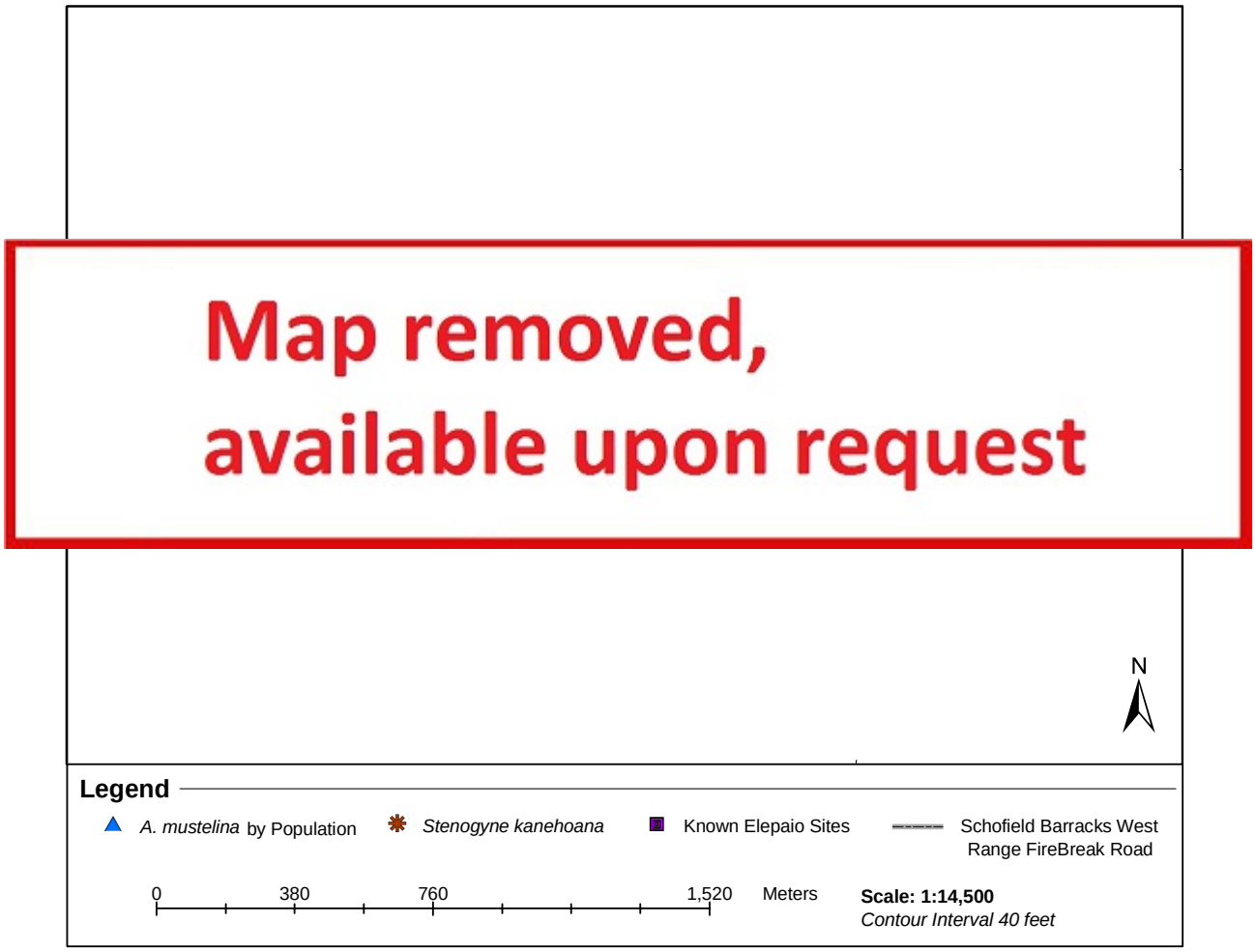
Pop Ref Code	**No. Snails as of 7/04**	**Size Classes**			**Pigs/ Goats**	**Weeds**	**Rats**	***Euglandina***
		Lg	**Med**	**Sml**				
SBW-A North Hale`au`au Hame Ridge	13	13			X	X	X	X
SBW-B North Hale`au`au one ridge north of Hame	7	7			X	X	X	X
SBW-C North Hale`au`au just above *Pouteria* pair territory	10	7	3		X	X	X	X
SBW-P Stekaa site	4	2	1	1	X	X	X	X
ANU-A Manuwai Gulch	1	1			X	X	X	X
TOTAL	**31**	**30**	**4**	**1**				

This table shows the number of snails, size classes, and threats to the snails in ESU C. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

Management for ESU C is challenging. The numbers of snails found at any one site within the ESU are few and the habitat quality is marginal. Access issues related to steep terrain and Schofield Barracks West Range compound these challenges. ESU-C was not managed prior to the MIP. Originally, the SBW-A, B and C sites were going to be combined into one site for management. Unfortunately, this site is difficult to access because of its location above the Schofield Barracks West Range (SBW) live-fire training area. At the May 2004 MIT snail subcommittee meeting a decision was made to survey the upper reaches of Manuwai gulch to

find a manageable population, as this area is already slated for large-scale fencing and unfortunately all appropriate habitat was surveyed and only one snail was found. Other proposals for management are discussed below. There are other sites in ESU-C not shown on the table above that could be revisited, considering current management challenges. *A. mustelina* from ESU-C are represented at the UH Tree Snail Laboratory.

Figure 5-8 ESU C



5.5.g.4.e.1 Schofield Barracks West Range-A, B, C, and P

These four sites will be discussed collectively because their situations are similar and related. All of these sites are located in North Hale`au`au gulch between 2,500 and 2,600 ft in elevation. The habitat is infested with pigs. This area is off-limits to hunters, therefore the pig population grows un-checked. There are no fences installed here. The high pig numbers facilitate the spread of *Psidium cattleianum*, which is a dominant canopy tree in the area. Native forest areas have a very tall canopy in Hale`au`au, which is dominated by *Metrosideros polymorpha*. The subcanopy is composed of *Antidesma platyphyllum*, *Melicope spp*., *Cheirodendron platyphyllum* and *Elaeocarpus bifidus*. This area was proposed for management because the terrain is

relatively flat in portions of this ESU and suitable for constructing snail exclosures similar to those in ESU-A. Since these exclosures require intense maintenance, Hale`au`au may not be suitable because of access restrictions. This being said, if management of *A. mustelina* overlapped with management of other species in SBW, then adequate access may be possible to obtain. The O`ahu Biological Opinion (O`ahu BO) mandates that two species must be managed within SBW, *Stenogyne kanehoana* and O`ahu `Elepaio. In this last year, one new *A. mustelina* site was discovered in the south fork of Hale`au`au in a spot where the other two O`ahu BO taxa are present. This is referred to in the table above as SBW-P. If substantial numbers of *A. mustelina* are found at the SBW-P site, rat baiting could be conducted in conjunction with O`ahu `Elepaio predator control and a fence could be constructed to protect all three species together. Additional surveys in the vicinity of the *S. kanehoana* in South Hale`au`au for *A. mustelina* are recommended. If substantial numbers of *A. mustelina* are found, NRS will collect genetic material so an ESU determination can be made.

5.5.g.4.e.2 ANU-A (Manuwai)

Manuwai is one of the gulches in Lower Mt. Ka`ala Natural Area Reserve (NAR). Lower Mt. Ka`ala NAR as a whole is characterized by very steep-walled gulches, which limit management options. There are plans for a fence in Manuwai in order to protect some rare plant populations found there. NRS theorized that *A. mustelina* could be managed in combination with these plants in one large fenced unit, however, based on the poor numbers of snails discovered during the survey conducted this year, NRS are re-evaluating again where and how to conduct management for *A. mustelina* in ESU-C. Therefore, the lone snail was not sampled to determine its ESU status. Other sites in Lower Mt. Ka`ala NAR are available for management. Surveys will be conducted in other gulches within this portion of ESU-C in order to determine if there are populations located in moderate terrain, within a healthy native forest and in areas that overlap with other species the Army must manage.

5.5.g.4.f ESU-D1 North Kalua`a and Pu`u Hāpapa

Table 5-7 Number of snail in ESU D1

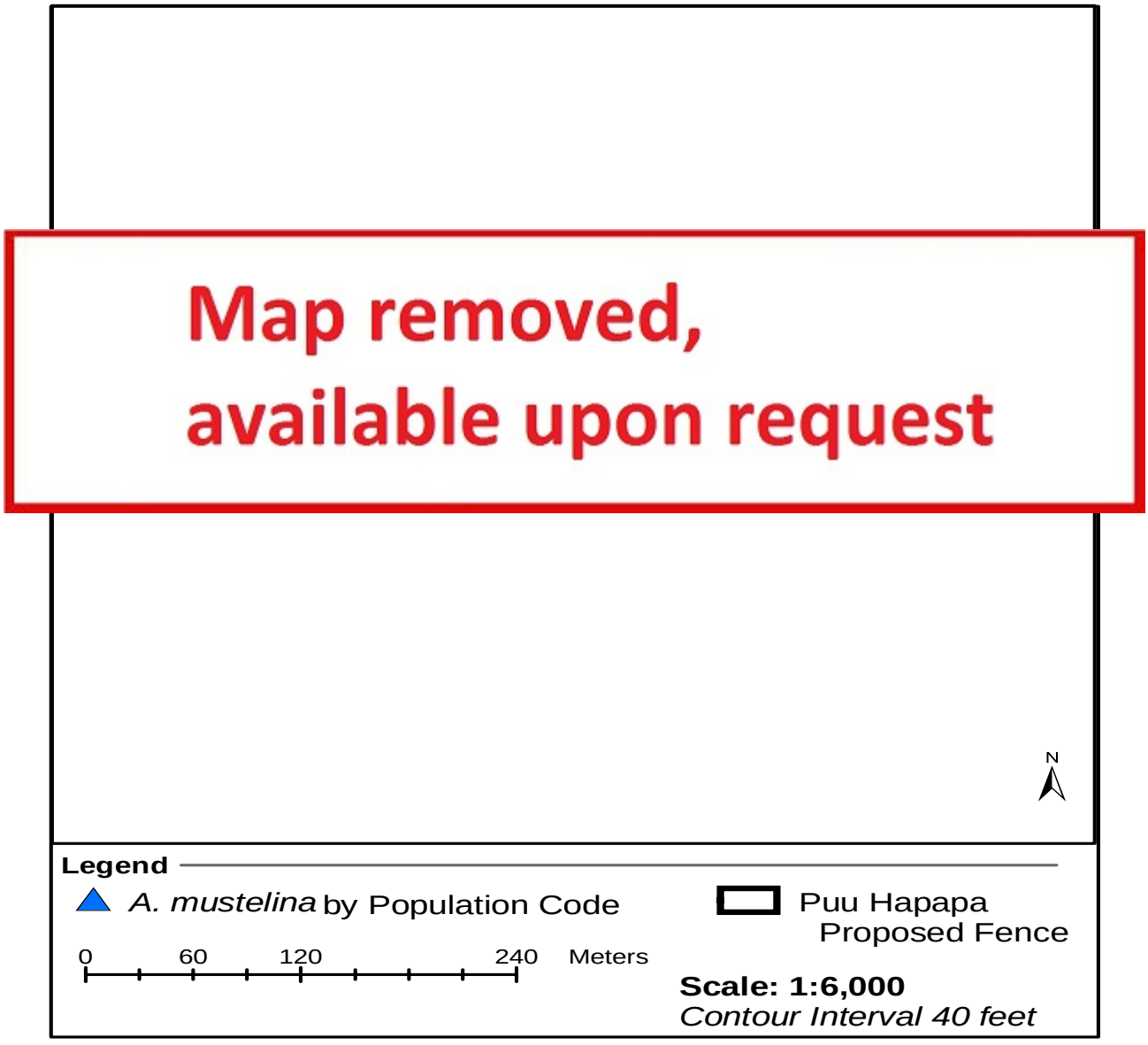
Pop Ref Code	No. Snails as of 8/04	Size Classes			Pigs/ Goats	Weeds	Rats	*Euglandina*
		Lg	Med	Sml				
KAL-A Kalua`a and Wai`eli	481	158	237	86	X	X	X	X
SBS-B Pu'u Hāpapa	196	131	44	21	X	X	X	X
TOTAL	**677**	**289**	**281**	**107**				

This table shows the number of snails, size classes, and threats to the snails in ESU D1. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

ESU D encompasses a large geographic area. For management purposes it has been split into two portions. D1 includes Pu`u Hāpapa and Kalua`a, and D2 includes Mākaha. Management for ESU D1 is promising. The numbers of snails found at both sites is substantial and habitat quality is good. The two sites are continuous and encompass most of the Pu`u Hāpapa summit. Rat baiting is already being conducted at both sites and plans are being developed to protect the ESU from pigs. Weed control is also conducted at both sites. The native species in this ESU

preferred by *A. mustelina* include *Freycinetia arborea* and *Myrsine lessertiana*. The native forest canopy is primarily *Metrosideros polymorpha*. Slow growing *Freycinetia arborea* is extremely susceptible to pig damage as it grows low to the ground. ESU D1 was managed prior to the MIP and the number of snails in the area reflects this. *A. mustelina* from ESU-D1 are represented at the UH Tree Snail Laboratory.

Figure 5-9 ESU D1



5.5.g.4.f.1 KAL-A, Kalua`a and Wai`eli (Land of 10,000 Snails)

NRS and TNC conducted a joint survey of this site. The total reflected in the table above is the result and shows that this site is one of the most robust in the Wai`anae Mountains. The Nature Conservancy (TNC) has been working here for the last three years, as it is located within the

Honouliuli Preserve. They have been administering rat bait to protect snails from rat predation and have been controlling pig populations in the area. TNC stocks 16 bait boxes each month and checks five snap traps near the core of the population. This year the Army funded a full-time field position to work on species covered in Army consultations located on Honouliuli Preserve. This staff person has been assisting with the rat baiting and ungulate control efforts at the Kalua`a and Wai`eli *A. mustelina* site. TNC applied for grant money to obtain fence materials to construct a fence to protect this site. NRS will assist TNC with this fencing effort. NRS will work with TNC staff to cooperatively maintain the rat bait stations and expand the rat-baiting grid if necessary.

5.5.g.4.f.2 Schofield Barracks South Range-B Pu`u Hāpapa

North Wai`eli gulch is situated within Schofield Barracks South Range (SBS). A portion of Pu`u Hāpapa, which is the peak at the top of Wai`eli gulch, is also a part of SBS. This portion of Pu`u Hāpapa is referred to as SBS-B. NRS have been controlling rats using diphacinone bait atop Pu`u Hāpapa since 2000. This year a total of 172 bait blocks were administered in 8 stations. Rat control is also intended to protect two other species of native snails that are found amongst *A. mustelina*. These taxa are *Laminella sanguinea* and *Amastra micans*. On a recent survey to Pu`u Hāpapa NRS counted 196 *A. mustelina* in an area less than 10 acres in size. This portion of Pu`u Hāpapa is very steep, which renders management efforts challenging. For safety, NRS work while on rappel in some areas. Nonetheless, NRS would like to expand the fencing project planned for KAL-A to include as much of SBS-B as possible. Weed control is underway at Pu`u Hāpapa and should directly improve the quality of habitat for *A. mustelina* in the area.

5.5.g.4.g ESU-D2 Mākaha

Table 5-8 Snail numbers for ESU D2

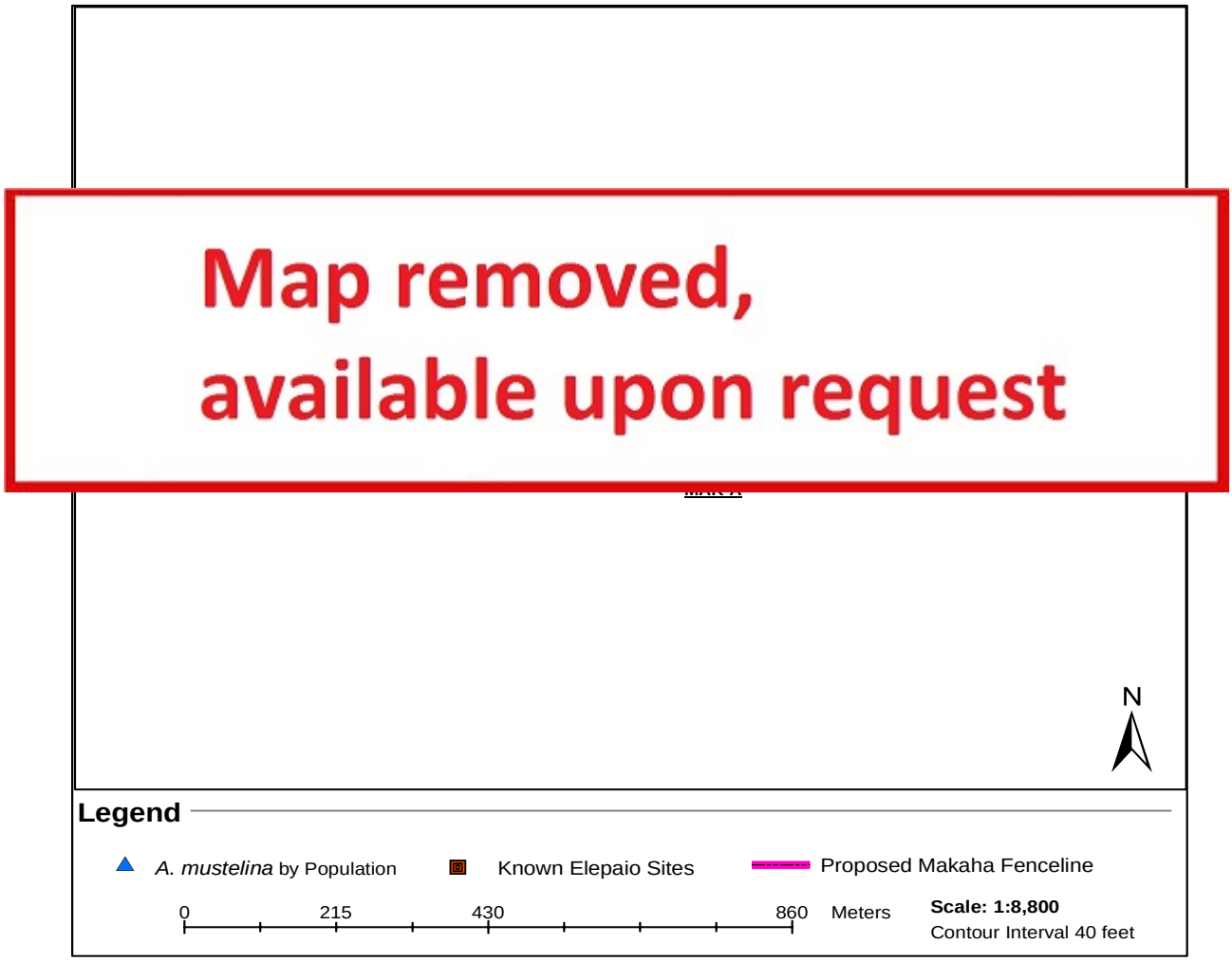
Pop Ref Code	No. Snails as of 7/04	Size Classes			Pigs/ Goats	Weeds	Rats	*Euglandina*
		Lg	Med	Sml				
MAK-A (Isolau ridge)	53	53			X	X	X	X
MAK-B (Kumaipo ridge crest)	4	3	1		X	X	X	X
TOTAL	**57**	**56**	**1**					

This table shows the number of snails, size classes, and threats to the snails in ESU D2. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

Management of ESU D2 has been limited thus far. Comprehensive surveys have yet to be conducted in Mākaha. In the lower elevation gulches within Mākaha (MAK-A), the native canopy is a mix of *Diospyros spp*., *Antidesma platyphyllum*, *Nestigis sandwicensis* and *Pisonia spp*. The forest canopy near the Kumaipo ridge crest (MAK-B) is dominated by *Acacia koa* and *Metrosideros polymorpha*. The numbers of snails at MAK-A is an old number and needs to be updated. The MAK-B number represents an incidental observation made along a portion of the proposed fence line near the Kumaipo ridge crest. NRS need to conduct methodical surveys to identify hot spots, look for evidence of predation and develop management plans. At this point, most of the staff time spent in Mākaha has been planning a large-scale fence project. MAK-A and MAK-B are both located within the proposed fence project. Ungulates are currently having a

significant negative impact on the forest within Mākaha. NRS have determined the best fence route, flagged the line, determined where strategic fencing is necessary and put together supporting paperwork for the project. The fence will protect 100 acres of mesic forest, most of which is suitable habitat for *A. mustelina*. The fence construction has been funded this year and construction is expected to begin in late Fiscal year 2005. Extensive weed control is required in order to improve the condition of this forest area. The most abundant canopy weeds are *Psidium cattleianum* and *Schinus terebinthifolius*. The Board of Water Supply has yet to authorize the use of pesticides in Mākaha Valley but the issue is being considered. BWS conducts rat baiting between January and June, during the O`ahu `Elepaio nesting season. This rat control probably benefits the snails found within those `Elepaio territories, if there are any. *A. mustelina* from ESU-D2 are represented at the UH Tree Snail Laboratory.

Figure 5-10 ESU D2



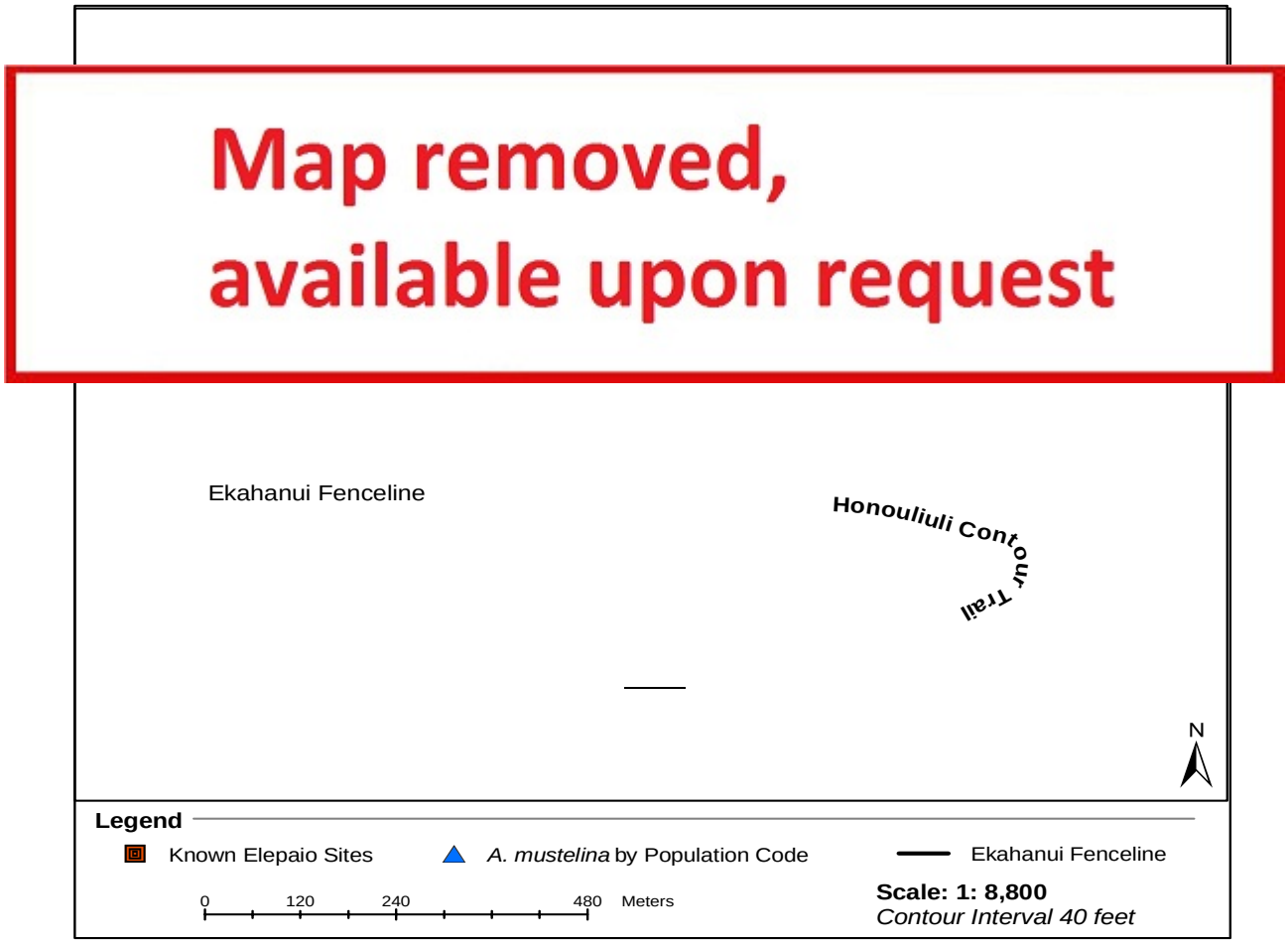
5.5.g.4.h ESU-E Pu`u Kaua/`Ēkahanui

Table 5-9 Number of snails in ESU E

Pop Ref Code	No. Snails as of ——	Size Classes			Pigs/ Goats	Weeds	Rats	*Euglandina*
		Lg	Med	Sml				
EKA-A (Pu`u Kaua)	51	51			X	X	X	X
EKA-B (Plapri site)	9	4	3	2	X	X	X	X
TOTAL	**60**	**55**	**3**	**2**				

This table shows the number of snails, size classes, and threats to the snails in ESU E. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

Figure 5-11 ESU E



Management for ESU E has been limited thus far. This ESU encompasses a few large concentrations of snails within the `Ēkahanui drainage and atop Pu`u Kaua. The Pu`u Kaua forest type is comprised mainly of wet forest species including *Metrosideros polymorpha*, *Metrosideros tremuloides*, *Melicope peduncularis*, and *Dicranopteris linearis*. Both EKA-A and EKA-B are situated in this type of ridge crest vegetation. The `Ēkahanui gulch area is a mix of alien and native forest patches. The native vegetation in areas within `Ēkahanui that have high

concentrations of *A. mustelina* consist of *Freycinetia arborea* and *Antidesma platyphyllum*. The management of this ESU has been limited so far as NRS are still getting oriented to the area. The Nature Conservancy is currently conducting rat control in the vicinity of an *Amastra spirazona* population. *Achatinella mustelina* do occur in the same habitat. Only two bait stations are currently deployed. In addition, rat control is conducted during the nesting season in the vicinity of `Elepaio and this baiting may benefit *A. mustelina* if there are snails nearby. NRS will assist TNC in these efforts. NRS should expand this grid based on comprehensive survey results. An ungulate exclosure that protects approximately 50 acres of forest already exists in the southern fork of `Ēkahanui, however, only part of EKA-A is located within this fence. The Army staff person working full-time with TNC is developing plans for additional fencing to protect the remaining portions of `Ēkahanui gulch. Ten snails were collected from the Pu`u Kaua site for captive propagation and are doing well at the UH Tree Snail Laboratory (see Attachment 1: Captive snail propagation data). Site KAL-B, located at a population of the endangered plant *Plantago princeps* needs further survey. A comprehensive *A. mustelina* survey should be conducted with knowledgeable TNC staff across `Ēkahanui in order to determine where the areas of highest density exist, look for evidence of predation and determine management needs.

5.5.g.4.i ESU-F Pu`u Palikea

Table 5-10 Numbers of Snails in ESU F

Pop Ref Code	No. Snails as of 8/04	Size Classes			Pigs/ Goats	Weeds	Rats	*Euglandina*
		Lg	Med	Sml				
PAK-A Pu`u Palikea `Ohia spot	9	5	2	2	X	X	X	X
PAK-B `Ie`ie Patch	13	11	1	1	X	X	X	X
PAK-C Steps spot	19	14	3	2	X	X	X	X
PAK-D Joel Lau's site	11	8	2	1	X	X	X	X
PAK-E Exogau site	6	4	1	1	X	X	X	X
PAK-F Dodonaea Site	5	3	2		X	X	X	X
PAK-G Hame and Alani site just above Cyagri fence	22	13	6	3	X	X	X	X
TOTAL	**85**	**58**	**17**	**10**				

This table shows the number of snails, size classes, and threats to the snails in ESU F. Shaded boxes indicate that the threat is being controlled, X's indicate that the threat is present. In some cases the threat may be present but not actively preying on *A. mustelina*.

Management conducted to protect ESU F has been limited thus far. Surveys to locate areas of high snail density were recently conducted in order to determine threats and plan management. The snails known from this ESU are scattered in distribution and are shown on the map below. At total of 85 snails were counted in the Pu`u Palikea vicinity during two days of survey. The habitat quality is good although introduced conifers dominate a large portion of the forest. The native forest in the area is dominated by *Metrosideros polymorpha*. The native plant species at Palikea that *A. mustelina* prefer as host trees include *Metrosideros polymorpha*, *Coprosma foliosa*, *Antidesma platyphyllum* and *Melicope o`ahuensis*. TNC and the Army constructed a fence that is approximately 2.5 acres in size in 1999 to protect an endangered plant, *Cyanea grimesiana* ssp. *obatae*. At this point there are no known *A. mustelina* found within this

exclosure but NRS have yet to survey the entire potential habitat within the fence. Weed control is conducted by TNC and the Army liaison to TNC within the exclosure perimeter on a regular basis. Of the 85 snails seen during the recent survey, only 11 were found at an outlier location to the north. Expanding the fence unit at Pu`u Palikea will protect habitat for the other 74 snails. NRS will make this a high priority action for this ESU. In addition some rat control is underway around the PAK-A, PAK-B and PAK-C snail locations and in the vicinity of the *Cyanea grimesiana* ssp. *obatae*. NRS will work with TNC to expand this predator control effort. *Achatinella concavospira* was also found during the recent survey and will benefit from any management in the Pu`u Palikea area. Snails collected from this ESU are represented at the UH Tree Snail Laboratory.

Figure 5-12 ESU F

▲ *A. mustelina* by Population Code ● *C. grimesiana* subsp. *grimesiana* ▭

0 80 160 320 Meters

Scale: 1: 5,500

Contour Interval 40 feet

5.5.h *Achatinella pulcherima*

Achatinella pulcherima was reported from two sites I KLOA; in 1974 from the Helemano drainage vicinity, and in 1993 from the `Ōpae`ula drainage. NRS have been unable to locate it. The areas where it was reported from 1993 are actually inside the `Ōpae`ula fence exclosure. Snails have been found here but have been classified as *A. sowerbyana*. Annual surveys will continue to be conducted between the Pe`ahināi`a and Poamoho Trails to search for individuals of this species. It is likely that *A. pulcherima* may already be extinct because it was known from lower elevations, where land snails have historically been extirpated. No surveys were conducted this year.

5.5.i *Achatinella sowerbyana*

Presently, this species is the most widespread of all the Ko`olau *Achatinella*. Historically it was found throughout KLOA, but today is found mostly in the Ko`olau Summit region in the Pe`ahināi`a and Poamoho Trail areas. Next to *A. mustelina*, it is considered to be the most common *Achatinella* species on O`ahu.

NRS have flagged trees in the Pe`ahināi`a and Poamoho areas where these snails have been identified. Considering the poor state of Ko`olau *Achatinella* in general, *A. sowerbyana* is doing surprisingly well. Although *A. sowerbyana* is subject to all the same threats that other Ko`olau *Achatinella* species face, they continue to survive at lower elevations and in a diversity of microhabitats.

Biannual surveys will be conducted to look for signs of predation. Census counts will be continued annually. Three of the known sites are currently baited for rats: “Shaka,” “290” and “Poamoho”. An emergency predator control plan will be developed in case rat predation is found at other sites. NRS recommend that further genetic studies be done to help distinguish between the species and determine management strategies. The table below details information pertinent to these three sites.

Table 5-11 Snail Sites With Rat Bait Stations in the Ko`olaus

Site Name	# bait stations	# snap traps	% bait take 2002	% bait take 2003	% bait take 2004
"Shaka"	6	6	52	47	72
"290"	6	12	23	69	59
"Poamoho"	8	8	site not baited	set up on 8/19/03	93

Predator control was begun at Poamoho after a NRS survey of some of Dr. Hadfield’s old study sites along the summit. On 25 September 2000 Dr. Hadfield escorted NRS to sites in the vicinity of the Poamoho Cabin. NRS had not surveyed these areas before. At the site south of the Poamoho Trail monument, at 2,450 ft elevation, a total of 17 *A. sowerbyana* were found. Only six *A.* sowerbyana were found here in March 2003. At the site just north of the Poamoho Trail junction a total of 64 *A. sowerbyana* were counted. A total of 41 were counted on the March 2003 survey and most of these were found in areas that extended the boundaries of the previous survey area. In response to these survey results, NRS set up eight rat bait stations at the northern site on 19 August 2003.

The `Ōpae`ula Watershed Project constructed a fence exclosure in the Pe`ahināi`a/Summit area in 2001. During the October 2002 survey, a total of 14 *A. sowerbyana* were counted above the hypalon stream crossing area of the exclosure. A total of six *A. sowerbyana* have been identified while surveying for the Helemano Watershed Project. Because of the weather conditions, terrain and thick vegetation in the Ko`olaus, it is often difficult to find evidence of rat-eaten snail shells. It is easier to prove the presence of rats and then discuss how best to implement a predator control program. NRS have not set up predator control at these sites.

A. sowerbyana have been seen during the most recent trips to the upper Poamoho Trail region for weed control. A total of 23 snails were counted on the February 2002 trip and 104 were recorded in February 2003 along the Poamoho Trail.

There are 41 *A. sowerbyana* in the lab at UH.

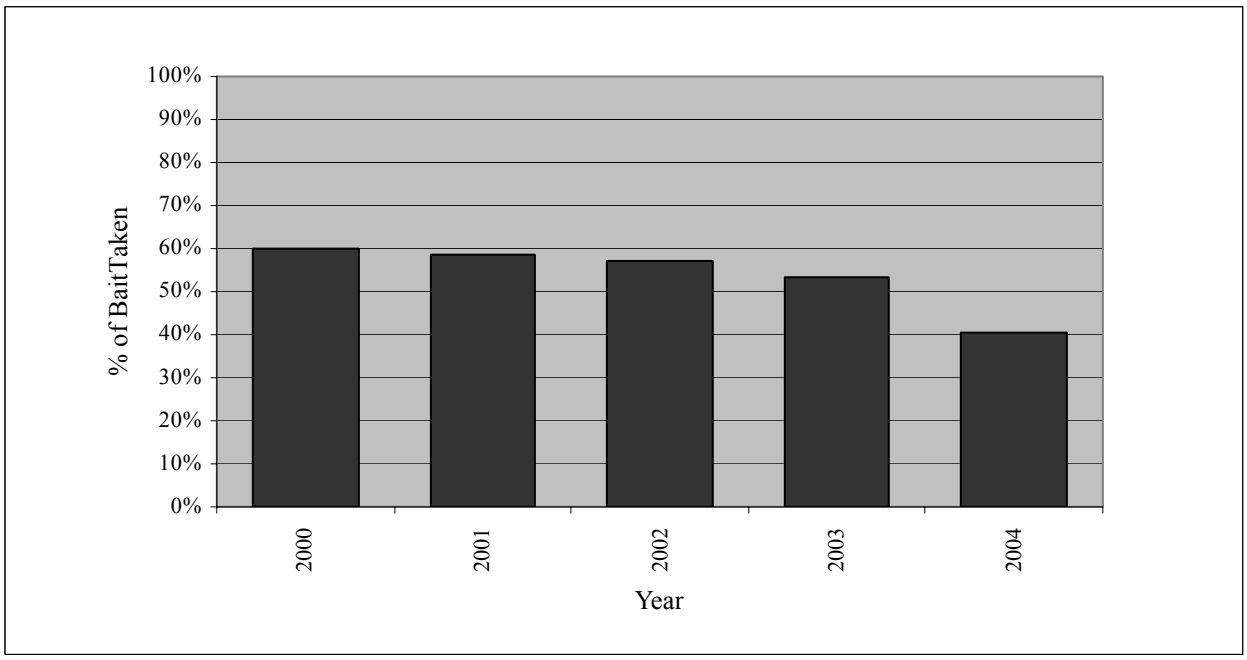
5.5.j *Amastra micans*

The amastrid land snails, a family of pulmonate gastropods endemic to the Hawaiian Islands, have been little investigated in recent years, and their biology is poorly known. Most biologists have largely ignored *Amastrids*, and this, along with their increasing rarity in the last few decades, has been responsible for their absence in the biological and conservation literature. Many shells of *Amastra* can be found in SBMR but it is very difficult to find any live specimens.

In SBS there are two areas of importance for *Amastrids*: the Pu`u Hāpapa area at 2500 ft. and the site below at 2300 ft. The upper area has eight rat bait stations and is considered too steep to fence. The lower area has six rat bait stations and was fenced in October 2003. NRS have concentrated weed control efforts to the area inside this exclosure. Long-range plans involve out-planting native plants and working to restore the habitat. So far, the fence has eliminated pig damage and demonstrated how fences can be important tools in protecting snail habitat. During the past three years no live *A. micans* have been observed although searching has not been extensive. NRS camped on Pu`u Hāpapa on 6-7 July 2004 and searched the area for *A. micans* but were unable to locate any in the vegetation or leaf litter.

Figure 5-13 below shows the four-year trend in diphacinone take from the eight bait stations on Pu`u Hāpapa.

Figure 5-13 SBS Pu`u Hāpapa Snail Population Rat Control 2000-2004

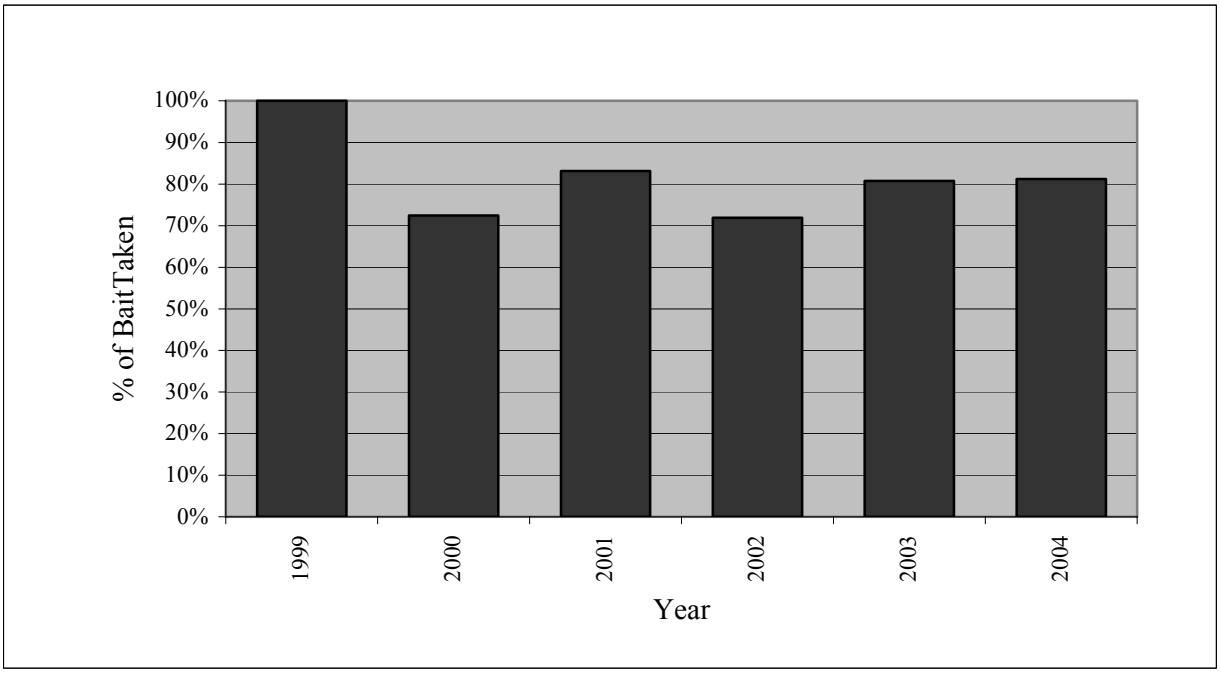


5.5.k *Laminella sanguinea*

L. sanguinea has also been found at the *A. micans* sites in SBS mentioned above. On 15 May 2003 a total of three *L. sanguinea* were counted in an area near the rat bait stations on Pu`u Hāpapa where they had never been seen before. In October 2002 a total of seven *L. sanguinea* were counted. On 31 July 2002 NRS visited the area with two staff from The Nature Conservancy of Hawai`i (TNCH). Pu`u Hāpapa forms the boundary between Army land to the north and Honouliuli Preserve (TNCH) to the south. On this day a total of five *L. sanguinea* were again seen here. The two agencies share similar natural resources as well as management challenges and often collaborate to solve problems together. There are proposals to work together on future fence projects in this area that would help to exclude pigs from rare snail habitat.

NRS camped on Pu`u Hāpapa 6-7 July 2004 and surveyed for snails. A total of 23 *L. sanguinea* were counted and all of these were found within the rat bait station grid. Figure 5-14 details the percent of rat bait take over the past five years in SBS.

Figure 5-14 SBS `Ie`ie Patch Snail Population Rat Control 1999-2004



5.6 Rare Snail Management Recommendations

The recent history of the native Hawaiian land snails shows that they are literally struggling for their existence and losing battles daily to the many threats opposing them. NRS will continue the following management:

- Marking and recapturing snails and collecting data to assist in management.
- Maintaining the Kahanahāiki snail enclosure as an area where native snails can live in a healthy environment free from the threats of rats and predatory snails and outplant native trees into the exclosure.
- Continuing to research and improve snail exclosure technology.
- Searching in areas of historic snail habitat with the expectation that if any critically rare snail is found, it will be given to the UH Snail Laboratory for captive rearing.
- Controlling predators while monitoring effectiveness.
- Supporting the licensing of a more effective tool to improve rat control in remote areas, such as aerial broadcast.
- Working with other agencies to develop long-range snail management strategies.

5.7 Rare Snail Monitoring and Management Schedule

This schedule is made to help NRS plan the continued searches for rare snails and the monitoring of known sites. Management actions to control threats will be determined as data is collected and analyzed. For some of these snails there are no known populations in the wild. For these

snails an 'X' will identify the quarter in which NRS will plan to search for this species. For species having known populations, an 'X' next to the species will designate in which quarter new areas will be searched for more populations.

Table 5-12 Recommended Action Time Table

Range	MU	Action	Q4	Q1	Q2	Q3
MMR	Kahanahāiki	Achmus mark/recapture			X	
MMR	Kahanahāiki	Monitor Achmus site/check salt/caulk/check current and voltage	X	X	X	X
MMR	Kahanahāiki	Achmus rat control (bimonthly)	X	X	X	X
MMR	Kahanahāiki	Outplant Nessan		X		
KLOA	KLOA	*Achatinella apexfulva* search		X		
KLOA	KLOA	*Achatinella byronii* search				X
KLOA	KLOA	*Achatinella curta* search (Kawailoa Trail)	X			
KLOA	KLOA	*Achatinella leucorraphe* search			X	
KLOA	KLOA	*Achatinella lila* search	X		X	
KLOA	KLOA	*Achatinella livida* search		X		X
KLOA	KLOA	*Achatinella pulcherima* search		X		
KLOA	KLOA	*Achatinella sowerbyana* search		X		X
KLOA	KLOA	Achlil bimonthly rat control (Pe`ahināi`a LZ and "Poamoho")	X	X	X	X
KLOA	KLOA	Achliv mark/recapture		X		X
KLOA	KLOA	Achliv bimonthly rat control("Northern," "Crispa" and "Radio")	X	X	X	X
KLOA	KLOA	Achsow bimonthly rat control ("Shaka" and "290")	X	X	X	X
KLOA	KLOA	Monitor known Achbyr sites				X
KLOA	KLOA	Achbyr survey for *E. rosea* or rat predation		X		X
KLOA	KLOA	Monitor known Achliv sites		X		X
KLOA	KLOA	Monitor known Achsow sites		X		X
MMR	`Ōhikilolo	Achmus bimonthly rat control (Kahanahaiki snail enclosure and Pteralyxia Gulch)	X	X	X	X
MMR	`Ōhikilolo	Monitor known Achmus sites	X	X	X	X
MMR	`Ōhikilolo	Outplant Myrles		X		
SBMR	SBS	Amamic & Lamsan bimonthly rat control	X	X	X	X
SBMR	SBS	Monitor Amamic & Lamsan sites		X		X
SBMR	SBS	Construct Amamic fence		X		
SBMR	SBW	Survey for Amamic and Lamsan		X		X
		Develop monitoring techniques	X	X	X	X
	General	Evaluate predator control efficiency at all sites and respond accordingly	X		X	
	General	Snail Working Group meeting	X	X	X	X
	General	Toxicant Working Group		X		
		Elecoq support control efforts	X	X	X	X
		Meet to discuss site options for Megxan	X			

Range	MU	Action	Q4	Q1	Q2	Q3
		translocation				
		Tripler Damselfly monitoring		X		X
	Offsite	Land of 10,000 snails – bait, coordinate with TNC	X	X	X	X
	Offsite	Ekahanui survey – set up rat bait	X	X	X	X
		East Makaleha	X	X	X	X
		Manuwai survey			X	

5.8 Rare Damselfly Management

NRS have been searching for a suitable stream for a translocation of the native Orange-black damselflies (*Megalagrion xanthomelas*) from Tripler Army Medical Center (TAMC). Most streams on O`ahu contain alien fish that would negatively impact the damselflies, making it difficult to find appropriate habitat for such a project.

The USFWS received grant funding to continue monitoring the TAMC site and are working in conjunction with the Bishop Museum to locate another site for a translocation. The South Fork of Kaukonahua Stream above the Canon Dam was surveyed in September 2002 by Bishop Museum staff, USFWS, and NRS to see if it is free of alien fish and crayfish. It did not prove to be a suitable habitat for *Megalagrion xanthomelas* because Chinese catfish were found above the dam. The USFWS and the Bishop Museum staff continue to monitor the TAMC site and the population appears to be stable. In July 2004 Bishop Museum staff translocated *Megalagrion xanthomelas* adults and niads into Makiki Stream in Honolulu. NRS will coordinate with the Bishop Museum staff and follow-up on this translocation.

5.9 *Eleutherodactylus coquí* Management

This taxon is discussed in this section because it potentially threatens native invertebrates.

In April 2001, NRS was alerted to the presence of *E. coquí* on SBE. Both the U. S. Fish and Wildlife Service and DOA had become aware of the infestation in a residential area of Wahiawā. While following up on the reports, personnel noted that the frogs had crossed the fence onto military property in SBE. NRS then became involved in coquí control. Coquí feed in leaf litter in the daytime, and at night males crawl up into trees to perform mating calls. Mating season is in the summer, and hence, summer is the best time to conduct control. Female coquí may be able to store sperm for as long as six months.

In 2002, FWS hired an Invasive Species Technician to facilitate and perform coquí control on O`ahu, OISC designated the coquí frog as one of its primary targets, and researchers found that 16% citric acid effectively kills coquí upon contact. Armed with a new management tool and increased support, FWS, DOA, OISC, and NRS pooled resources to attack the infestation. FWS mapped the extent of the infestation: the population includes a gulch which stretches between SBE and private homeowners' backyards, houses bordering SBE, and a flat strip of land on SBE next to these houses. A management plan was developed involving monitoring trips and large

citric acid spray operations. The purpose of the monitoring trips was to hand capture frogs, spray frogs with backpack sprayers, census the frog population by observing numbers of calls, and track success of large spray efforts. NRS assisted with one monitoring trip in 9/2003. NRS primarily assisted with the large spray efforts and vegetation clearing done to facilitate the spray efforts. Large spray efforts occurred in 9/2003, 6/2004, and 7/2004.

Efforts have been relatively successful; however the coquí population is persistent, and the concerned agencies committed to spraying the entire infested area at least twice this year. NRS expect the same level of commitment next summer.

Attachment 1: Captive Snail Propagation Data

Species	Population	ESU	# *juv*	# *sub*	# *adult*	# Individuals
A. mustelina	10,000 snails	D1	*8*	*22*	*0*	**30**
	Ala'ihe'ihe Gulch	C	*14*	*4*	*4*	**22**
	Bornhorst		*1*	*1*	*1*	**3**
	Ekahanui - Hono'uli'uli	E	*24*	*2*	*3*	**29**
	Ka'ala S-ridge	B2	*23*	*0*	*6*	**29**
	Makaha	D2	*16*	*0*	*8*	**24**
	Ohikilolo - Makai	B1	*27*	*0*	*4*	**31**
	Ohikilolo - Mauka	B1	*20*	*5*	*0*	**25**
	Palehua	F	*3*	*0*	*4*	**8**
	Palikea Gulch	C	*20*	*1*	*8*	**29**
	Peacock Flats	A	*8*	*11*	*4*	**23**
	Recombined		*0*	*3*	*0*	**3**
	Schofield		*1*	*4*	*1*	**6**
	Schofield South Range	D2	*18*	*7*	*3*	**28**
	Schofield West Range	C	*15*	*1*	*9*	**25**
	TOTAL					**315**

Species	# *juv*	# *sub*	# *adult*	# Individuals
A. apexfulva	*3*	*7*	*1*	**11**
A. decipiens	*6*	*17*	*7*	**30**
A. fucsobasis	*165*	*60*	*112*	**362**
A. lila	*113*	*101*	*5*	**218**
A. livida	*35*	*31*	*6*	**72**
A. sowerbyana	*12*	*23*	*12*	**47**

Number of snails as of April, 2004

Attachment 2: Assessment of Genetic Variation among Populations of *Achatinella mustelina*: Results of DNA Sequence Analyses and Implications for Management Prioritization.

By Brendan Holland and Michael G. Hadfield

In order to investigate intra-specific genetic divergence among populations of *Achatinella mustelina* in the Wai`anae Mountains, we selected a relatively rapidly evolving target gene from the mitochondrial genome: cytochrome oxidase subunit I (COI). At this time, we have generated a data set for *A. mustelina* consisting of DNA sequences of 680 basepairs each, from three individuals, from each of 16 different Wai`anae Range populations. Tissue samples were obtained using a laboratory tested, non-lethal technique. During the course of this study, we found that the COI gene is ideally suited to the objectives of this project, and the resulting data set has proven highly informative. Results of DNA analysis show a high degree of interpopulation genetic structure. The pattern of genetic variation is strongly correlated with regional geographic features. The primary breaks in genetic variation occur across valleys and mountain summits. Genetic variation remains extremely low along relatively long geographic distances following ridge crests.

Data summary:

- Overall within-population mean genetic distance = **0.006 (*i.e.*,. 0.6%)**
- For 2 of 16 populations (12.5%), all three individuals characterized were genetically identical (100% sequence identity).
- For 3 of 16 populations (19%: 10, 11, and 12), or 3 individuals of the 48 characterized (0.6%), genetic divergence was relatively high, 1.2-3.0%. In each case the mean value was drastically increased by a single anomalous individual sequence, an indication of a relatively recent migration event. These three populations account for about half of the overall within population mean genetic distance. An alternative interpretation is that 19% of populations show evidence of interpopulation migration.

There is a strong geographic component to the overall pattern of genetic variation. Several unique haplotypes were identified, and several historical migratory events were detected. Reproductive barriers in the form of geographic features, principally valleys and the 1220 m peak of Mt. Kaala, rather than strict geographic distances, are correlated with the highest genetic distance values observed. The data reveal numerous instances where low genetic distances (*i.e.*, great genetic similarity), values at or below the mean within-population value, persist over relatively long geographic distances following ridge crests in roughly linear patterns (*e.g.*, Figure 1, ESU-F). There are two alternative interpretations of the observed geographic pattern of DNA sequence variation. One possible explanation is that observed genetic similarity along ridge crests indicates geologically recent dispersal and colonization events along these features. A more likely explanation is that the patterns of genetic similarity indicate that the distribution of forest coverage (tree-snail habitat) along ridge crests was previously continuous, allowing panmixia via tree-to-tree migration and gene flow, despite current fragmentation of suitable tree snail habitat.

Table 2.3 Pairwise Genetic Distance Matrix This table shows mean inter and intrapopulation molecular sequence divergence values and standard errors (SE) for 69 specimens from 18 populations of *Achatinella mustelina* sampled in the Wai`anae Mountains of O`ahu . Within population mean distances are underlined, shown along diagonal. Mean among population distances are below diagonal. SE values (above diagonal) were computed using the bootstrap method with 500 replicates and a random number seed. Values were determined based on partial COI sequences using a Kimura 2-parameter substitution model (Kumar *et al*. 2001). Populations comprising the eight distance-based ESUs are as follows: ESU A = 1 - 3; ESU B = 4 - 7; ESU C = 8; ESU D = 9; ESU E = 10; ESU F = 11 - 16; ESU G = 17; and ESU H = 18. Note that populations are arranged in roughly north-south, west-east fashion, from 1-18 (Fig. 1).

	ESU A			ESU B				ESU C	ESU D	ESU E	ESU F						ESU G	ESU H	
Pop	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
1	**0.000**	0.001	0.000	0.004	0.004	0.004	0.004	0.004	0.006	0.005	0.008	0.008	0.008	0.008	0.008	0.008	0.006	0.008	
2	0.001	**0.005**	0.001	0.004	0.004	0.004	0.004	0.004	0.006	0.005	0.008	0.008	0.008	0.007	0.008	0.007	0.006	0.008	
3	0.000	0.001	**0.005**	0.004	0.004	0.003	0.004	0.004	0.006	0.005	0.008	0.008	0.008	0.007	0.008	0.007	0.006	0.007	
4	0.011	0.011	0.010	**0.006**	0.001	0.001	0.002	0.005	0.007	0.005	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.008	
5	0.013	0.013	0.011	0.001	**0.003**	0.000	0.002	0.005	0.006	0.005	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.007	
6	0.010	0.011	0.009	0.000	0.001	**0.005**	0.001	0.005	0.007	0.005	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.008	
7	0.014	0.015	0.013	0.003	0.004	0.001	**0.002**	0.005	0.007	0.006	0.009	0.009	0.009	0.008	0.009	0.008	0.008	0.008	
8	0.020	0.021	0.018	0.021	0.019	0.021	0.024	**0.019**	0.000	0.000	0.006	0.005	0.006	0.005	0.005	0.005	0.005	0.006	
9	0.027	0.027	0.026	0.028	0.025	0.028	0.032	0.000	**0.008**	0.001	0.006	0.006	0.006	0.006	0.006	0.006	0.005	0.006	
10	0.022	0.022	0.020	0.021	0.018	0.021	0.025	0.000	0.001	**0.013**	0.006	0.006	0.006	0.006	0.006	0.005	0.005	0.006	
11	0.041	0.040	0.039	0.039	0.037	0.039	0.043	0.024	0.025	0.024	**0.002**	0.001	0.002	0.003	0.003	0.003	0.006	0.007	
12	0.039	0.038	0.037	0.038	0.035	0.037	0.042	0.022	0.023	0.023	0.002	**0.004**	0.000	0.002	0.003	0.002	0.005	0.007	
13	0.040	0.040	0.038	0.039	0.036	0.039	0.043	0.024	0.025	0.025	0.003	0.000	**0.000**	0.002	0.002	0.002	0.006	0.007	
14	0.039	0.039	0.037	0.039	0.035	0.037	0.040	0.023	0.025	0.024	0.008	0.006	0.005	**0.005**	0.002	0.001	0.005	0.007	
15	0.041	0.040	0.039	0.040	0.037	0.040	0.044	0.023	0.025	0.025	0.008	0.005	0.004	0.003	**0.002**	0.001	0.006	0.007	
16	0.039	0.038	0.037	0.038	0.034	0.037	0.041	0.021	0.024	0.023	0.007	0.004	0.004	0.001	0.002	**0.007**	0.005	0.007	
17	0.030	0.029	0.029	0.030	0.028	0.031	0.035	0.018	0.016	0.019	0.024	0.021	0.023	0.021	0.024	0.021	**0.000**	0.004	
18	0.039	0.039	0.037	0.040	0.037	0.040	0.044	0.026	0.025	0.026	0.032	0.031	0.032	0.030	0.033	0.031	0.015	**0.001**	

Conservation and Management Implications of Findings

A. mustelina is widely and patchily distributed throughout the upper elevations of the Wai`anae Mountain Range of the island of O`ahu . In order to utilize available financial resources in the most effective way possible, genetic data were used to construct guidelines by which the maximum amount of genetic diversity might be preserved. By designation of genetically similar populations as ESUs, it is possible to divide extant tree snail populations into genetically similar ESUs, and to focus management efforts on those biological entities or groupings that are thought to be evolving independently of one another. We felt that the most appropriate genetic threshold upon which to base the designation of ESUs approximates the empirically determined mean intrapopulation genetic divergence, or an uncorrected pairwise average value of 1.0% or less (average intrapopulation genetic divergence was 0.006 or 0.6%).

When this level is applied, all populations sampled in this study collapse into 8 ESUs as indicated in Figure 1. All populations sampled from within each ESU depicted were at or within the 1% genetic distance threshold (note: the highest within-ESU genetic distance was that between populations 9a and 17 at the extreme ends of ESU-F: 0.010 or 1%). It is assumed that populations within each ESU which were not sampled also fall within the 1% genetic divergence threshold.

Historically there has been some controversy surrounding the taxonomic status of *A. mustelina.* Welch's (1938) attempt to subdivide the species into 26 subspecies based on shell characters and distribution data was never widely accepted by the scientific community, and the genetic data presented here also provide little support to most of Welch's separations. Although a precise molecular clock has yet to be applied to the Hawai`ian tree snails (Achatinellinae), genetic divergence values at the higher end of the range indicate reproductive isolation periods approaching hundreds of thousands of years. At the very least, the data strongly indicate that presently isolated populations are evolving independently of one another, and that we may be witnessing evidence of incipient speciation. From a conservation biology perspective, this notion strengthens the justification for maximizing preservation of observed genetic diversity in *A. mustelina* populations sampled during this investigation.

Figure 1. Grouping of 18 *A. mustelina* sampling sites into 8 ESU's. ESU's A through H show the relative positions of each in the Wai`anae Mountains of western O`ahu . The threshold of genetic distance separating the ESUs was set at 1%. Each population within a given ESU has a pairwise genetic distance to all other populations with the same ESU of 1% or less. Note that the exact shape and extent of each ESU is unknown and therefore the contours depicted are partially theoretical.

Attachment 3

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Islands within an island: phylogeography and conservation genetics of the endangered Hawai`ian tree snail *Achatinella mustelina*

Brenden S. Holland and Michael G. Hadfield*†*

Abstract

Mitochondrial DNA (mtDNA) sequences were used to evaluate phylogeographic structure within and among populations of three endangered Hawai`ian tree snail species (*n* = 86). The primary focus of this investigation was on setting conservation priorities for *Achatinella mustelina*. Limited data sets for two additional endangered Hawai`ian tree snails, *A. livida* and *A. sowerbyana,* were also developed for comparative purposes. Pairwise genetic distance matrices and phylogenetic trees were generated, and an analysis of molecular variance was performed on 675-base pair cytochrome oxidase I gene sequences from multiple populations of Hawai`ian tree snails. Sequence data were analysed under distance-based maximum-likelihood, and maximum-parsimony optimality criteria. Within the focal species, *A. mustelina*, numbers of variable and parsimony informative sites were 90 and 69, respectively. Pairwise intraspecific mtDNA sequence divergence ranged from 0 to 5.3% in *A. mustelina*, from 0 to 1.0% in *A. livida* and from 0 to 1.9% in *A. sowerbyana*. For *A. mustelina*, population genetic structure and mountain topography were strongly correlated. Maximum genetic distances were observed across deep, largely deforested valleys, and steep mountain peaks, independent of geographical distance. However, in certain areas where forest cover is presently fragmented, little mtDNA sequence divergence exists despite large geographical scales (8 km). Genetic data were used to define evolutionarily significant units for conservation purposes including decisions regarding placement of predator exclusion fences, captive propagation, re-introduction and translocation.

Introduction

The Hawai`ian Islands contain the most isolated terrestrial ecosystems on Earth. The nearest landmasses to Hawai`i are North America, >4300 km away, and Japan >6400 km away (Coles et al. 1999). The combined evolutionary effects of geographical isolation and habitat diversity have resulted in unparalleled levels of endemism of Hawai`ian biota. It is estimated that 95% of the native terrestrial Hawai`ian flora and fauna are endemic (Carlquist 1970). Among native Hawai`ian land snails, more than 750 valid species are recognized, 99% of which are endemic (Cowie et al. 1995).

Correspondence: Brenden S. Holland. Fax: (808) 599 4817; E-mail: bholland@Hawai`i.edu

The endemic Hawai`ian land snail fauna is considered by some researchers to be the most remarkable in the world (e.g. Zimmerman 1948).

Among the most distinctive and diverse elements of the Hawai`ian land snail fauna are the species within the endemic subfamily Achatinellinae (Pulmonata, family Achatinellideae). The shells of these tree dwelling snails exhibit a diverse array of color and banding patterns that have fascinated and confounded scientists and shell collectors for over a century (Gulick 1873; Zimmerman 1948; Cooke & Kondo 1960). Hawai`ian tree snails exist in relatively small, fragmented populations and have limited vagility. They are therefore particularly attractive for studies of population structure and speciation, and played a significant role in the early development of evolutionary thought (Gulick

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